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Linking Community Service, Learning, and Enviromental Analytical Chemistry

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Undergraduates go beyond field studies and right into neighborhoods, community debates, and public policy.

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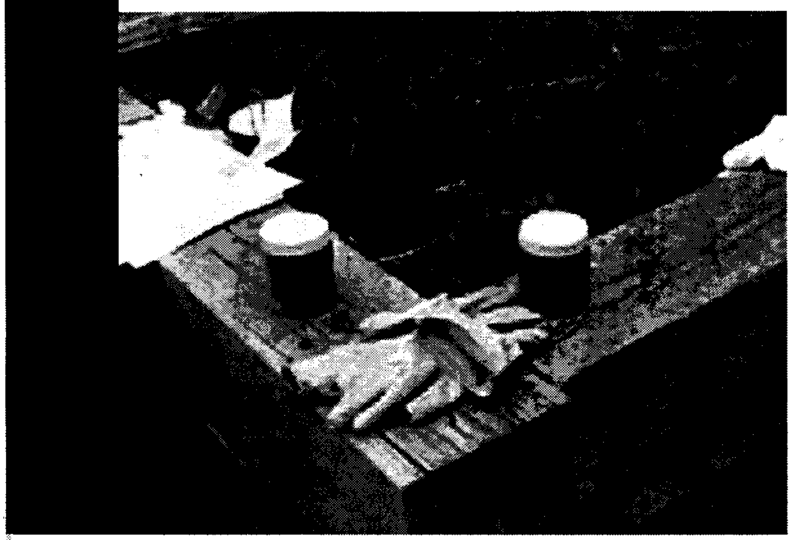
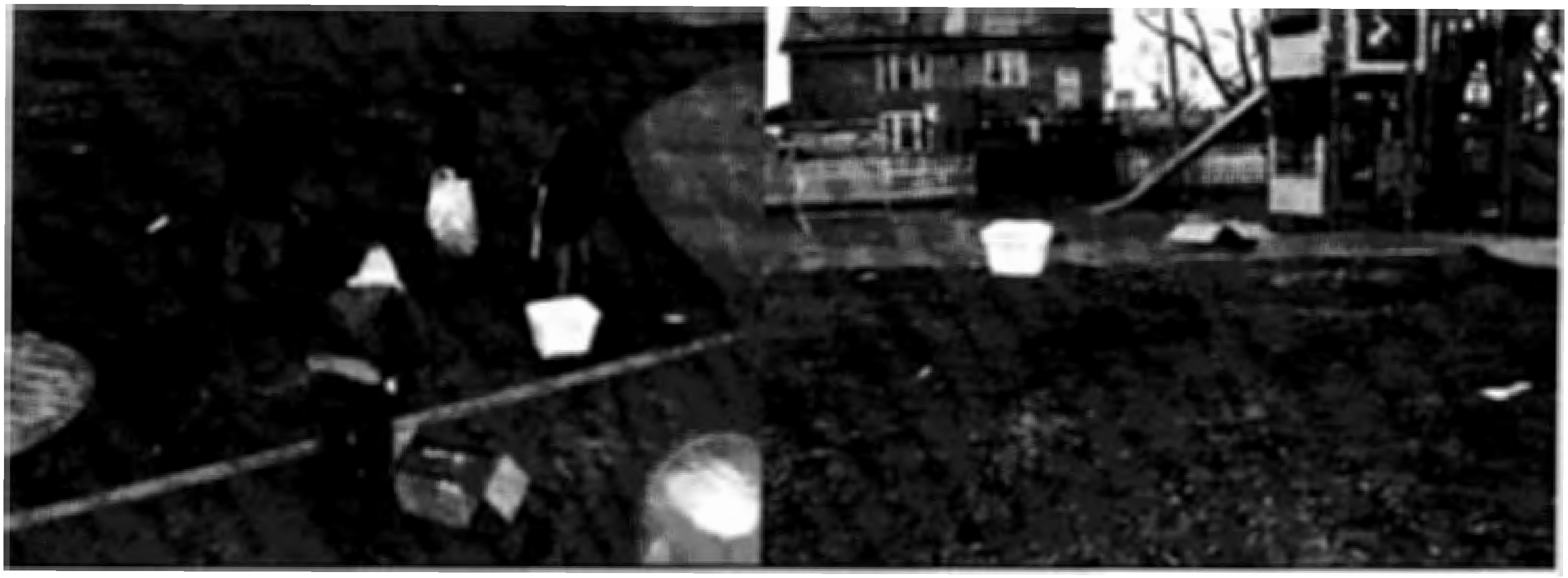


JOSEPH GARDELLA

In 1994, during a tour of the then-new natural sciences building—a $43 million teaching and research complex fully equipped with the latest in technology and instrumentation for chemistry and geology courses—a member of the Buffalo Public Schools Board of Education asked, "How can the community [that paid for it] have access to this teaching and research equipment?" That question triggered the effort reported here—a program to better link teaching and research to community service.

