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In the Classroom

Environmental Chemistry in the General Chemistry Laboratory, Part I: A Context-Based Approach To Teaching Chemistry

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With real-world problems it is possible to highlight the interdisciplinary nature of chemistry and the relevance of chemistry to the lives of students.

This is the first of two closely-related articles describing a context-based approach to teaching first-year chemistry. This first article provides details of the methods for teaching the course, and the following article discusses the student evaluation data obtained for the project. The goals of the project were threefold: (1) to increase students' interest in science early in their academic careers, particularly women and minority students; (2) to raise students' awareness of the connections between chemistry and real-life issues; and (3) to engender a more sophisticated view of science among students. To achieve these goals, we created a module-based laboratory curriculum in which the students spend three to four weeks learning chemistry in the context of a specific environmental problem. Five modules have been developed on the topics of drinking-water quality, lead in urban parks and gardens, pesticides in fruits and vegetables, polychlorinated biphenyls (PCBs) in marine sediments, and risk

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assessment related to hair dye use. A variety of alternative teaching techniques were employed to increase student participation and motivation. This paper will present an overview of these new laboratory experiments.

Introduction

There have been a variety of reports by chemistry educators and national leaders over the last decade that provide evidence for the need to rethink the way we teach chemistry. Research has shown that students find our introductory courses frustrating because the material is difficult, boring, and irrelevant to their lives. All too often, students opt to drop out of these courses. Although we might like to believe that this is because they lack sufficient talent, there is research that indicates that even the brightest leave, often because they are disinterested [1–3]. In this paper we describe a context-based approach to teaching the general chemistry laboratory that has been designed to increase students' interest in chemistry and to raise their awareness of the connection between chemistry and real-life issues.

Discussions in the chemical education community have generated a variety of reports and recommendations for reforming the chemistry curriculum [4–8]. Teaching chemistry in the context of real-world issues has been suggested as a way to motivate and interest students. With real-world problems it is possible to highlight the interdisciplinary nature of chemistry and the relevance of chemistry to the lives of students. Another recommendation has been to create a more active learning environment requiring students to solve more sophisticated problems, design their own experiments, and think critically about the results. We have attempted to incorporate these recommendations by using environmental chemistry as a springboard for introducing chemistry.

Rising enrollments in environmentally-related courses [9] indicate that the study of environmental chemistry is presently particularly interesting to students. Certainly, societal awareness of global warming, hazardous waste dumps, the ozone hole, groundwater contamination, and overdevelopment has increased. Thus, the chemistry involved in both studying and solving environmental problems has an immediate relevance, and it provides the student with significant motivation to understand the underlying chemical principles and the interdisciplinary aspects of the issues. An added benefit of studying environmental chemistry is the fact that the instructors don't know the answer to questions like "How much lead is in the soil in the park?" This creates a

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setting in which the students and instructors work together to solve a scientific problem, a situation in which camaraderie, mutual scientific curiosity, and support pervades the interpersonal interactions.

In this paper, we describe five modular laboratory experiments in which students spend three to four weeks learning chemistry in the context of a specific environmental problem. The five modules are concerned with drinking-water quality, lead in urban parks and gardens, pesticides in fruits and vegetables, polychlorinated biphenyls (PCBs) in marine sediments, and risk assessment related to hair dye use. Each module begins with a question about the environment that the students will answer through several weeks of laboratory work. The students are involved in relatively sophisticated experimental design, sampling and field work, data collection using modern instruments, data analysis and critical thinking regarding the data, and report writing. Various alternative teaching techniques are employed within each module to increase student participation and motivation.

These modules were tested beginning in 1993 in several special environmental chemistry laboratory sections of the General Chemistry course, Chemistry 1A, at University of California, Berkeley. More than 2,000 students enroll in this course each year. Chemistry 1A includes two hours of lecture, one hour of discussion, and four hours of laboratory per week. The Environmental laboratory sections were offered as an option to 60–70 self-selected students each semester. These students attended the same lecture and were given the same examinations, but performed different laboratory experiments.

