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Utilizing Service-Learning in the Analytical Chemistry Laboratory: Soil and Water Analysis in Rochester, New York

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Abstract

For an analytical chemistry course at St. John Fisher College, instructors designed a servicelearning project on soil and water analysis to achieve the following two goals: 1) to introduce analytical chemistry students to soil- and water-testing methods by working in collaboration with surrounding neighborhoods residents and government agencies and 2) to prepare written reports of the results for the designated community partners. Service-learning students conducted soil testing for lead on homes and perspective community garden sites around Rochester, NY with plans to establish planting methods to revitalize polluted soil. Four different communities contributed soil samples. The entire project was performed in connection with Lynn Donahue, St. John Fisher College's service-learning director. To analyze the lead in the soil, EPA method 3050b including acid digestion was utilized, followed by Flame Atomic Absorption Spectrometry (FAAS). Results showed that many of the home sites contained levels of lead far above the accepted EPA guidelines of 400 ppm for play areas and 1,200 ppm for non-play areas. To further assist homeowners, students provided written reports detailing the results of the four sites tested on their property and provided suggestions of ways to rid the soil of lead and protect themselves from lead-containing soil. The students also conducted water testing on both Buckland Creek (before and after rain events) and the Genesee River in coordination with the Department of Environmental Services, Division of Pure Waters. Testing included pH, dissolved oxygen levels, buffering capacity, sulfide, carbon dioxide, chloride, alkalinity, water hardness, chemical oxygen demand, phosphorus, nitrates, zinc, lead and copper. Experimental methods involved the comparison of up to three techniques per analyte, utilizing titration methods, commercial kits, electrode probes, and spectrophotometric instrumentation.

Keywords

lead, soil, water pollution, chemistry, phytoremediation

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Soil and Water Analysis in Rochester, New York

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Abstract

For an analytical chemistry course at St. John Fisher College, instructors designed a service-learning project on soil and water analysis to achieve the following two goals: 1) to introduce analytical chemistry students to soil- and water-testing methods by working in collaboration with surrounding neighborhood residents and government agencies and 2) to prepare written reports of the results for the designated community partners. Service-learning students conducted soil testing for lead on homes and perspective community garden sites around Rochester, NY with plans to establish planting methods to revitalize polluted soil. Four different communities contributed soil samples. The entire project was performed in connection with Lynn Donahue, St. John Fisher College's service-learning director. To analyze the lead in the soil, EPA method 3050b, including acid digestion, was utilized, followed by Flame Atomic Absorption Spectrometry (FAAS). Results showed many of the home sites contained levels of lead far above the accepted EPA guidelines of 400 ppm for play areas and 1,200 ppm for non-play areas. To further assist homeowners, students provided written reports detailing the results of the four sites tested on their property and provided suggestions of ways to rid the soil of lead and protect residents from lead-containing soil. The students also conducted water testing on both Buckland Creek (before and after rain events) and the Genesee River in coordination with the Department of Environmental Services, Division of Pure Waters. Testing included pH, dissolved oxygen levels, buffering capacity, sulfide, carbon dioxide, chloride, alkalinity, water hardness, chemical oxygen demand, phosphorus, nitrates, zinc, lead and copper. Experimental methods involved the comparison of up to three techniques per analyte, utilizing titration methods, commercial kits, electrode probes, and spectrophotometric instrumentation.

Key words
Lead, Soil, Water Pollution, Chemistry, Phytoremediation

This work is adapted from a presentation of the same name given by Kimberly D. Chichester at the New York Metro Area Partnership for Service-Learning (NYAPS) Third Annual Symposium on March 23, 2011.

Scholastic Rationale

A challenge that professors undertake every day is how to spark the interest of students both in the classroom and in the laboratory. Evidence clearly suggests that the students at St. John Fisher College were interested in environmental analysis through community-based service-learning. The projects presented served both of these interests and merged them into a rewarding experience that helped the community and created a partnership between St. John Fisher and local community agencies. Additionally, students benefited from conducting environmental sampling and testing firsthand and from writing reports of the tests results for local residents. Students also felt a personal connection with the project because they live and swim in the area and use water from these sources.