Since 1982, the lead author had been teaching a senior chemistry course entitled "Analytical chemistry of pollutants", in which students working in teams designed and executed field studies, including sampling, analysis, and reporting. In addition, for some years, the lead author had responded to community questions about environmental pollution issues, with mixed results. Some could be dealt with by the cooperation of students and by using existing equipment; others required capabilities that were not readily available. Thinking more widely about the opportunities that the new facilities would bring led to an action plan to marry the course resources to community needs in a classic example of public-service learning (*1*, *2*). The resulting 12 years of work has had a broad impact on teaching, research, and service in environmental analytical chemistry at the University at Buffalo (UB) and in western New York.

When we put together the course, we were mindful of Santayana's famous dictum, "Those who cannot remember the past are condemned to repeat it." Many lessons from the lead author's previous undergraduate experiences in environmental pollution analysis done in service to the community were captured in the new course. One project of the lead author's was the identification of illegal connections of human-waste sewers to storm sewers in Lake Orion, Mich. These sewers polluted Paint Creek,



a stream that connects Lake Orion to Rochester, Mich. (*3*, *4*). Students learned about working with elected leaders and public-agency personnel, interdisciplinary work, the communication of science to the public, and the state of standard methods in environmental analysis. Many of the ideas that led to the present program grew out of this undergraduate research experience.

With this history, we set out to modify the UB chemistry course and align it to community needs at a time when attention to service-learning opportunities in science was increasing (*1*, *2*, *5–9*). Alanah Fitch and Edward Eyring showed how the need for lead analysis in communities can be linked to courses and laboratory experiences at various levels (*6*, *7*). Many other faculty at colleges and universities have developed innovative field courses to study environmental indicators of pollution and transform students' skills into useful expertise for their communities (*5*, *8*, *9*).

A last introductory note involves the special history and geography of western New York. The lead author came to Buffalo in 1982, in the midst of the Love Canal controversy (*10*, *11*). The two most important lessons from that episode are that community activism is required to get industry and government to respond to pollution-based problems (regardless of the advances in regulatory efforts) and that some local, state, and federal health and environmental agency representatives lack respect for (and some actually fear) community activism. They see it as stemming from a lack of knowledge about chemical exposure, toxicology, and relative risk. It is important to prepare students for dealing with the public and with these existing historical prejudices.

Chemistry 470, the analytical chemistry of pollutants

This class has been taught at UB since the 1970s. In the early 1980s, the course involved a lecture component focused on environmental statistics and analytical methodologies for detecting pollutants in air, water, soil, sediment, and solid wastes. The field-study project involved students writing a proposal and work plan for sampling and analysis, then executing the plan and reporting their results. The projects often relied on the students who had experience or were working part-time in commercial or government environmental laboratories, and students often used laboratory resources from those sites.

The course was revised in the mid-1990s (Table 1). A component on the physical chemistry and thermodynamics of pollutant movement was added to enhance the development of sampling strategies. The lecture components focused on analytical methodologies for various media (air, water, soil, solid waste, and sediment) and were adapted to real-world case studies on the basis of the infrastructure at UB as the National Center for Case Study Teaching in Science (*12*, *13*). Original case studies were

Table 1. Course overview and content.

Topic	Weeks	Lecture topics	Case studies
Statistics for environmental analysis	1, 2	Statistics definitions	Applications and issues
Thermodynamics of pollutant movement	3, 4	Transport in water, sediment, soil, and air; equilibrium and kinetic predictors	
Analysis of natural water systems	5–7	Metals in water, chemical transformations, elemental analysis	Organophosphate pesticides in water, degradation products
Analysis of soil and solid waste	8–11	Volatile and semivolatile organics in soil; partitioning in soil, sediment, and solid waste; GC, LC, and GC/MS	Organochlorine pesticides, dioxin analysis
Analysis of air pollution	12–14	FTIR methodology; remote, source, and particulate sampling	Ozone-hole chemistry, global warming
Reports and presentations	15	—	—

developed to complement the lecture material.

