Heavy Metal Analysis of Potable Water Sources:
An Educational Activity to Introduce Undergraduate Students to Toxicology

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ABSTRACT

Early introduction to research is pivotal to kindling student interest in fields such as toxicology and environmental health sciences. Of the contaminants in our environment, heavy metals have been relevant to human health historically, but have recently resurfaced as a cause for concern in the United States, with events such as those in Flint Michigan. Undergraduate students in the Ernest Mario School of Pharmacy Summer Undergraduate Research Fellowship (SURF) Program at Rutgers participated in an educational activity to provide experience in environmental sampling while also assessing heavy metal contamination of drinking water in NJ. This project was part of a 10-week research program that included didactic sessions on developmental neurotoxicity of lead and assessment of heavy metal concentrations in the environment. Hypotheses included potential contributions, from naturally-occurring and anthropogenic sources, water system sources, and electronic waste were assessed.

Objective: To increase scientific literacy of toxicology, environmental and exposure science as well as promote team-based learning.

Hypotheses: Drinking water field sampling as an learning activity will increase understanding of exposure science, experimental design and analysis.

METHODS

Twenty students were divided into four teams to determine a list of sites for sampling. Students were provided materials and instructions on how to collect specimens. Nine metals, were included based on hazardous or environmental notoriety and are included in the table below. Samples were quantified via high resolution inductively coupled plasma – mass spectrometry (HR-ICP-MS) [Nu Instruments Attom®, UK]. The water samples were acidified with 5% Trace Metal Grade Nitric Acid and introduced through an ASX-500 Model 510 Auto Sampler (Cetac®) and into a Gass Expansion Conikal Nebulizer within the Peltier cooling system. Data was sent into the Attom software (Attolab v.1) and analyzed with NuQuant by using a seven-point multi-element calibration curve. Teams were provided with their data and asked to compare their results to the NJ Drinking Water Quality Standards for real-world context and regulatory interpretation. Graphing and R^2 values were created using Graphpad Prism Software (La Jolla, CA).

Sample Ranges Compared to NJDEP Standards

Metal	NJDEP Standard	Highest Value	Lowest Value	Detection Limit
Aluminum	200	81.00	0.5	0.5
Cadmium	5	1.80	0.1	0.1
Chromium	100	1.20	0.1	0.1
Lead	15	9.2	0.05	0.05
Lithium	NS	5.40	0.60	0.1
Vanadium	NS	0.73	0.13	0.1
Arsenic	5	0.81	0.21	0.05
Nickel	NS	87.50	0.21	ND
Manganese	500	85.70	0.03	0.05

Table 1. Sample ranges were compared to New Jersey Department of Environmental Protection (NJDEP) Drinking Water Quality Standards for nine heavy metals, and the detection level for each metal is listed in the rightmost column. NS: No standard; all values are expressed in PPB.

RESULTS

To illustrate the potential effect of flushing (a recommended remediation strategy for contaminated water systems) our activity included an analysis of initial draw and post-purge. Water systems may be a potential source of metals in potable water. Historically, lead and nickel have been found in both interior water pipes and pipes connecting a house to municipal water. These metals can leach from corrosion either from the fixtures or solder, especially if the water is stagnant for long periods of time. We hypothesized that initial draw samples contain elevated concentrations of lead and nickel as compared to post-purge; however, lead concentrations remained unchanged and nickel was observed to decrease post-purge (Figure 1) Additionally, Water quality could be impacted by increased electronic waste observed in correlations between Nickel and Cadmium or Aluminum and Lithium (displayed in Figure 2). Linear Regression was performed to analyze the potential relationship between metals coupled together in electronic waste. Correlation coefficients were derived using Graphpad Prism. R^2: 0.044 for Cd-Ni, and R^2: 0.046 for Li-Al. All units are expressed in PPB.