We specifically chose to test these modules in the first semester General Chemistry course because we wanted to influence students early in their careers. In implementing this context-based approach, our goals were threefold: (1) to increase students’ interest in science early in their academic careers, particularly women and minority students; (2) to raise students’ awareness of the connections between chemistry and real-life issues; and (3) to engender a more sophisticated view of science among students. This is the first of two closely related papers documenting the tests that we conducted with this modular approach. This first article provides details of the approach and a description of the modules developed. The following article discusses the student evaluation data that we obtained for the project in order to determine whether or not we were successful in meeting our goals [10].

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The Modules

In order to have time to develop fully the context of the environmental issue studied, we used a modular approach that integrated three to four weeks of laboratory work around one overarching related theme. Five modules on environmental issues were developed over the course of the project. The topics were chosen to illustrate the interdisciplinary nature of environmental problems, as well as basic chemical concepts. The students were expected to learn the background material and to make connections between multiple chemical concepts related to the topic of the module. In the course of a 15-week semester, the students performed four modules with the following general features.

At the start of several of the modules, the students went on a field trip to collect samples. Such trips are vital because it is difficult to fully evaluate an environmental problem without personal observation of the site in question—knowledge of topography, proximity to hazards and/or neighborhoods, and the potentially affected population is important for making recommendations once the data are in hand. These trips developed skills in recording observations relevant to the question of interest, designing a sampling plan, and collecting samples. It was our observation that the trips served to excite the students, and they returned to the laboratory eager to analyze the samples that they had decided to collect.

In the laboratory the use of a modular approach created a flexible setting in which students had time to do experiments, make mistakes, evaluate their data, and redo experiments from one week to the next. Students were not penalized for not getting the “right answer” because in all situations we didn’t really know the “right answer”; however, they were expected to do careful experiments employing accurate methods and to use statistical methods to find the *best* answer and justify it scientifically.

State-of-the-art instrumental methods and computerized data analysis were included in this laboratory course to demonstrate to the students how modern scientific analyses are carried out. An added benefit was the excitement generated by allowing students hands-on use of sophisticated instrumentation. Work done at the University of Michigan has demonstrated that this combination of encouraging students to think for themselves and teaching them how to approach problems like a real chemist would is an effective means for motivating students and improving their problem-solving abilities [11]. The students were expected to learn how to calibrate and use instruments, such as an ion chromatograph atomic absorption spectrophotometer, supercritical fluid extractor, and capillary gas chromatograph, and how to use Kaleidagraph™ or Microsoft® Excel to present their data graphically.

The ability to “think like a scientist” is a complex set of skills that we wished to develop in our students with the new curriculum. To this end, experimental design and teamwork were both required of students as they created sampling plans that would allow them to answer the questions posed by the modules. Analyses and interpretation of extensive data sets gave the students practice in thinking critically about their data and in using statistics to enhance the quality of their data sets.

Emphasis was placed on writing, because writing has been shown to increase students’ understanding of a subject [12]. Even in large chemistry classes, writing has been used to enhance student understanding of difficult concepts [13]. At the end of each module students wrote an 8–10 page laboratory report on the data they collected. They interpreted their data in the context of existing federal and state regulations, and they were encouraged to write their reports as if they were submitting the data to a local government agency for review. For particularly complex concepts (i.e., acid-base chemistry, how analytical instruments work), students also wrote appendices for their laboratory reports where they discussed these concepts in their own words.

The students were graded on their data collection, data analyses, conclusions, and scientific writing ability. A great deal of feedback was provided on the graded reports so that the students learned what a good report should look like. To this end, students were given a chance to rewrite and resubmit the first report.

A description of the specific modules follows.

(1) The Chemistry of Water—Would you drink the water [14]?

The goal of this three to four week laboratory module is for students to assess the water quality of a local lake or stream and determine whether it might be usable as a potential drinking-water source. The laboratory begins with a field trip to the site of interest where students collect observations, design a sampling plan, and take field measurements (total dissolved solids, dissolved oxygen, and turbidity) that will help them answer the question. After collecting samples and field measurements, students return to the laboratory and perform a bacteriological analysis for total and fecal coliform bacteria to obtain information on the biological contaminants in the water.

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During the next two laboratory periods, students analyze their water samples for pH, alkalinity, conductivity, then use ion chromatography to quantify commonly-occurring anions (Cl^-, F^-, NO_3^-, PO_4^{-3}, and SO_4^{-2}) and atomic absorption spectrophotometry to measure the concentrations of three of the four major cations in natural waters (Na^+, Ca^{+2}, and Mg^{+2}). A final laboratory period is spent reviewing the data, learning about data handling and statistics, and learning to use the statistical and graphing functions of Kaleidagraph™ or Microsoft® Excel.