We wanted to shift the course emphases as they related to the development of the public-service environmental analysis projects. The old field study requirement involved small groups of two to four students, often focused on evaluating new measurement technologies. This requirement evolved to larger, class-based projects that necessitated not just collection of data but also validation of methods and data. The studies could potentially be used to make recommendations to the public, elected officials, industry representatives, and environmental agency professionals.

We had to consider that a university laboratory for student education and research is unlikely to meet Good Laboratory Practice standards or achieve U.S. Environmental Protection Agency (EPA) or New York state (NYS) certification for environmental data collection and validation. Thus, we shifted the emphasis of analytical methodology to focus on the strengths and limitations of standard methods. This meant infusing concepts of standardization and the need for standard methods in the environmental testing industry. Although the rise of new analytical technology is still a focus of the lectures, analytical performance of standard methodology is stressed as those methods are set up, validated, and used. Standard methods are commonly used in two areas: elemental analysis of metals and semivolatile organic compounds (SVOCs) in soils (EPA methods series 6000 and 8270) and air pollution analysis of VOCs (adapted from National Institute for Occupational Safety and Health (NIOSH) methods TO1 and TO2).

The shift of focus to standard methods from an approach emphasizing newer methodologies can clearly take away from the more fundamental analytical and instrumental chemistry aspects of a chemistry course. We have endeavored to emphasize the limitations of standard methodology while introducing emerging technologies—for example, inductively coupled plasma MS—that are listed as optional in EPA standard methods. Reviewing the evolution of standard methods allows students to see new approaches on the horizon, and these are reviewed also.

In addition, although statistical analysis of data has always been emphasized throughout the core of analytical chemistry syllabi, a stronger emphasis on data quality for environmental measurements was introduced. For this, the Guidelines for Data Acquisition and Data Quality Evaluation in Environmental Chemistry are used (*14*). This document was first published in 1980 by the American Chemical Society Committee on Environmental Improvement and the subcommittee on Environmental Analytical Chemistry. An emphasis on reviewing analytical performance, data quality evaluation, and quality assurance has also been added to the course. This is incorporated as a review of the field study, after an introduction to environmental applications of experimental statistics.

The fourth and final change involved the transformation of the field study into projects that responded to community requests and concerns. This was accomplished in two steps. In the initial phase, a project was developed as a result of a request from the Buffalo Office of the Environment. The project examined soil contamination in areas adjacent to Stachowski Park, an urban park along the Buffalo River in the Kaisertown neighborhood. Next to the park is a site presently used by residents as if it were an extension of the park. However, this land had been a popular dumping ground until the 1970s for waste from the City Parks Department, along with local industries, who were both suspected of illegal dumping. The NYS Department of Environmental Conservation (DEC) had identified contaminants and surface soils similar to combustion residue, but because no single party was potentially responsible, the site was removed from lists ("delisted") for state-funded remediation.

The first phase project involved the entire class of 26 students, divided into four teams: planning and reporting; sampling; sample workup for metals and semivolatiles; and chemical analysis. Soils were tested and compared with those from the park and from adjacent and nearby housing. Elevated levels of heavy metals, polycyclic aromatic hydrocarbons (PAHs), and chlorinated pesticide residues were quantified. One interesting result was the detection of metabolites and residues of the insecticide DDT in the surface soil, some 30 years after this compound was banned. This discovery reinforced for the students the persistence of the compound, a lesson which had more impact than evaluating textbook plots of degradation rates.

Testing results were supported by split samples analyzed by a commercial, certified environmental laboratory. With a detailed report in hand, the local city council member could obtain federal block grant funding for remediation of the lot. The program was successful from the standpoint of implementation of the methodologies, validation of the results, and outcome of the students' work. However, no block clubs, community members, or groups had been engaged in the planning and reporting.

Equipped with this experience, and naïve about how successful the process could be, we undertook the second phase, incorporating community consultation into projects, in subsequent years. During this phase, students were organized into groups of

Box 1. Studies undertaken in communities.

