pHew! That's a Relief: Assessing Drinking Water Quality and Treatment of Water Supply

Abstract

Safe drinking water is a right that should be guaranteed to all populations. In the United States, we know that many urban areas have the ability to obtain safe drinking water, but can rural communities similarly do so? If there is limited access, can technologies, such as point-of-use devices, temporarily improve water quality? With this in mind, we designed an experiment to test water quality of locations of close vicinity around a midwestern liberal arts institution. Two variables of interest were location of water supply and filtration on how they affect drinking water quality. Using the pH level as a measure for water quality, we found a significant difference in pH level of drinking water between the institution's facilities and the surrounding residential area. We found that using a BRITA Standard Filter significantly decreases the pH level of water. This effect, however, depends on the locations from where water was sampled. Although the results indicate a significant effect of these factors, it is important to note that the pH level for all samples are between 6.5 to 8.5, which is the recommended range for safe drinking water.

Background and Significance

Access to safe drinking water is a basic human right, but not every state has necessarily taken measures to protect this right. For example, an Iowan town found that the level of lead in their water supply is three times higher than what is considered safe by the Environmental Protection Agency (Des Moines Register, 2016). Consumption of water containing chemicals can raise the risk of long-term health consequences, thus directly affecting the health of the population (Davison et al., 2005). Based on similar information, students from a midwestern liberal arts institution were critical of their local water supply, so we aim to observe the differences in water quality on their campus along with the surrounding residences.

One way to improve the water quality at a quick, affordable cost is the implementation of a point-of-use device, such as water pitcher filters. There are a wide variety of water filters that vary in the contaminants they remove (Anumo et al., 2015; Brophy, 2016). BRITA, a German company that specializes in water-filtration devices, manufactures filters that can remove common contaminants like chlorine and copper while taking care of more serious compounds like benzene and trichloroethylene (TCE) (BRITA, LP, 2017). Pitcher filters are exemplary of advancements in engineering that can benefit populations with limited access to safe drinking water. Inspired by this community of students, we designed an experiment to test the quality of drinking water from different locations around the vicinity (academic buildings, residence halls, off-campus residences) and to evaluate the effectiveness of point-of-use devices in improving water quality.

Method

Data Collection: We chose pH level as a measure for water quality. Research has shown that the pH level can signify the presence of chemicals and heavy metal in water (The United States Geological Survey). The pH of water is measured on a scale from 0 to 14, where lower pH means increasing acidity and higher pH means increasing alkalinity. Drinking water should have the pH level between 6.5 and 8.5 to be considered safe (WHO).

We carried out our experiment for a period of six days. On each day, we obtained water samples from three different types of locations within the vicinity of the institution: academic buildings (any building on college grounds where classes are scheduled), residence halls, and off-campus residences (a selection of apartments/houses located outside college grounds). For each of these types of location, we had a subset of buildings from which we randomly selected one to collect the sample. We randomized the order that we visited three buildings for each day of water collection. At each building, we collected two water samples from kitchen/kitchenette sinks: one treated with a BRITA Standard Filter[1] and another left untreated. If the building had no kitchen/kitchenette sinks, we obtained our sample from a water fountain inside that building. We transported samples to a laboratory to measure the pH level. In the laboratory, we took our samples and measured the pH level using a PASCO Scientific pH Electrode & Software.

Analysis: Our factorial experimental design has two factors – location (academic building, residence hall, off-campus residence) and filtration treatment (filtered, not filtered) – with six treatment combinations and six replicates for each, resulting in a total of 36 observations. We used a two-way analysis of variance (ANOVA) to test the mean difference between treatment groups. For statistically significant results, we used Tukey's test for multiple comparisons to identify which particular groups were significantly different.

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[1] We bought a new BRITA Standard Filter and followed the instruction to set up the filter recommended by BRITA to ensure the quality of the filter for this experiment.

Result

We analyzed our data using a two-way ANOVA with the following sources: location (locat), treatment (treat), interaction term (locat*treat)[2]. The effect of location leads to significant differences in pH level ($F = 18.80$, $p < 0.0001$); the results of Tukey's test displays different assigned groupings between off-campus residences (A, $\bar{X}$ = 7.725) and the other groups, academic buildings (B, $\bar{X}$ = 7.950) and residence halls (B, $\bar{X}$ = 8.025) (Figure 1). The effect of water filter treatment leads to significant differences in pH level ($F = 132.07$, $p < 0.0001$); pH level of filtered water (A, $\bar{X}$ = 7.661) is significantly lower than that of untreated water (B, $\bar{X}$ = 8.139) (Figure 2). The effect of interaction was found to be significant; the effect of location depends on the effect of water filter treatment (Figure 3).