The chemical concepts covered in this four-week module include: solutions, concentrations, Beer’s Law, pH and alkalinity, titration and titration curves, ion exchange chromatography, conductimetric detection of dissolved ionic substances, flame AA spectroscopy, and the statistical analysis of data. The laboratory manual provides background information on the chemical concepts, as well as a detailed look at how the instruments work. Federal Water Quality Standards are also included for students to use for comparison purposes.

(2) Lead in the Environment—Is it safe for children to play in these parks?

The students survey lead contamination of soils in Oakland (California) City parks in order to answer the question “Is it safe for children to play in this park?” The experiment begins with students using their knowledge of the occurrence of lead in the environment (from the assigned reading in the laboratory manual) to select a city park to sample for possible lead contamination. A field trip to the site permits the students to make observations and collect soil, water, and paint samples for analysis.

We note that the field trips to inner-city Oakland lead to some particularly positive, if unanticipated, interactions. On many occasions, interested neighbors and park visitors ask the students what they are doing. These conversations occasionally lead the students to sample alternate sites than those they had originally planned, as they are diverted to the homes and gardens of neighborhood residents. Students then have the responsibility of reporting their results to these residents, a task which they do with great care. We found that experiences like these are important in providing students a reason to do the analyses and to do them carefully.

During the laboratory period following the field trip, students measure the pH of their soil samples [15], carry out a hot-acid digestion [16] on the sample, and begin analyses of the digestates by graphite furnace atomic absorption spectroscopy. In the third week,

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students discuss their data and reprocess any suspicious data points. In addition, they prepare a set of standards to test their ability to successfully calculate and prepare solutions of precise concentration.

A variety of other experiments are included in different semesters, depending on the sequence of the topics covered in the lecture part of the course. In semesters in which there was a need to focus on equilibrium, students evaluate the solubility characteristics of lead salts and lead metal in water and acid, and they are assigned a worksheet to provide them with practice solving equilibrium problems. In other semesters, quantum theory and spectroscopy are highlighted by having students work with emission lamps and spectroscopes to enhance their understanding of the concepts behind the spectroscopic method of analysis used.

The chemical concepts covered in this three-week module include: solubility equilibria, acid-base equilibria, Le Chatelier's principle, effects of pH on the potential toxicity of lead in soils, redox behavior of metals in acidic solution, graphite furnace AA spectroscopy, and preparation of standards. The laboratory manual contains information on the health effects of lead and sources in the environment, as well as the details of the chemical equilibria governing the solubility of lead in neutral and aqueous solutions.

(3) Polychlorinated Biphenyl (PCB) Contamination in Marine Sediments—Is it safe to eat these fish [17]?

In this module, students assess the potential hazard of eating fish from the San Francisco Bay by measuring sediment concentrations of PCBs. The first week involves a field trip to local fishing piers to take dredge samples of sediments. Students process their samples during the following laboratory period using the EPA sonication method for extraction of PCBs in sediments and Gas Chromotography-Electron Capture Detector (GC-ECD) analysis of the extracts [18].

In the third laboratory period, students study the solubility properties of a variety of PCB-like organic compounds to illustrate the process of extraction and the need for choosing an effective extraction solvent. Students also spend time during this laboratory period interpreting their chromatograms and doing a worksheet that steps them through the analysis used for identifying the different Aroclors™. For the final report, the students are asked to comment on their data in light of their knowledge of bioaccumulation of organochlorine compounds from the sediments to the fish that people

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eat and to make recommendations on whether the fish from the San Francisco Bay should be eaten.

The chemical concepts covered in this three-week module include: structure/solubility relationships, polar and nonpolar compounds, distillation, extraction, gas chromatography, bioaccumulation, and biodegradation. The laboratory manual contains background material on what PCBs are and where they are found in the environment, as well as information on bioaccumulation, biodegradation, and the theory behind the extraction techniques and instruments used in the experiment.