Community	Studies
Seneca Babcock (Buffalo)	Air study of emitted indigo-dye-related pollutants; soil study of neighborhood park near lead-emitting source
Hickory Woods (Buffalo)	Soil studies of metals; PAH source apportionment by multivariate statistics; GIS studies of soil contamination, location, and sources
Bellevue (Cheektowaga)	Air pollutants emitted from quarry; comparative study of prevalence of autoimmune diseases and asthma
E. Ferry St. (Buffalo)	Lead contamination outside Superfund site; GIS analysis of lead hot spots; comparative public-health studies of blood lead level and prevalence of lupus and asthma
Tonawanda	Soil contamination at school adjacent to Manhattan Project uranium processing plant; air pollutants emitted from multiple industries
Lewiston-Porter	Soil contamination at school adjacent to WWII TNT plant; radium storage site and hazardous waste landfill; community GIS soil and groundwater pollution

four or five and focused on a particular analytical project within an area of concern. So, unlike the first year, when the entire class focused on one soil analysis project, student groups might be involved in soils analysis or air analysis. Nevertheless, they were all involved in the same community problem. Rather than distributing the work across the entire class, the group projects were focused on a particular analytical problem, and the group had to organize all facets of the project (design, sampling, analysis, and reporting/validation) within their group.

Finally, a key issue in public-service learning is the need to sustain collaborations with communities beyond the end of the semester. As the course has been modified, it has also served as a vehicle for recruiting students into longer-term undergraduate and graduate research projects. This creates unique opportunities both to expand the development of the course materials and to sustain the interactions with communities.

Grading in the course has several components. First, students take midterm and final exams on the class lecture and case study material. As shown in Table 1, there are problem sets for statistical analysis and thermodynamics of pollutant movement. In addition, the students must give two oral presentations, one on a research paper and one summarizing their contributions to the project. The project reports must be fully documented with data tables and a PowerPoint presentation, which the students deliver to the community; this document is also graded. Besides the homework, exams, oral presentations, and final report, the students are asked to prepare self-evaluations and group evaluations. Using journals, self-reflection, and other methods of assessment that are common in service-learning courses (*1*, *2*, *5*), the students review their own contributions to the project and those of their team members in a narrative essay. That material serves as a means to assign distribution of credit in the project and to have the students critique their participation.

Development of community participation

During the past 12 years, we have developed long-standing relationships and collaborations with six different communities. Box 1 summarizes the studies that have taken place in each neighborhood. Two are presented as case studies; two others are described schematically. They all exemplify a number of key issues: community participation in study design and execution, the need to prepare students to interact with the community, the advocacy that follows a commitment to a long-term project, and the impact of work done in urban environments.

An outcome of this work has been the development of approaches that prepare students to interact as collaborators with the community. The work is not simply a matter of providing "expert" advice as a consultant to people who do not know what questions to ask. In fact, our observation is that community members ask sophisticated, complex, and difficult questions of students. We also know that many parties are involved. Many times, our efforts were "welcomed" by all, but clear tensions developed among other professionals and industry, agency, and elected officials. The lead author has been involved in many pitched political battles as a result; however, these experiences have yielded some clear advice and training for students involved in these studies.

The key ideas in Box 2 are a shorthand way for students to think about information and process when working in the community. Many science and engineering students have not been prepared for political debate and public communication. Much of what was developed for students was guided by the principles of community engagement and public policy. For public participation (as opposed to public notification), the International Association for Public Participation (www.iap2.org) has particular relevance for environmental decision making. Their core values speak to the public's right to know, understand, and participate in planning and decision making. This standard of behavior is not often matched when government agencies or industry interact with communities.

Seneca Babcock case study

Seneca Babcock is an extremely poor neighborhood (per capita annual income $7000) located just north of the Buffalo River. It was built as employee housing for the Schoellkopf Dye Works (later the National Aniline Corp.) when the company's first chem-

Box 2. Rules of engagement for students and faculty interacting with the community.