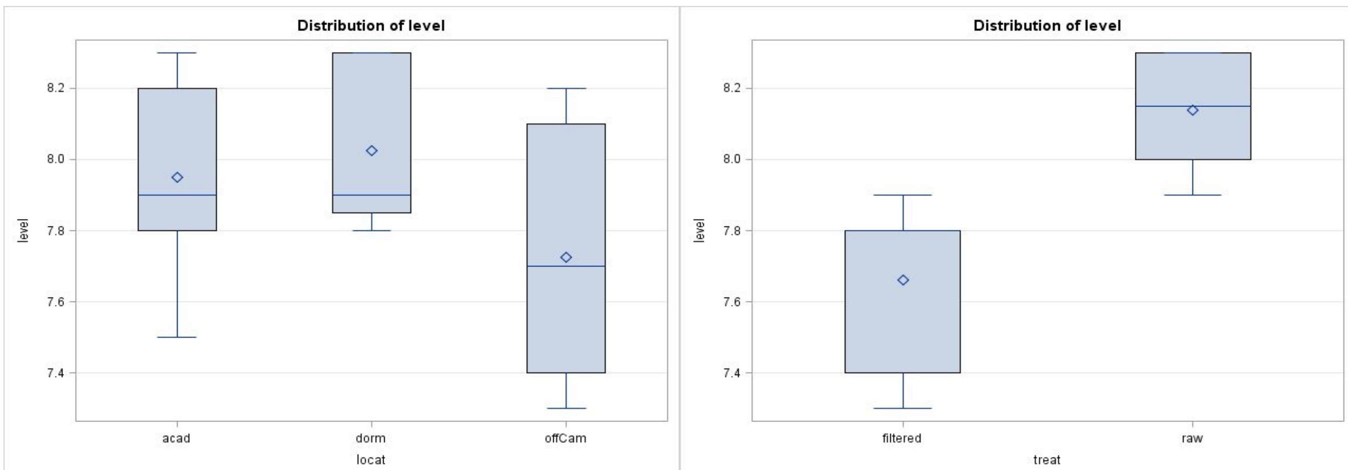

Figure 1: Boxplot of pH Levels of Drinking Water. Samples of drinking water were collected from three different locations around the institution (acad = academic buildings; dorm = residence halls; offCam = off-campus residences) and were either run through a BRITA Standard Filter (filtered) or left untreated (raw): academic buildings (acad), residence halls (dorm), and off-campus residences (offCam) and measured for pH level. The effects of both location (left) ($F = 18.80$, $p < 0.0001$) and treatment (right) ($F = 132.07$, $p < 0.0001$) were significant.

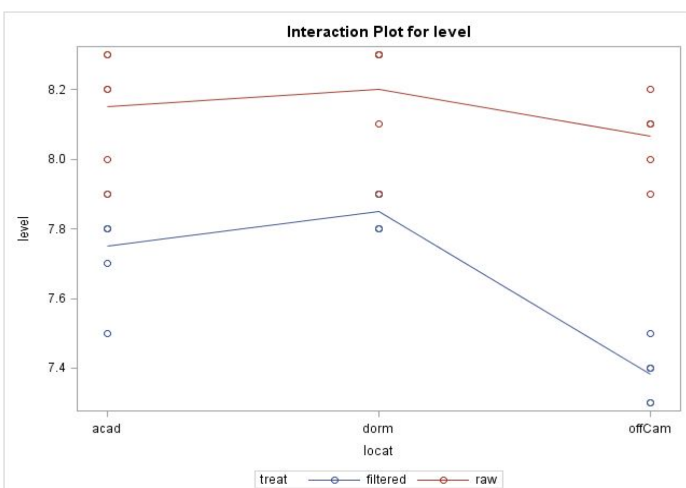

Figure 2: Interaction Plot of pH Levels for Location and Treatment. The interaction between the location and treatment variables was assessed to determine whether or not there was a significant effect. The treatment variable was used to distinguish whether a particular grouping was treated ($F = 6.23$, $p = 0.0055$).

[2] For more information on the results of our two-way ANOVA and how we implemented our analysis, see Appendix.

Discussion

Regarding the effect of location on water quality, we found that off-campus locations have a significantly lower pH level than that of the institution's academic buildings and residence halls. There was no evidence of a significant difference between the water quality of academic buildings and that of residence halls (Figure 1, left). We speculate that this difference in pH level may be present due to the age of the structures; many of the off-campus residences are quite old as compared to some of the institution's facilities built within the past ten years, which may have corroding piping that may contaminate the water and affect the pH level. However, past research contradicts our findings and has shown that corrosion of piping leads to an increase in pH (Kim et al., 2011). Limited research has been conducted regarding the differences in water quality between institutional facilities and the surrounding city or town, so our experiment presents novel findings for research in this area.

Regarding the effect of filter treatment on water quality, we found that water treated with a BRITA Standard Filter has a significantly lower pH level than water without any treatment. Unfiltered water has an average pH level much closer to the higher extreme of drinking water of 8.5 (Figure 1, right). Running drinking water through a BRITA Standard Filter allegedly purifies it, as the BRITA Standard Filter removes chlorine, copper, cadmium, mercury, and zinc (BRITA, LP, 2017). Although filters and other point-of-use devices are capable of removing significant amounts of organic contaminants in water, note that removal of specific compounds may interact differently depending on molecular characteristics and treatment technology implemented in a filter-cartridge (Anumo et al., 2015).