This is a difficult experiment for first-year students for several reasons: (1) multiple new concepts are introduced, (2) the experimental work is lengthy and requires good planning and efficient time management to finish on time, and (3) the chromatograms from the analysis are complex and difficult for students to interpret. This experiment is probably best performed by students with some prior experience, for example, in an organic or analytical chemistry class.

(4) Organochlorine Pesticides in Fruits and Vegetables-How do you assess the risks associated with pesticide exposure [19]?

In this module the students analyze fruits and vegetables for residues of organochlorine pesticides and use the data to debate the issue of pesticide use in the United States. The PCB and pesticide experiments cover similar concepts and are never used in the same semester.

In the first laboratory period, students study the solubility properties of a variety of organic compounds to illustrate the process of extraction and the need for choosing an effective extraction solvent. They also perform a writing exercise on risk assessment in which they are asked to evaluate critically an excerpt from a book on pesticides and risk [20].

During the second period, students bring produce they have obtained at the grocery store to the laboratory for processing and analysis. The extraction procedure was adapted from the California Department of Food and Agriculture method [21], and involves an acetonitrile extraction followed by a hexane solvent exchange and Florisil™ cleanup. The final extract is analyzed by GC-ECD, using a 14-component standard for comparison and quantification. Students receive their chromatograms during the third

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laboratory period and must interpret them and carry out the complex calculations to determine the concentration of pesticide residues on the produce they analyzed. Measurable organochlorine pesticide residues were observed in approximately 20% of the samples analyzed.

The fourth laboratory period is dedicated to a debate on the issue of pesticide use. Students play the role of either an “Environmentalist” or an “Agribusiness advocate” and use their data to debate whether the regulation of pesticides in the food supply should be changed. A more detailed study of the pesticide debate will follow in a later paper.

The chemical concepts covered in this four-week module are nearly identical to those covered by the PCB module and include: structure/solubility relationships, polar and non-polar compounds, extraction, use of a surrogate standard, gas chromatography, bioaccumulation, and biodegradation. The laboratory manual contains background material on organochlorine pesticides, risk assessment, and the laws regulating pesticide use, as well as information on bioaccumulation, biodegradation, and the theory behind the extraction techniques and instruments used in the experiment.

(5) Hair Dyes and Health Effects—I’ve always wanted to be a brunette. What’s the problem [22]?

In this module, the students carry out a risk assessment for hair-dye use by isolating *p*-phenylenediamine from hair dyes to determine the dose received by consumers. They begin the experiment by carrying out solubility tests on a variety of organic substances, including compounds similar to the organic acids and bases used in hair-dye formulations (resorcinol, naphthol, and a variety of aromatic amines). Knowledge of these solubility properties is helpful in understanding the multistep acid-base extraction scheme used to separate the *p*-phenylenediamine from the other components in commercial hair-dye formulations. The extraction process is done in microscale and is carried out during the first laboratory period as well.

The sample extracts are analyzed by GC, and students are given their chromatograms to interpret during the second laboratory period. They also carry out TLC analyses of commercial hair dyes and do a mass spectrometry worksheet involving the identification of hair dye reaction products.

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An additional exercise in critical thinking is required of the students for the write-up of this experiment. A set of abstracts from research papers on the safety of hair dyes is provided for students to critique. Papers published by Clairol or Revlon present different viewpoints than those published by other workers in the field, and students are asked to discuss these differences and comment on the quality of the study.

The chemical concepts covered in this two to three week module include: structure/solubility relationships, polar and nonpolar compounds, organic compounds as acids and bases, extraction, gas chromatography, thin-layer chromatography, and mass spectrometry. The laboratory manual contains background information on risk assessment and the epidemiological studies related to hair-dye use, as well as the chemistry information necessary to understand the extraction process and GC analysis.

(6) Independent Project Module

During three of the five semesters the course was taught, students performed independent projects—miniresearch projects in which students chose an environmental topic to research over the course of three weeks. The students choose a topic of interest to themselves and work in pairs to collect and analyze samples, interpret the data, and prepare a poster presentation on their results. The project module is very time-intensive for both students and faculty, but quite valuable in providing students with a researchlike experience and showing them how scientists approach a problem.

Expansion to the Larger Freshman Chemistry Class In the Spring and Fall semesters of 1994 and 1995, the modules on “Lead in the Environment” and “Water Chemistry” were incorporated into all of the regular General Chemistry laboratory sections. This involved 1,200+ students during the Fall semester and 700+ in the Spring. Although the students were not taken on field trips, they were given information and shown a video documenting sample collection.