Rules	Key questions and comments
Define the problem	What does each stakeholder want to achieve?
Define the players	What are the specific roles and responsibilities of all participants and stakeholders? Which roles and responsibilities are driven by statutory or regulatory concerns?
Consult the community (listen)	How can all voices be heard and respected? Learn to develop collaborative methods for agendas, meetings, and hearings. Don't accept conventional wisdom from agency, industry, or community experts without listening to all voices.
Get the data	What are the relevant measurements? How do these measurements relate to regulated measurements? What information is not being collected by standard measurements and monitoring? Can the community design the measurement strategies?
Interpret and make decisions	Define the results of the measurements to the community. Use collaborative techniques to answer further questions from the community.
Make recommendations	Deliver clear reports that address specific recommendations to community, industry, elected, and regulatory officials.

ical plant opened in western New York in 1880. National Aniline was later acquired by Allied and split into Allied (Signal) Buffalo Research Laboratories, Buffalo Color Corp., and PVS Chemical. Allied is now the Honeywell Corp., and Buffalo Color continued manufacturing aniline-based dyes until 2002. PVS Chemical produces sulfuric acid and related chemicals.

In 1996, sulfur dioxide air emissions from PVS Chemical were centered over the neighborhood for 5 days. The neighborhood community association, with assistance from the city of Buffalo, established a Good Neighbors Planning Alliance and developed an environmental committee to examine how to better work with industries in the area to reduce emissions and exposure. The lead author was approached by the Buffalo City Office of the Environment to provide technical support to the residents. He quickly established this neighborhood as a base for public-service learning projects.

The first projects involved community-based air sampling to address concerns about fugitive odors in the neighborhood along with emissions documented by the Toxics Release Inventory (TRI). The community emphasized its need to understand basic aspects of exposure and VOCs, and a strategy was developed to focus on individual exposure. Several projects resulted that addressed citizens' questions about the relationship between air pollution and exposure in the neighborhood, including one in which NIOSH methods were adapted to measure personal air exposure.

One study was particularly interesting. Students worked with residents concerned about exposures to pollutants; they also addressed industry's concern about the relationships among sources of common pollutants. Buffalo Color listed formaldehyde as a compound that was disposed of, according to the TRI, in the sewer system as an aqueous solution. Yet formaldehyde could be part of hazardous air exposure. This was the classic situation in which industry complained about TRI information that could be misrepresented by people intent on blaming the company rather than considering other sources for the chemical.

Standard formaldehyde-specific badges with NIOSH method 3500 for UV spectroscopic analysis (*15*, *16*) were used to measure formaldehyde exposures from 48 residents over a period of 2 weeks in the spring. Residents collected samples over 8-h time periods during normal days and kept detailed records of their exposures inside and outside their homes. At a community meeting, the students and residents reported the key result: significant formaldehyde exposure occurred only for residents who were, or lived with, two-pack-per-day cigarette smokers. Thus, the residents and students concluded that cigarette smoke and other exposures were more significant than that from TRI-reported releases. This confirmed the hypothesis of the company's representatives, but it was done by the residents collecting the data themselves, not based on the claim of industry representatives who had no data.

The outcome from this single study convinced Buffalo Color that a solution to community understanding of industry operations lay in the residents collecting their own data. After the semester, a student developed an independent study project in collaboration with Buffalo Color. They delivered a presentation on risk-based exposure analysis to the community and facilitated a discussion of TRI releases and technical sampling to discover odor sources in the neighborhood. Other companies also began stronger community collaborations on data collection related to pollution. All of these studies can be found on the Seneca Babcock study website (*17*).

The initial focus was community-based air sampling, but it later moved to joint soil sampling and finally to community collaborations to prevent polluting industries from locating in the neighborhood. The students learned to develop new sampling methods and to collaborate with residents to collect and interpret data in a variety of circumstances. Finally, the ability of the population to keep detailed logbooks of their exposures reinforced for the students the need to keep good laboratory note-

