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# Low-Level Radioactive Waste Disposal: An Exercise in Dealing with Pollution

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Each year commercial and governmental sources in the United States generate about 1.4 million cubic feet of "low-level radioactive waste" (LLRW). States can play a role in the disposal of LLRW and citizens can decide what factors to use in determining LLRW disposal sites. Hazardous waste disposal, particularly of radioactive wastes, is a largely unsolved problem in the United States and the rest of the world. Like the problem of the U.S. budget deficit and the funding of Social Security, its solution is being delayed for future generations. Yet LLRW disposal sites will impact some people more than others. Students are surprised and delighted to discover the importance of local citizen participation on the national agenda, especially when that participation is well informed.

Teachers of interdisciplinary courses looking for a relevant topic which students find stimulating might wish to try this Contemporary Problem exercise dealing with issues involved in low-level radioactive waste disposal. The full problem is available on *JCE Online*. It has been structured as a primarily classroom-centered, two- to three-week, group problem-based learning module. The goals are (i) scientific: to increase chemical–biological literacy in radiation and human health; (ii) political–social: to develop a framework for informed decision-making; and (iii) ethical: to systematically examine the ethical dimensions of decision making.

Core concepts in chemistry include the particulate nature of matter, atomic structure and periodic properties, structure and bonding, states of matter, dynamics (transport of matter), and nuclear energetics. Core concepts from other disciplines include risk analysis (statistics), cost–benefit analysis (economics), biological half-life and biological effects of radiation (biology), public perceptions (psychology), and decision making (political science, ethics). The exercise requires students to think like scientists and asks them to critically analyze data, access new information, think critically, solve problems as an individual and as part of a group, and communicate with others.

The LLRW exercise has been used as a four-week module in Problems of Environmental Quality, a continuing education course taught by Temple University faculty for Environmental Protection Agency employees. The class of 25 students was divided into five groups of five members each. Introduction of the problem to the group for discussion identified a near absence of recognition of the chemical concepts presented. For two weeks there were teacher presentations for review of the basic chemical concepts related to radiation. This was accompanied by homework assignments asking students to learn the material on the information cards using the text and sources they found in the library. During the third and fourth weeks the students discussed the exercise in groups and prepared group answers to the questions asked. The groups were free to develop team strategies for answering the questions. However, individuals were responsible for all the material in the problem, and the examination asked for brief definitions of new terms and short essay answers for questions requiring analysis, application, or synthesis of information.

The problem-based learning exercise appears suitable for college students of introductory chemistry in society or environmental studies courses and for advanced high school junior and seniors in any environmental science, problems of democracy, or interdisciplinary science course. Students responded that they appreciated the structure of the exercise as a vehicle to learn about radiation. In prior courses radiation concepts were presented in a lecture format, and not as part of a problem approach, to students enrolled in an elective environmental studies course designed to fulfill a college science requirement. The instructor observed that the continuing education students using the problem-based exercise initially appeared to be less well prepared academically than the matriculated college students. However, exam essay responses indicated that the continuing education students ultimately were better able to express an understanding of radiation issues than those who were taught only by the lecture method.

The following Contemporary Problems and Case Studies (CP/CS) documentation will be found in *JCE Online*:

- **The CP/CS summary**
- **The full CP/CS**
- **Written directions for students**
- **Instructor notes** and useful references. For the leading reference, see Contreras, J. In the Village Square: Risk Misperception and Decisionmaking in the Regulation of Low-Level Radioactive Waste; *Ecol. Law Q.* **1992,** *19*, 481–545. This was the source of information for most of the information cards.

  It should be noted (112 Supreme Court Reporter 2408, 1992) that a take title provision requiring states to accept ownership of waste or regulate according to the instructions of Congress was found to be inconsistent with the 10th amendment. The other provisions of the act were found to be separable.

[W]Supplementary materials for this article are available on *JCE Online* at *http://jchemed.chem.wisc.edu/Journal/issues/1998/Dec/abs1583.html.*

G. Tyler Miller's *Living in the Environment*, 7th ed. (Wadsworth: Belmont, CA, 1992) is a useful reference for background information on radiation concepts, cost–benefit analysis, ethical principles, and political structures.