Scientific Rationale

Soil Analysis

Lead poisoning is a serious health issue caused by exposure to excess amounts of lead-containing products including lead paint, lead residue from plumbing supplies, factory pollution, and leaded gasoline. The U.S. government has prohibited the use of both leaded paint and gasoline; however residues from their use are still prevalent in the soil surrounding houses and near roads. [1]

Soil's role is often overshadowed by that of lead-based paint as a pathway of lead ingestion. Despite conclusive evidence found by national agencies, many do not regard soil as a major source of lead ingestion. Soil is, however, a significant source because it not only contains lead paint particles, but because it also contains particles from leaded gasoline and industrial emissions. As stated by Mielke, et al, "experiments on lead in soil and paint show that two to six times as much lead can be biologically extracted from soil as from paint" [2]. The Centers for Disease Control and Prevention (CDC) and the U.S. Environmental Protection Agency (EPA) have classified lead-contaminated soil as a health hazard and have implemented strict testing and accepted level policies. Health concerns are reached when lead levels exceed 400 ppm for play areas and 1,200 ppm for all other locations [3]. Lead is found naturally in soil, but well below hazardous levels. The concentration of lead in soil naturally is around 17 ppm, and does not become a serious concern until it reaches the 400 ppm level for highly used areas [4].

Inner cities report many more cases of lead poisoning compared with rural and suburban areas. Several reasons account for this. First, cities are traffic-dense areas, and therefore have higher levels of gasoline emissions in the air and ground. Studies have found a direct correlation between city size and the concentration of lead in the soil [2]. Second, most inner city homes were built during the early part of the twentieth century when leaded

More than 12 million children are at risk of getting lead poisoning.

Chronic exposure to lead by children can lead to learning disabilities.

paint was used of the inside and outside a high proportion of buildings. Third, residents of poorer neighborhoods often do not have the means to eradicate the lead paint or to clean up the flaked-off paint. Thus, the children in these areas are at greater risk of exposure.

Young children are often the most prone to developing lead poisoning because they tend to put things in their mouths and because they absorb metals more quickly into their bodies than than adults do. Children under 5 years of age can absorb half of the consumed lead into their bodies [2]. Lead poisoning is a preventable condition, yet it affects a substantial portion of the children living in the Rochester, New York area and across the country. According to Meilke, et al, "10 million metric tons of lead residues resulting from gasoline and paint use" are emitted into the environment [2]. It is estimated that more than 12 million children are at risk of getting lead poisoning based on their exposure to lead in the environment [2].

Chronic exposure to lead by children can lead to learning disabilities, behavioral problems, and neurological and growth disorders. Children with elevated levels of lead in their blood have been reported to score much lower on IQ and standardized tests. It has been suggested that children in inner city or poorer neighborhoods suffer from increased exposure to lead, which could contribute to lower test scoring and increased episodes of disruptive behavior. This suggests that lead poisoning is not only a scientific and medical issue, but also a social one. Adults do not develop lead poisoning at the same rate as children do; however, they can develop conditions such as sterility, miscarriage or stillbirth, elevated blood pressure, problems with the kidneys and gastrointestinal tract, and nervous system disorders when exposed to high levels of lead [5].

Water Analysis

The Monroe County Department of Environmental Services: Division of Pure Waters conducts water testing to assess the level of contamination in and around Buckland Creek and the Genesee River. The division's goal is to reduce levels of pollution in Irondequoit Bay, the Genesee River, areas of Lake Ontario, and other waters of Monroe County to safe and healthful levels. The division is interested in examining the impact of human activity on water quality in Buckland Creek and in the sewer system where the creek discharges into the Genesee River, to better educate residents about ways to avoid discharging pollutants such as cleaning supplies into the ground or the water system. With the help of St. John Fisher College students, the division collected data to assess the baseline levels of phosphorus, chlorides, nitrates, total suspended solids, phosphorus, zinc, lead, and copper. Knowledge of baseline levels of analytes is necessary for routine monitoring and for assessing the effects of urbanization.