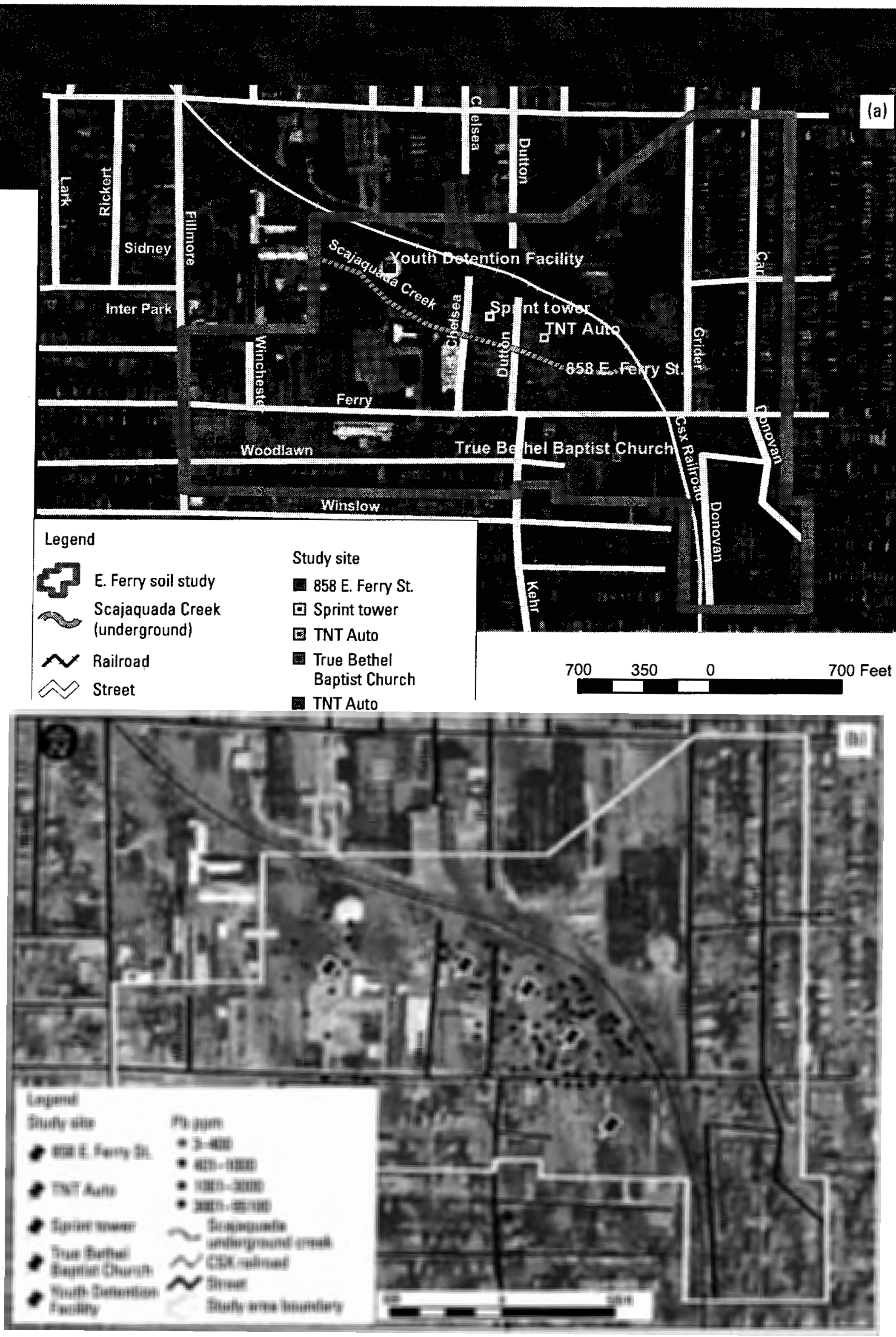


FIGURE 1. (a) Overlay of high-resolution aerial photo identifying sites along E. Ferry St. and areas sampled by previous studies. (b) Combination of aerial photograph and GIS analysis of lead contamination results from all studies.

books. This is a lesson instructors have never been able to get across to students, but the residents did—if they can do it, the students can do it.

E. Ferry St. Superfund site

This site was first identified as hazardous in 1997 by the city of Buffalo. The contamination resulted from an abandoned industrial complex that housed a zinc and lead smelter and a refining operation that ran from the 1920s through the early 1970s (when the smelter building was demolished). The original site at 858 E. Ferry (the name that the community knows as the site), a 3.32-acre empty lot, was used as a dump for waste ash and slag. Adjacent to the site, at 856 E. Ferry, was the actual 2.3-acre smelter facility, according to the city's 1939 Sanborn maps.

The investigations showed extensive lead contamination—subsurface soil values for lead were as high as 96,000 ppm or 9.6%. Furthermore, the true geographic extent of lead contamination was not defined in the early studies. Residents were concerned about a variety of health issues and whether those problems were linked to this Superfund site. The neighborhood is part of a zip code district with one of the highest incidences of elevated blood lead levels in children, according to NYS Department of Health (DOH) data (*18*, *19*).