For references dealing with problem-based learning, see the following publications by D. L. Woods: *Problem-Based Learning: How to Gain the Most from PBL*; Donald R. Woods, Pub., Waterdoen, Ontario, LOR 2HO, 1994 (phone 905/25-9140); and Problem Based Learning, *J. College Sci. Teach.* 1996, *25*, 300.

Experience suggests that the instructor must assess the ability of the students to understand the information cards and assign readings or lecture as appropriate. The instructor should constantly move within the groups as they work to assess group progress.

To add excitement to the learning experience, try assigning roles that might exist at a public hearing on an LLRW facility. Students prepare written testimony for the hearing, which takes place in class. Hearing examiner roles are also assigned. Hearing examiners take notes, prepare summaries of their views on the basis of their community roles and the quality of the testimony, and present their findings orally at the next class. Poll the class as a whole to determine if the majority agree with the examiners' consensus view, then discuss why or why not. Alternatively, the instructor can evaluate student understanding of concepts by holding a public hearing in which the students pull roles from a hat, much as formal debaters must be prepared to defend multiple positions.

- **Assessment strategies**: see instructor notes, above. Essay questions on the exam were designed to elicit student understanding of the group discussion material.

  Sample question #1: You are the state hearing examiner on the issue of LLRW siting. You have heard public testimony from the residents of five counties. What factors will you take into consideration in your decision-making process in deciding whether or where to site the facility? A grading rubric includes coverage of ethical, economic, environmental, and political considerations.

  Sample question #2: Compare the long-term effects of background low-level radiation with the exposures expected from an LLRW disposal site.

  A grading rubric includes a discussion of sources and types of radiation (isotopes involved), radiation exposure pathways, target organs (lungs, skin, pancreas, bone, reproductive organs) for isotopes, biological half-lives of radioisotopes, and cumulative effects of exposures.

## Mission Statement: Teaching with Problems and Case Studies

Teaching with Problems and Case Studies (TPCS) is a new feature column to provide faculty of all levels with real-world scenarios that involve chemistry and encourage students to appreciate how chemistry and science shape our lives. This column will contain examples of every day occurrences where chemistry-based course material is applied. If students are given scenarios or problems that they can visualize and are familiar with, they will be more apt to remember and comprehend the underlying chemical concepts. As a result, contemporary problems and case studies can fuel student learning (*1, 2*). The format of these problems and case studies may be teacher-guided, informal class discussions, written research reports, oral presentations, or student-directed group projects. Contemporary problems and case studies are increasingly being used as vehicles for teaching course material (*3*). These are not intended to be laboratory-driven, although they may be supported by germane demonstration and laboratory experiences (solely laboratory-based cases should be submitted as laboratory experiment manuscripts). This column was created because of the lack of resources in which educators can find contemporary problems and case studies for teaching chemistry-based concepts.

Manuscripts chosen for publication in the TPCS column will be presented in two parts: (i) a summary, which will be published in the print version of *JCE*, and (ii) all supporting material, which will appear at *JCE Online*. Special guidelines for submitting manuscripts to this feature column are available online at ***http://jchemed.chem.wisc.edu/Journal/Authors/TPCS/index.html***.

### Literature Cited


1. Woods, D. R. *Problem-Based Learning: How to Gain the Most from PBL*, Donald R. Woods, Waterdown, ON, 1994.
2. For representative examples of contemporary problems and case studies, see: Herreid, C. F. Case Study Teaching in Science: A Dilemma Case on "Animal Rights"; *J. Coll. Sci. Teach.* **1996**, *25*, 413–418. Jones, M. Use of a Classroom Jury Trial to Enhance Students' Perception of Science as Part of Their Lives; *J. Chem. Educ.* **1997**, *74*, 537. Corneley, K. Use of Case Studies in an Undergraduate Biochemistry Course; *J. Chem. Educ.* **1998**, *75*, 475–478. Case Studies in Science Web Page, SUNY-Buffalo, *http://ublib.buffalo.edu/libraries/projects/cases/ubcase.htm*.
3. *Chemistry in Context: Applying Chemistry to Society*; W. C. Brown: Dubuque, IA, 1994. *ChemCom. Chemistry in the Community*; Kendall/Hunt: Dubuque, IA, 1988.



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