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Chem 313

Lab 02: Statistical Error Analysis & Hypothesis Testing

Concentrations of heavy metals in our atmosphere can become a concern for the health and well-being of people and the environment, and are an important factor in the design of various industrial factories around the globe. Through a moss study in 2015, the Bullseye Glass Company in the Brooklyn neighborhood was identified as a possible source to high atmospheric heavy metal concentrations in the area.[1] Responding to calls from the Oregon Department of Environmental Quality (DEQ), they worked to install baghouse systems on many of their large furnaces that produce glass containing potentially harmful heavy metals.[2] Airborne metal concentrations were measured again by the DEQ in 2017.

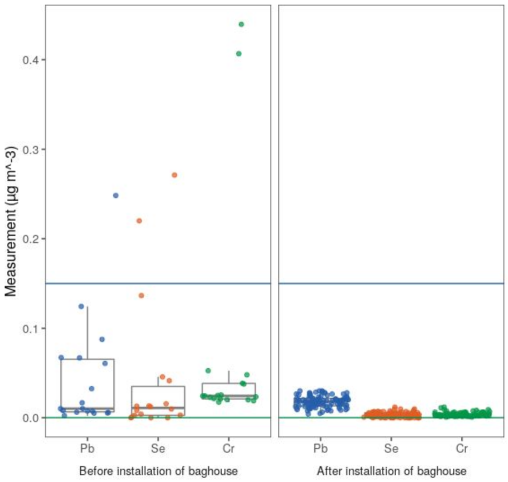

Figure 1. Scatterplot with underlying boxplots (gray) of local concentrations (µg m^{-3}) of metals (Pb: blue, Se: orange, Cr: green) before and after installation of baghouses at Bullseye Glass. Ambient benchmark concentrations (ABCs) established by the DEQ are included as horizontal lines of the corresponding colors for Pb (0.15 µg m^{-3}) and Cr (0.00008 µg m^{-3}).[3] No ABC for Se has been assigned because of inadequate chronic toxicology information.

To quantitatively analyze the data, and in order to determine if heavy metal concentration had decreased in a significant way since baghouse installation, a series of statistical tests was conducted on the concentration data before and after installation of the baghouse. Metals focused on in this analysis are **lead (Pb)**, **selenium (Se)**, and **chromium (Cr)**. A graphical representation of the changes in concentration can be seen in **Figure 1**. Ultimately, it was determined that **selenium and chromium concentrations had decreased in a statistically significant way, but lead concentrations had not.**

First, what is known as an "*f*-test" was performed for each metal in order to determine if the standard deviations significantly differed before and after the installation—this is conducted in order to ascertain which "*t*-test" will be used later. Looking at Figure 1 leads us to the prediction that these differences in standard deviations are significant, as the variances in each metal's data before are much more spread out than after. The *f*-tests for each metal indeed reported that the variances were statistically significant, meaning that the *t*-test to be performed would not pool each metal's before and after data.

Each metal was then subjected to an unpooled Welch two-sample *t*-test in order to determine if the average values after installation of the baghouse were statistically significant from the average values before. In other words, this test was used to calculate if the average concentration of each heavy metal had indeed decreased after baghouse installation.

In order for the results to be considered statistically significant within the 95% confidence interval ($p < 0.05$), the t statistic must be greater than the critical t statistic value for the same degrees of freedom: $t_{crit}(DF = 17) = 1.740$, $p = 0.05$. The *t*-test results (**Table 1**) led to the conclusion that the concentrations of both selenium and chromium had statistically significantly decreased after baghouse installation, but lead had not. We can see this because the t statistic for selenium and chromium are both greater than the critical t value, and their p values are both less than 0.05 (indicating a high level of confidence). Comparatively, the t statistic for lead is less than the critical t value, in addition to the fact that its p value is greater than 0.05.

Table 1. Results of *t*-tests.

Metal	|*t* statistic|	*p* value
Pb	1.7005	0.1072
Se	2.1609	0.04526
Cr	2.2405	0.0387

Although just two of the three metals decreased in a statistically significant way, it should still be considered a step in the right direction for the health of people in the Brooklyn neighborhood. Since baghouse installation, Bullseye Glass has resumed production of many glasses they had temporarily stopped producing due to health concerns.[4] It will be interesting to see how the results change after a longer period of time, as these datasets were taken only two years apart.

[1] Donovan, G. H.; Jovan, S. E.; Gatziolis, D.; Burstyn, I.; Michael, Y. L.; Amacher, M. C.; Monleon, V. J. Using an Epiphytic Moss to Identify Previously Unknown Sources of Atmospheric Cadmium Pollution. *Science of The Total Environment* **2016**, 559, 84–93.
[2] Baghouse Filtration System and Production Update http://www.bullseyeglass.com/news/baghouse-filtration-system-and-production-update.html.
[3] Ambient Benchmark Concentrations. Oregon Department of Environmental Quality https://www.oregon.gov/deq/FilterDocs/airtox-abc.pdf May 11, 2018.
[4] Bullseye Glass Resumes Production of Chromium Greens http://www.bullseyeglass.com/news/chromium-announcement.html.