In the late 1990s, a local minister purchased an abandoned supermarket site across the street and converted it into the True Bethel Baptist Church, which now has >4000 members. Concerns in the community about environmentally related illnesses led to the establishment of the Toxic Waste Lupus Coalition (TWLC) (*20*). The TWLC was awarded a 5-year National Institutes of Environmental Health Sciences grant in 2001 to study, in collaboration with UB, the incidence of lupus, other autoimmune diseases, and asthma. The True Bethel Church would serve as a locus for community activities.

Because of inaction by the NYS legislature and governor, funding for the NYS Superfund program was depleted in the late 1990s, and reauthorization took several years. Because the initial studies at 858 E. Ferry indicated that the extent of lead contamination was not clearly delineated, residents, church members, and the TWLC approached the authors in 2003 to consider pro-

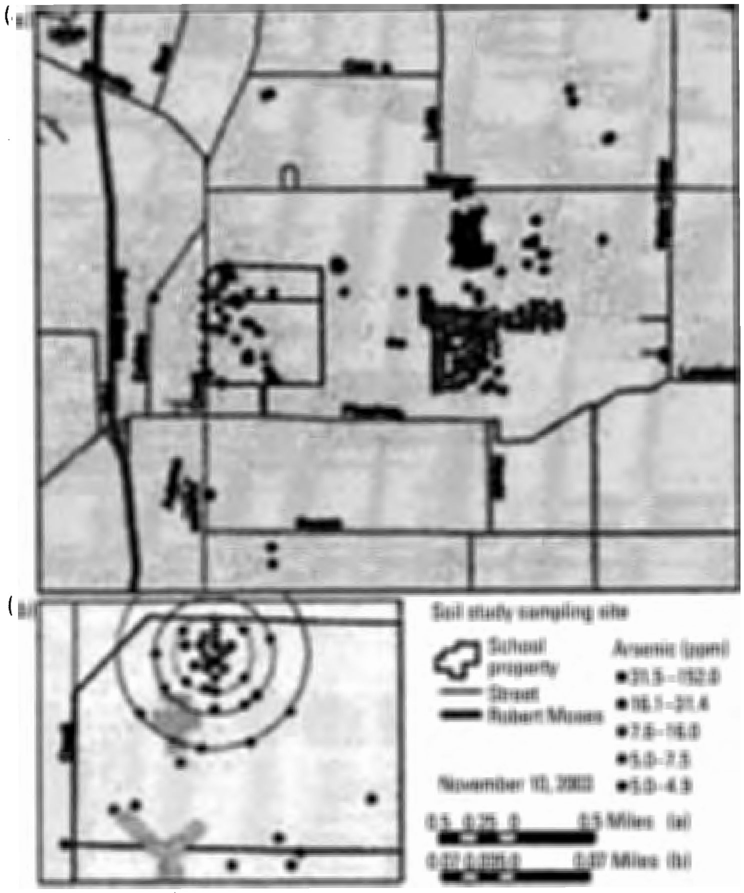


FIGURE 2. (a) Arsenic concentrations located near the Lewiston-Porter Schools. (b) Expanded view of box in (a) shows areas of elevated arsenic concentration. Near school, black spots show follow-up sampling plan for localized identification of region of contamination and remediation.

viding additional lead soil data to determine the extent of the pollution. Students first created geographic information system (GIS) maps of the existing environmental data from NYS DEC analyses from the neighborhood (Figure 1a).

These maps, which included overlays of high-resolution aerial maps, allowed the community to visualize where samples had been taken and what was known about the geographic extent of lead and other contamination. Using these maps, residents, members of the community, and 10 students planned and collected 30 soil samples in the summer of 2003. These samples were taken from private residences, nearby public housing, and the church property and were analyzed for heavy metals by an EPA-certified commercial laboratory. Data showed elevated lead levels of 500–1000 ppm in surface soil samples from outside of the 856 and 858 E. Ferry sites (Figure 1b).

As a result of this study, NYS DEC planned much more extensive site sampling. In 2004, they reported that the geographic extent of elevated lead contamination was farther west than first identified (*21*, *22*). Three additional industrial properties adjacent to 810 E. Ferry showed elevated lead levels and were targeted for cleanup. The residents worked with a newly funded NYS Superfund planning process to propose their own remediation plan, which was accepted by NYS DEC in 2005. Work began in October 2006 to excavate and remediate the entire area, with significant cleanup to residential standards at 858 E. Ferry.