Initial Draw and Post Purge Heavy Metal Concentrations

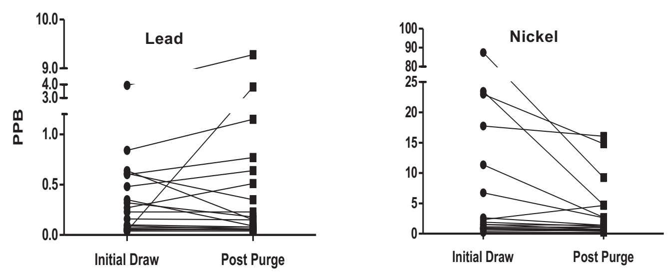

Figure 1. Two metals show pre and post purge differences. Initial draw and post-purge comparison for lead and nickel. These metal ranges including the other metals that had detectable ranged as follows: Al (0.5-81.0 PPB), As (0.21-0.81 PPB), Cd (0.1-1.8 PPB), Cr (0.1-1.2 PPB), Pb (0.05-9.2 PPB) Li (0.6-5.4 PPB), Mn (0.05-85.7 PPB), V (0.13-0.73 PPB) and Ni (0.20-87.5 PPB).

Heavy Metal Enrichment

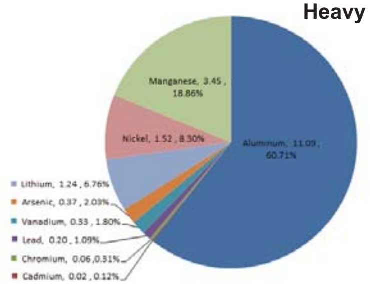

Figure 2: Each specific metal contribution was determined by compiling the median values of each metal analyzed in the initial purge samples. Values are expressed in PPB, and percent.

Students were provided with the data above for interpretation and trend analysis. All samples were below NJDEP Drinking Water Quality Standards as depicted in Table 1. There were no observed trends indicating significant differences in concentrations between initial draws and following a purge (Figure 1), or in contributions from electronic waste contributing to a positive correlation between metals commonly used in the same products (Figure 2). Additionally, the median values of the ten heavy metals were compiled in Figure 3 to determine proportional metal content. Of the metals analyzed, the largest proportion was comprised of aluminum, while chromium and cadmium contributions were less than 1%.

Of the topics and activities included in the SURF program, this team-based water sampling exercise, coupled toxicology, exposure, and environmental health science, and was rated favorably amongst participants, fostering collaboration and networking. Pre- and post-surveys of scientific confidence for the SURF program were analyzed, as depicted in Table 2.

Pre- and Post- Scientific Literacy Surveys

Application of knowledge to research:	
Analyzing data for patterns	18%
Predicting next step in a research project	33%
Problem-solving in general	12%
Formulating a research question that could be answered with data	28%
Identifying limitations of research methods and designs	28%
Understanding the theory and concepts guiding a research project	20%
Understanding the connections among scientific disciplines	20%
Understanding the relevance of research to my coursework	22%
Scientific abilities:	
Confidence in my ability to contribute to science	15%
Comfort in discussing scientific concepts with others	20%
Comfort in working collaboratively with others	14%
Take great care in conducting procedures in the lab, field or clinic	17%
Research abilities:	
Defending an argument when asked questions	27%
Explaining a research project to people outside my field	25%
Keeping a detailed research notebook	28%
Conducting observations in the lab, field, or clinic	23%
Using statistics to analyze data	29%

Table 2: Paired t-tests were completed (pre- and post- survey) for each competency. Significant improvement was observed in all competencies analyzed. The percent change in pre- vs post- scores are listed for each competency.

Future Direction

This activity was rated favorably among students. Although the survey for the program showed improvement, scientific literacy questions specific to this activity will be provided. Additionally, the activity future will include mapping sampling locations to evaluate building similarities with respect to sample elevation as well as age building. Students will also determine which metals they would like to have analyzed and each group will be assigned a short historical evaluation of its route of exposure and toxicity.

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There are no conflicts of interest to disclose.

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