Contamination from industrial waste and from the construction of new industrial and residential areas have greatly affected the waters in Rochester. Therefore, both the health of the aquatic ecosystems in the creek and river and the safety of water usage are assessed. Each type of analyte assessed has a different effect on the environment, and thus, has been assigned a specific regulatory limits based upon its toxicity. Nitrates, for example, have a limit of 10 ppm in New York State because of their negative effects on human respiration and the circulatory system. Phosphorus is only now being regulated because high levels can lead to kidney damage, stomach irritation, and impacts on the circulatory system. Heavy metal contamination can lead to intestinal issues and brain damage within the human body, and can disrupt soil ecosystems.

The Monroe County Department of Environmental Services handles the remediation of water pollution, and the students' reports provide the department with valuable data that helps the staff identify water quality impairments in Buckland Creek and in the Genesee River and determine the implications for these waterways.

The results further help the department to educate the public on the quality of their water and to provide information on how the pollution could affect residents' health.

Approach ■

Soil Analysis

Students in the analytical chemistry classes for both the 2008–2009 and 2009–2010 (Figure 1) academic years participated in the soil-testing project. In particular, the students gathered and tested soil samples for the Clara Barton, Highland Park, South Wedge and Beechwood neighborhoods in Rochester. The students collected only the top half-inch of bare or exposed soil because lead does not travel any further into the ground. Sample locations at traditional home sites included a spot close to the road, one close to the front of the house, one close to back of the house, and one last location in the far part of the backyard. Students also tested designated garden or playground areas and took samples next to painted garages. Students collected each sample using a plastic shovel, which they cleaned with soap and water prior to each use and stored in a plastic bag to avoid cross contamination. Collected soil samples were subjected to lead extraction procedures using acid digestion (EPA method 3050b) and analyzed using Flame Atomic Absorption Spectroscopy (FAAS). FAAS is the established and preferred method for the

Contamination from industrial waste has greatly affected the waters in Rochester.

Student reports provide the department with valuable data on water quality.

detection of metals in environmental samples with detection limits well below the reported values for normal soil lead concentration.

Certain plants, hyper accumulators, have been found to be effective in removing polluting metals from contaminated soil. The process, called phytoremediation, has been researched as a cost efficient and effective way to remove metals from contaminated soil [6]. This project also aimed to determine which plants are most effective at phytoremediation when lead is the contaminating metal, and to provide homeowners with a green and eye-catching alternative to soil removal. Once the levels of lead were determined, the project team gave the contaminated soil to researchers in the Biology Department to determine what plants would be effective in removing lead from the soil and which vegetables might be safe to eat from gardens containing lead. The non-contaminated soil was used as a control to mimic the soil conditions of Rochester-area homes.

Water Analysis

Water analysis involved students sampling Buckland Creek before and after rain events and sampling the Genesee River on a single occasion. Four sites were chosen for each waterway. Grab water samples were collected by lowering a plastic container into the creek and, for the river, over the side of bridges. The samples were stored in a cooler for transport to the laboratory, preserved and stored following EPA-recommended methods for waters and wastewater samples. Buckland Creek was analyzed for pH, dissolved oxygen levels, buffering capacity, sulfide, carbon dioxide, chloride, alkalinity, water hardness, nitrates, phosphorus, ammonia, and several heavy metals (zinc, lead, and copper) to determine the effect on the health of the creek around areas of industrial growth. The students used titrations, ion selective electrodes, ultraviolet-visible spectroscopy, FAAS, and commercial kits, which were an extension of the current course curriculum. The Genesee River was tested for phosphorus, nitrates, alkalinity, chemical oxygen demand and chlorides. As with the soil analysis, students prepared a written report of their findings and suggestions, and presented it to the Department of Environmental Services.

Assessment

To assess service-learning outcomes for both projects, students completed two sets of course evaluations. One was a general course evaluation. The other was an assessment of the service-learning project, which included a written reflection in the form of a report. It included guiding questions that pushed students to analyze the source and effects of each analyte, the meaning of the results relative to state or federal limits, and the merits of real-world analysis versus traditional lab experiments.

Scientific Outcomes ■

Soil Analysis

The soil analyses completed by the analytical chemistry classes in the 2008–2009 and 2009–2010 academic years are reported in Tables 1 and 2.