We found a significant interaction effect between the factors of location and treatment. The effect of water treatment with a BRITA Standard Filter has a similar effect on pH in drinking water from academic buildings and residence halls. However, the impact of water treatment with a BRITA Standard Filter is much more drastic when dealing with water from off-campus locations (Figure 2). There is a more significant drop in pH level due to the filter treatment for off-campus samples than for academic building and residence hall samples. Since water samples from off-campus locations have a significantly different pH than that of water from the institution's facilities, we suspect that there may be more chemicals and other materials present in one water source than the other that can be removed by the BRITA Standard Filter.

There are some limitations in the design and implementation of our experiment that could be improved in future iterations of this study. Diagnostic plots of the residuals showed minor issues with non-constant variance and deviation from normality[3]. Increasing the number of replicates for this experiment may aid in alleviating this problem. With regards to determinants of water quality, studies have recorded measures, such as amount of a specific organic compound, that may better indicate the quality of drinking water than the pH level alone.

Overall, all of our water samples regardless of the treatments had their pH levels within the recommended range for safe drinking water. Our experiment showed that off-campus water had a significantly lower pH level than academic buildings and residence halls. It also confirmed that the BRITA Standard Filter significantly decreased the pH of drinking water, though the magnitude of this effect depended on the location where the water was sampled from. However, the significant difference in pH level found in this research should not be mistaken with an increase or decrease in water quality since the pH of our samples was within the range for safe drinking water.

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[3] For more information on our diagnostic plots, see Appendix.

References

Anumol T. Clarke BO. Merel S. Snyder SA. Point-of-Use Devices for Attenuation of Trace Organic Compounds in Water. *American Water Works Association*. Sept 2015; 107(9): E474-E485. https://www.awwa.org/publications/journal-awwa/abstract/articleid/53620391.aspx

Brita, LP. See what we filter out of your tap. 2017. https://www.brita.com/why-brita/what-we-filter/

Brophy R. Impacts of Water Sources on the Effectiveness of Point-Of-Use Water Treatment. *Honors Research Projects*. 2016; 291. http://ideaexchange.uakron.edu/honors_research_projects/291/

Davison A. Howard G. Stevens M. Callan P. Fewtrell L. Deere D. Bartram J. Water Safety Plan: Managing drinking-water quality from catchment to consumer. World Health Organization. 2005. http://www.who.int/water_sanitation_health/dwq/wsp170805.pdf

Elmer M. Thousans of Iowans' Drinking Water Threatened by Lead Contamination. *Des Moines Register*. Dec 2016. http://www.desmoinesregister.com/story/news/local/2016/12/17/iowa-drinking-lead-water-epa-dnr/95338700/

Kim EJ. Herrera JE. Huggins D. Braam J. Koshowski S. Effect of pH on the concentrations of lead and trace contaminants in drinking water: A combined batch, pipe loop and sentinel home study. *Water Research*. Apr 2011; 45(9): 2763-2774.

Melchiori KJ. Mallett RK. Durnbaugh AN. Pham HD. Material Values, Goals, and Water Use: Results from a Campus Residence Hall Survey. *The Contribution of Social Sciences to Sustainable Development at Universities*. Jan 2016; 273-287. https://link.springer.com/chapter/10.1007/978-3-319-26866-8_17

The United States Geological Survey. pH - Water Properties. Date accessed: May 1st, 2017 https://water.usgs.gov/edu/ph.html

World Health Organization (WHO). pH in Drinking-water: Revised background document for development of WHO Guidelines for Drinking-water Quality. 2017. http://www.who.int/water_sanitation_health/dwq/chemicals/ph_revised_2007_clean_version.pdf

Appendix

1. Data Codebook

VariableName	Description
date	Date; the day when the water sample was collected; formatted as mm/dd/yyyy; date ranges from 04/04/2017 to 04/09/2017
locat	Location; the general category of location where water was collected; acad = Academic, buildings on the campus of the midwestern liberal arts institution where classes or events can take place; dorm = Dorm, student residence halls; offCam = Off-Campus, houses and/or apartments that are not directly on-campus but are within its vicinity
locatSpec	Specific location; the name of the street/building where the structure was located
treat	Treatment; the filtration treatment the sample of water was given; raw = water was left untouched after collection; filtered = water was filtered once through a Brita filter
level	pH; the pH level of the water when recorded using PASCO Scientific software; note that the range of pH for safe drinking water is between 6.5 to 8.5

2. *ANOVA Table*

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	2.83333333	0.56666667	36.43	<.0001
Error	30	0.46666667	0.01555556		
Corrected Total	35	3.30000000			

Source	DF	Type I SS	Mean Square	F Value	Pr > F
locat	2	0.58500000	0.29250000	18.80	<.0001
treat	1	2.05444444	2.05444444	132.07	<.0001
locat*treat	2	0.19388889	0.09694444	6.23	0.0055

3. *Diagnostic Plots.*