In the Fall of 1994, the samples for the module on “Lead in the Environment” were taken from Oakland City land that neighbors wanted to turn into a neighborhood garden. By using the autosampler on the graphite furnace atomic absorption spectrophotometer and an undergraduate instrument operator, all of the samples prepared by the 1200+ students were analyzed over the course of a week’s time. The students were provided

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with an absorbance reading and the slope of the standard curve from the instrument such that they could calculate the concentration of lead in their own sample.

Due to the large quantity of data, we obtained a statistically significant sampling of the soil from the site under investigation. The students were given the entire data set to analyze. Their analyses showed clear trends in lead distribution in the park as a function of proximity to painted buildings, streets, picnic areas, and play areas. Moreover, the results indicated that the proposed garden site had very high lead levels; thus, it would not be a good site for a community garden.

In the Spring and Fall semesters of 1995, the lead experiment was modified to incorporate experimental design. This was done by allowing students to ask their own questions related to lead in the environment. The students in each laboratory section posed and investigated a question as a research team. Example projects included investigating answers to the following questions:

- Is there lead in the water in the dorms?
- Do crabs from the San Francisco Bay contain lead?
- Is there a difference in the lead content of newsprint over the years?
- Is there lead in the soil near the big painted letters on the hillside near the stadium?
- Is there a difference in the lead content of hair from people who have lived in different locales?

With their questions in mind, the students planned an experiment that would answer their question, gathered samples, carried out the procedures, obtained the data, and wrote a detailed report on the results. The work was divided up so as to obtain data for adequate numbers of samples and for adequate numbers of analyses on a particular sample. We observed that there was much more student enthusiasm when the students chose and designed the project, rather than when we constructed one for them.

In the Fall of 1995, the module on *The Chemistry of Water* was carried out by the entire Freshman chemistry class at UC Berkeley. Samples from a nearby lake were collected by the staff of the course and brought back to the laboratory for the students to analyze over the next several weeks. During the course of the analyses, approximately one-third of the students had an opportunity to use the ion chromatograph hands-on to analyze

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selected samples from their section for anion content. The students pooled their data and used statistical analyses to draw conclusions about the potability of the water in the lake.

The modules that focused on organic analyses (PCBs, Pesticides, and Hairdyes) were less transferable to the larger class because of the long run-time required for the GC analysis (20–45 minutes). In addition, the expense of the organic solvents and the disposal costs were prohibitive.

Summary Five context-based modular experiments centered around environmental issues were created for use in the first-year chemistry course. Students were introduced not only to the chemistry concepts necessary for understanding environmental issues, but also to principles of sampling, risk assessment, and the persistence of organic compounds in the environment. The experiments related to water and lead are readily transferable to the large class and serve to demonstrate to students the role of chemistry in evaluating and solving environmental problems.

The ability to think critically and take a broader view of the limits of science are essential for scientific literacy. Our methods for developing these skills in the students included role-playing in the context of a debate centered on the issue of pesticide use in the food supply and an assignment where students critiqued a set of conflicting abstracts of scientific papers describing studies on the connection between hair dye use and carcinogenesis. Because neither of these issues are clear-cut, these exercises were valuable tools for introducing students to the idea that it is important to recognize complexity and deal with it in a scientifically valid manner.

The following paper in this series presents the student evaluation data collected for the Environmental Laboratory.

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REFERENCES

1. Carter, C. S.; Brickhouse, N. W. *J. Chem. Educ.* **1989**, *66*, 223.

2. Seymour, E. *J. Coll. Sci. Teaching*, **1995**, *May*, 392.

3. (a) Tobias, S. *Revitalizing Undergraduate Science: Why Some Things Work and Most Don't*; Research Corporation: Tuscon, AZ, 1992; (b) Tobias, S. *Revitalizing Undergraduate Science: Why Some Things Work and Most Don't*; Research Corporation: Tucson, AZ, 1990.

4. "New Directions for General Chemistry"; Lloyd, B. W., Ed.; report from the ACS Task Force on the General Chemistry Curriculum; Division of Chemical Education. American Chemical Society: Washington, DC, 1994 and references reprinted from *J. Chem. Educ.* contained within.