Table 1: Lead Concentration Values for Neighborhood Samples

	Front- near Lead conc. (ppm)	Front - far Lead conc. (ppm)	Back - near Lead conc. (ppm)	Back - far Lead conc. (ppm)
Clara Barton 1a	8,260	625	2,163	1,688
Clara Barton 4b	4,232	843	762	913
Clara Barton 5b	4,449	546	1,334	1,055
Clara Barton 7b	634	418	1,908	615
Highland Park 1a	7,563	221	2,457	1,774
Highland Park 1b	8,486	404	2,928	2,725
Highland Park 2b	764	226	18,854*	Not detected
Highland Park 3b	3,788	1,072	1,418	3,918
Highland Park 6 b	2,200	150	4,820	410

a - beaker set-up b - round-bottom set-up
*** - averaged value**

The majority of the values in Table 1 are above the EPA standard for play areas, 400 ppm, and almost half are above the EPA standard for non-play areas of the yard, 1,200 ppm. In some cases, samples with high lead levels were retested for accuracy in an attempt to avoid unnecessarily scaring homeowners. The values also show a trend indicating that in each section of the yard, both the front and the back, there is a higher concentration of lead closer to the house. Because the houses are not located on a road with heavy traffic, paint on the exterior of the house may be a contributing factor for soil contamination. The majority of values also show a trend towards higher concentrations near the front of the house. This may be because homeowners are more likely to paint the fronts of houses. If lead-based paint is used, when the layers deteriote and flake off, this may cause more contamination in the soil in the front of the house.

The values in Table 2 support the trend

Students reported the results to homeowners in formal reports.

that the majority of the soil tested contained a concentration of lead higher than the EPA standard of 400 ppm for play areas. However, there was a lower percentage of samples above the EPA standard for non-play areas, 1,200 ppm. Table 2 also presents information on five gardens at different homes. Of the five gardens, three were above the EPA standard for play areas and one was above the EPA standard for non-play areas. This result led students to worry about the safety of the food homeowners were ingesting. The planned phytoremediation study will aid homeowners in determining which types of plants grown in leaded soil are safe to eat and which are a health risk. It will also provide information on plants that can remove lead from the contaminated soil.

The students wrote reports in the fall and spring of 2009 and the spring of 2010, which Lynn Donahue forwarded to the homeowners. Students reported the results of all soil samples to homeowners in the form of a formal report and a letter with suggestions of ways to revitalize their soil. Homeowners who contacted the service-learning department were pleased with both the testing results and the professionalism of the students' letters and suggestions. One neighborhood took their results very seriously and treated their contaminated soil, understanding that their soil would be retested afterward. Analysis of the cleaned soil demonstrated the success of their cleaning methods.

Table 2: Lead Concentration Values for Neighborhood Samples with Varied Locations.

	Location 1 Lead conc. (ppm)	Location 2 Lead conc. (ppm)	Location 3 Lead conc. (ppm)	Location 4 Lead conc. (ppm)
Clara Barton 2b	Garden 268.26	Side of House 713.79	Back-near 630.22	Back-far 647.30
Clara Barton 3b	Back-garage 574.91	Back Close 8,244.3	Back-mid 583.22	Back-far 1,433.5
Clara Barton 6b	Front-near 1,743.07	Front-garden 689.58	Back-near 2,627.66	Back-far 2,396.46
Highland Park 4b	Front-far 869	Front-near 3,152	Back-near 1,369	Garden 3,578
Highland Park 5b	Front-near 695.71	Side of House-near 4,401.45	Back-near 424.35	Back-far 602.34
Highland Park 7b	Front-garden 831	Back-garden 191	Back-near 1,190	Back-far 368

b- round-bottom set-up

Water Analysis

The 2009–2010 and 2010–2011 analytical chemistry classes completed water analysis. The classes analyzed four sites along Buckland Creek during both years; the 2010–2011 classes analyzed four sites along the Genesee River. Results from Buckland Creek studies include a single day examination (Table 3) and results before and after three rain events in the fall of 2009 and 2010 (Table 4 and 5). Genesee River results are shown in Table 6.