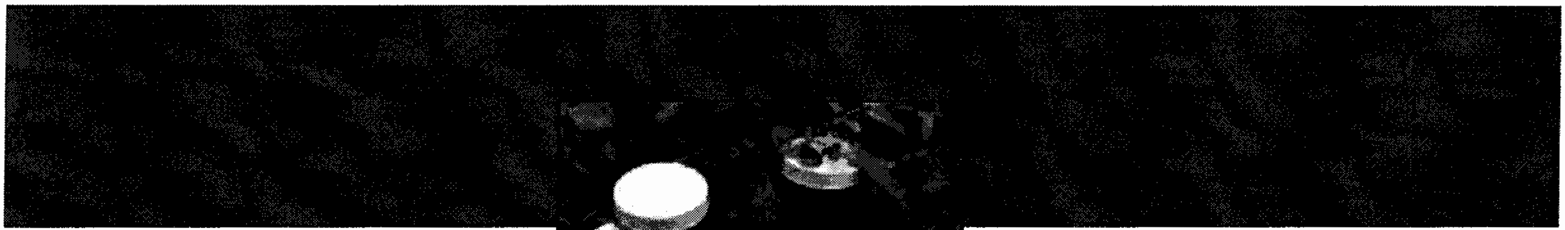
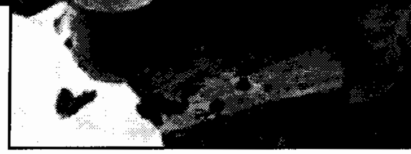
Students worked with community members for several years to develop maps that summarized and explained data. These maps were used to identify areas of the neighborhood that had not been sampled previously but needed to be. The community learned about sample collection, chain of custody, data analysis, and comparison of soil data from surface and subsurface samples. Furthermore, they had data that was outside of the public agencies' control, which allowed them to learn how to use their questions and information to prepare their own remediation plan. NYS DEC representatives noted that this was one of the few sites where community involvement actually created the accepted remediation plan.

Two other projects involved similar considerations. Hickory Woods is a community of federal- and state-subsidized construction of new housing built adjacent to a former coke plant and steel mill, now a NYS Superfund site that is presently being remediated. Some of the housing was built on contaminated land with city knowledge, despite warnings from the NYS DOH that a phase I environmental assessment should be conducted. Our work included interpretation of extensive EPA sampling in the area with GIS mapping methods—the goal was to answer fundamental questions about contaminated soil "hot spots" (*23–25*). This work was done before the E. Ferry project and provided insight into the power of GIS analysis methods that were so critical to the work at E. Ferry.

An ongoing and extensive study that uses GIS for identifying areas of concern in soil and groundwater sampling is also focused at the Lake Ontario Ordnance Works (LOOW) site (*26–29*). In Lewiston-Porter, the schools were built on a buffer zone from the LOOW, a TNT plant from World War II that was later used to store radium with a radioactivity of 2000 curies. This high-level nuclear material is presently stored at the Niagara Falls Storage Site on the adjacent land. A portion of the "remediated" land was then sold to create NYS's only hazardous-waste landfill. In this study, GIS analysis was used to plan community-based sampling, identify contaminated areas, and define remediation areas (*30*; Figure 2).

Conclusions and outcomes

In all the cases, the evolution of the course provided a vehicle for environmental chemical analysis for the public good. It provided a means for residents, industry, government, and community groups to have additional work accomplished, to survey potential problems, and to provide analytical work that is above the capabilities of regulatory-driven analysis. The goals for the students are to learn environmental analytical chemistry, methods, sampling, and interpretation with practical participation. The goals for the community include a better understanding of important analytical concepts, such as precision, accuracy, and validity, and

developing the means to pose and answer questions about the presence, identity, concentration, risk, and impact of pollutants and contaminants in air, soil, and water. In particular, the use of GIS analysis has evolved into a serious research and public-service effort.

The outcome of this work is a different view for students of the role of analytical chemistry in public policy. Rather than simply interpreting or implementing regulations, students see the limits of policy and regulation and find out they have the ability to influence them. The students and faculty at UB have contributed to a broader discussion of remediation where pollution exists, rather than focusing on specific sites with boundaries decided by a street or fence.

As is the case for most environmental work, science, public policy, and regulation intersect with economic and political decisions. For the students and the faculty, immersion in political processes can only be healthy, because more science should be used in public policy and environmental decision making.

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