5. "Innovations and Change in the Chemistry Curriculum"; National Science Foundation. Division of Undergraduate Education: Washington, DC, 1993.

6. *Entry Level Undergraduate Courses in Science, Mathematics and Engineering: An Investment in Human Resources*; Sigma Xi: Research Triangle Park, NC, 1990.

7. "America's Academic Future"; report of the Presidential Young Investigator Colloquium on U.S. Engineering, Mathematics, and Science Education for the Year 2010 and Beyond; National Science Foundation. Directorate for Education and Human Resources: Washington, DC, 1992.

8. Spencer, J. report of the ACS Task Force on the General Chemistry Curriculum. Division of Chemical Education. American Chemical Society: Washington, DC, July 1995.

9. Sloan, D., Director of Environmental Science Program at UC Berkeley, private communication.

10. Kegley, S. E.; Stacy, A. M., Gutwill, J. P., *The Chemical Educator,* **1996**, *1* (*4*): S 1430-4171(96) 04053-8. Avail. URL: http://journals.springer-ny. com/chedr.

11. (a) Ege, S. N.; Coppola, B. P.; Lawton, R. G. "The University of Michigan Undergraduate Chemistry curriculum. 1. Philosophy, Curriculum, and the Nature of Change" *J. Chem. Educ.*, in press as of September 1996; (b) Coppola, B. P.; Ege, S. N.; Lawton, R. G. "The University of Michigan Undergraduate Chemistry Curriculum. 2. Instructional Strategies and Asssessment" *J. Chem. Educ.*, in press as of September 1996.

12. Zissner, W. *Writing to Learn*; Harper and Row: New York, 1988.

ISSN 1430-4171
http://journals.springer-ny.com/chedr
S 1430-4171 (96) 04052-6

13. (a) Van Orden, N. *J. Chem. Educ.*, **1990**, *67*, 583; (b) Cooper, M. M. *J. Chem. Educ.*, **1993**, *70*, 476; (c) Sunderwirth, S. G. *J. Chem. Educ.*, **1993**, *70*, 474; (d) Beall, H.; Trimbur, J. *J. Chem. Educ.*, **1993**, *70*, 478.

14. Kegley, S. E.; Stacy, A. M.; Andrews, J. *The Chemistry of Water*; University Science Books: Sausalito, CA, in press Fall, 1996.

15. *Soil Sampling and Methods of Analysis*; Carter, M. R., Ed.; Lewis Publishers: Boca Raton, FL, 1993, p 141.

16. Adapted from Method 200.2; Smoley, C. K. *Methods for the Determination of Metals in Environmental Samples*; Environmental Protection Agency. CRC Press: Boca Raton, FL, 1992, p 22.

17. Kegley, S. E.; Hansen, K. J.; Cunningham, K. *J. Chem. Educ.*, **1996**, *73*, 558.

18. (a) United States Environmental Protection Agency Method 608; *Fed. Regist.*, **1984**, *49*, p 89; (b) United States Environmental Protection Agency Method 8080, Environmental Monitoring and Support Laboratory. U. S. Environmental Protection Agency: Cincinnati, OH 1986.

19. Kegley, S. E; Wise, L. J. *Organochlorine Pesticides in Fruits and Vegetables*; University Science Books: Sausalito, CA, in press Fall, 1996.

20. *Pesticide Residues and Food Safety: A Harvest of Viewpoints*; Tweedy, B. G.; Dishburger, H. J.; Ballantine, L. G.; McCarthy, J., Eds.; American Chemical Society: Washington, DC, **1991**.

21. *Multi-Residue Pesticide Screens*; California Department of Food and Agriculture. Division of Inspection Services. Chemistry Laboratory Services Branch Pesticide Residue Program: Sacramento, CA, 1988.

22. (a) Kegley, S. E.; Wise, L. J. “Hair Dyes and Health Effects, 1: Teaching Risk Assessment in the Undergraduate Laboratory”; manuscript in preparation for submission to *Chem. Educator*; (b) Kegley, S. E.; Wise, L. J. “Hair Dyes and Health Effects, 2: Determination of the Dose of *p*-Phenylenediamine from Commercial Hair Dye Use”; manuscript in preparation for submission to *Chem. Educator.*