The majority of the tested parameters were below the standard limits set by the EPA. Nitrates and phosphorus are the only two nutrients that were found to be slightly higher than expected for Buckland Creek. This is likely because this creek runs through a highly developed residential area and thus the quality of its water is directly related to human activities such as treatment of lawns and gardens with fertilizers.

All results were reported to the Department of Environmental Services: Division of Pure Waters to add to previously collected data. The class compiled a report of the health effects of all analytes to aid their understanding of the benefits of water quality assessment. The information is continually distributed to the homeowners in the affected communities along with periodic compilations of data.

Table 3: One Day Analysis of Buckland Creek, Fall 2009

	pH	Alkalinity (ppm)	Hardness T	CO2	Sulfide	Chloride (ppm)	Oxygen	Buffer Capacity
		T	**T**	**E**		**E**	**E**	**E**
Chelms-ford	8	286 (330)	419 (329)	7	(0)	460 (420)	7 (9)	0.014
Winton	8	286 (290)	442 (379)	13	(0)	476 (370)	6 (9)	0.015
Elmwood	8	305 (325)	496 (324)	12	(0)	618 (470)	7 (10)	0.020
Lac de Ville	8	326 (300)	446 (400)	10	(0)	560 (405)	7 (11)	0.015

Values in parentheses were determined using a commercial kit; T = titration; E = electrode

Conclusion

Student Outcomes

Students provided feedback through course evaluations, class discussions, and service-learning evaluations. In all cases, students reported that the service-learning project was their favorite activity of the year. Many students noted the benefits of learning to deal with real-world sampling and learning how to communicate with local residents. Four of the students who worked on the project as independent researchers are currently in graduate or professional schools, and they have remarked that the time they spent in the lab was a great way to prepare for the rigor of independent research. Class results have been reported at several conferences by both Drs. Kimaru and Chichester and several student presenters.

Positive comments from the students about the value of the soil project prompted the instructor to expand the focus on water analysis within the curriculum. Learning to use chemistry outside of the classroom to benefit the students' community was the driving force behind the project. Upon first meeting with Andrew Sansone and Erin McGee from the Department of Environmental Services, the students commented that they had no idea such jobs existed for students educated in chemistry techniques. Thus, the experience provided critical information to the community, taught the students chemistry techniques, and exposed them to job options. In their final report, the students commented that the project presented them with research experience and opportunities to develop problem-solving and teamwork skills, and to relate course work with real-world issues, explore career options, and help the community. The only negative aspect of the project was its weather dependent nature, which meant students had to wait for rain events and these did not always fit into students' schedules.

Community Partner Outcomes

Lynn Donahue coordinated the soil project and was the liaison with homeowners, who handled the news of the results in a variety of ways. Some used the information as the basis to clean or treat their soil, which was then were retested. These homeowners were quite happy with the improved results. Results of the current and proposed community garden sites tested (data not shown) showed no levels of dectable lead, meaning they were safe areas for residents to grow their food. On one sampling trip, many more samples were collected than there were students to analyze them, which led to some homeowners to wait several months for results. This delay in obtaining results was the only area of concern for the project from the homeowners.

Table 4: Ongoing Buckland Creek Analysis

		NO3 (ppm)	NH3 (ppm)	P (ppm)	Cu (ppm)	Zn (ppm)	Pb (ppm)
9/23/09	Chelmsford	3.6	0.32	-	ND	ND	ND
	Winton	6.5	0.26	-	ND	ND	ND
	Lac de Ville	6.5	0.41	-	ND	ND	ND
	Elmwood	4.8	0.75	-	ND	ND	ND
10/2/09	Chelmsford	8.3	1.8	0.15	ND	ND	ND
	Winton	11.6	1.2	0.13	ND	ND	ND
	Lac de Ville	10.2	0.51	0.08	ND	ND	ND
	Elmwood	7.3	0.85	0.12	ND	ND	ND
10/28/09	Chelmsford	7.6	0.57	-	ND	ND	ND
	Winton	7.8	0.62	-	ND	ND	ND
	Lac de Ville	9.7	0.33	-	ND	ND	ND
	Elmwood	15	0.49	-	ND	ND	ND
11/2/09	Chelmsford	5.2	0.21	0.06	ND	ND	ND
	Winton	8.3	0.14	0.05	ND	ND	ND
	Lac de Ville	12.0	0.24	0.02	ND	ND	ND
	Elmwood	10.1	0.36	0.04	ND	ND	ND

ND = not detected;
- = no analysis was conducted

Sansone and McGee of the Department of Environmental Services: Division of Pure Waters were highly impressed with the students' level of engagement as well as with the professionalism of the students and their reports. Buckland Creek had not been previously sampled, and the data the students reported provided a quick overview of the quality of the water. Sansone and McGee were also pleased to be able to expand their message of water quality and stream stewardship to a new audience. The partnership is continuing because of the high interest of both parties and because a longer study is needed to form conclusions on how best to deal with the results.

One neighborhood treated their contaminated soil.

Faculty Outcomes

The projects have been successful in the classroom and have facilitated successful independent research. The soil project has been the subject of three newspaper articles including a write-up in the *Democrat and Chronicle*, Rochester's leading paper, and has been presented at several conferences on and off campus. Student interest has also grown with the addition of new senior level chemistry and biology majors working on the project. The analytical chemistry classes will also continue to work on the projects as part of a service-learning laboratory activity that has been well received by students the past two years. The water analysis service-learning laboratory activity was been added to the curriculum because of the positive feedback from the lead soil project. Further service-learning projects will be developed due to the interest and success. The biggest area of concern for the projects is the extensive number of samples collected; there is not always ample time and resources to complete all of the analyses. Scientific research requires analyzing a sample more than once, and in some cases students are getting only one opportunity to analyze a sample, which is less than ideal. In the future, either fewer samples should be taken or more independent researchers will be required to duplicate results. On a more collegiate plane, the project has allowed four members of the Fisher academic community (Irene Kimaru, Maryann Hermann, Lynn Donahue and Kimberly Chichester) to collaborate on a long-term project.

Students reported that the service-learning project was their favorite activity of the year.

Table 5: Ongoing Buckland Creek Analysis

		NO3 (ppm)	NH3 (ppm)	P (ppm)	Cu (ppm)	Zn (ppm)
9/16/10	Chelmsford	7.44	3.437	0.0148	ND	0.00143
	Winton	6.35	3.115	0.01286	ND	0.01933
	Lac de Ville	12.4	3.544	0.01297	ND	0.01613
	Elmwood	1.94	2.954	0.01391	ND	0.00393
9/28/10	Chelmsford	-	8.287	0.0157	ND	0
	Winton	-	7.5	0.01402	ND	0.002
	Lac de Ville	-	6.342	0.01601	ND	0.00177
	Elmwood	-	7.1296	0.01591	ND	0.00097
10/4/10	Chelmsford	10.33	1.351	0.01412	ND	0.0001
	Winton	14.15	1.436	0.02745	ND	0.002633
	Lac de Ville	4.11	1.978	-	ND	0.0022
	Elmwood	3.84	0.978	-	ND	0.0054

ND = not detected;
- = no analysis was conducted

Table 6: Genesee River Analysis, Fall 2010

Location	nitrates (ppm)	Alkalinity (ppm) Titration methods			chemical oxygen demand (mg O2/L)	Total Phosphorus (ppm)	Dissolved Phosphorus (ppm)	Chlorides (ppm)		
	E	I	P	K		T	T	M	E	K
Jefferson Road	0.50	126.856 ± 1.143	109	-	35.02	0.0450	0.00495	129 ± 0.512	140	15
Main Street	0.35	129.7 ± 1.2	132.6	115	27.2	0.0381	0.0274	36.7 ± 0.1	34.0	14
University	2.90	123.8 ± 6.7	-	-	53.14	0.0377	0.0307	40.8 ± 0.1	51.4	8
Port of Charlotte	1.73	175	149	-	56.90	0.0757	0.0209	52.8 ±0.1	66	9

I = indicator titration; P= potentiometric titration; K = commercially available kit; M = Mohr titration; E= ion selective electrode; T= titration

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