A Case on Septic Systems and Well Water Requiring In-Depth Analysis and Including Optional Laboratory Experiments

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A case is a written document that presents a complex, real-world dilemma that calls for collaborative and in-depth analysis by students. Cases introduce students to discipline principles in a relevant context, and introduce students to the nuances of making scientifically based decisions as they strive for a resolution to the given dilemma (1–12). Through a student-centered discussion of the case material, students are called upon to recognize and define the dilemma, identify relevant data, perform problem solving and analysis, and then make a recommendation for a course of action. Originally developed by the Harvard Business School, the case discussion method is noted for its effectiveness in imparting higher order reasoning skills (1–5). In recent years, the case pedagogy has expanded to a variety of other fields, most notably law, medicine, biology, and chemistry (6–20).

Well Wishes is a case that engages students in the chemistry of groundwater purification, dilution, and the nitrogen cycle within a familiar context—the septic system. Nearly a third (21, 22) of homes in the United States use some form of self-contained waste treatment facility. Central to the analysis of the dilemma presented in Well Wishes is an understanding of the relationship among various nitrogen-containing species present in the septic system (23), groundwater and aquifer, and subsequently determining the extent to which household waste contributes to a homeowner’s water supply. The scenario presented in Well Wishes is fictitious, although it is based largely on groundwater experiments and data reported by Robertson and Cherry and co-workers at the Waterloo Centre for Groundwater Research (24–26).

Through the analysis of the real-world problem in the Well Wishes case, chemical principles are developed and applied to a realistic situation. As a teaching tool, we articulate five specific goals that may be met using this case.

1. To engage students in analysis involving the following chemical principles: the calculation of solution concentrations (especially ppm), the use of stoichiometry to obtain the concentration of a variety of species in solution, the dilution of solutions and their subsequent concentrations, aqueous reactions (especially redox reactions) and an introduction to the carbon and nitrogen cycles as they pertain to wastewater.

2. To teach students critical reading skills, problem formulation, and advanced analysis skills by evaluating a complex, real-world problem and developing a problem solving strategy for a dilemma that has no single correct answer.

3. To unify the goals of the classroom and laboratory by leading students to determine that information for the case analysis must be gathered by experiment in a laboratory setting, and by requiring them to bring their experimental findings to bear upon the classroom discussion of the case.

4. To impart how a septic system functions to purify household wastewater and the environmental impact of using septic systems.

5. To examine the consequences of an individual’s actions on the environment in his/her daily life, including the concepts of sustainability and sustainable lifestyles.

This case can be used at a variety of levels, including introductory chemistry and analytical chemistry, as well as environmental courses designed for science majors or non-majors.

Well Wishes Case Synopsis

Standing water over a septic system drain field causes new homeowners to become concerned about the quality of their well water and the viability of their septic system. Upon testing the well water, they find it contains high levels of nitrate, a species known to cause health problems. The amount of nitrogen generated daily by the household (as measured in the septic system effluent) is the basis of the case analysis. Students convert all nitrogen-containing species to nitrate and account for groundwater and aquifer dilution. After comparing the measured well water nitrate levels with calculated values, the septic system can be either ruled out or identified as the source of hazardous nitrate levels in the well water. Based on this analysis, the homeowners must find a way to improve the quality of their well water and determine whether their septic system needs to be modified or replaced.

Laboratory Components

This case can be used solely as a discussion and analysis tool in the classroom, or in conjunction with laboratory experiments that generate data relevant to the case; the laboratory exercises are provided in the Supplemental Material. Detailed protocols for a spectrophotometric determination of nitrate and a Mohr titration for chloride are included. In

In the Classroom

Teaching with Problems and Case Studies

Well Wishes

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Laboratory Components

This case can be used solely as a discussion and analysis tool in the classroom, or in conjunction with laboratory experiments that generate data relevant to the case; the laboratory exercises are provided in the Supplemental Material. Detailed protocols for a spectrophotometric determination of nitrate and a Mohr titration for chloride are included. In
addition, suggestions for using ion selective electrodes to determine nitrate or chloride levels are given.

The laboratory exercises, if used, are a means of finding critical information needed for the resolution of the case dilemma. For example, one experiment involves the measurement of nitrate in the homeowners’ well water. Knowing whether the well water has high levels of nitrate is critical in determining whether the homeowners should continue drinking their water. If the instructor chooses not to include the laboratory activities, the same information can be provided to students in report form. The reports are provided in the Supplemental Materials.

Use of the Case

This case can be used in introductory chemistry, analytical chemistry, or environmental chemistry courses for science majors or non-science majors. Depending on the level of the course, the case discussion could focus on different aspects of the case. For example, students in a non-majors environmental chemistry class might focus more on the economic impact of different waste treatment options while an introductory chemistry course for science majors might dwell most on the nitrogen cycle in septic systems and the dilution of wastewater effluent in the aquifer. Because the context of this case is so rich, it can be used in myriad ways that require very little background in chemistry, as well as in courses where a great deal of earlier chemistry background is expected.

Variations

This case can be used in a wide variety of class and lab combinations. Depending on the time and facilities available, between 2–5 class periods and 0–2 lab periods could be dedicated to discussion and analysis of the case. Details of general approaches for these variations are included in the Supplemental Materials.

Examples of Variations

This case was used at St. Olaf College in a non-majors environmental chemistry course. Part A of Well Wishes was distributed along with some preparatory questions. The students then discussed the case during a 90-minute class period that preceded a three-hour laboratory session. This strategy compelled students to test the well water for nitrate in the lab, so as to obtain information needed to resolve the case. Upon completion of the spectrophotometric nitrate experiment, the class was given Part B of the case and the Well Water Report (including their nitrate data) and the case discussion was concluded in the next class period.

At Drew University, the Well Wishes case was used in an upper-level analytical chemistry course over portions of a two-week period and incorporated two laboratory experiments—the spectrophotometric nitrate determination and the Mohr titration chloride determination. Initially, students spent one to two 50-minute class periods defining and exploring the issues in the case. Over the next week, the class focused on some of the underlying chemical principles, such as oxidation–reduction reactions in an aqueous environment, various expressions for concentrations and conversion between them, and dilution strategies. During this same period of time, students performed preliminary calculations on data present in the case as homework, and also analyzed the septic system effluent for chloride concentration in the first laboratory meeting. In portions of class meetings over the second week, analysis results were compared and verified, and additional analysis strategies outlined. Finally, students measured the nitrate concentration in the homeowners’ well water in the second laboratory meeting, and a portion of an additional class period was used to complete the case analysis as a group.

Student Assignments

A full set of the student assignments are provided in the Supplemental Materials. These assignments may be collected and graded to assess student mastery of the material. Participation in the class discussion or small group projects may be assigned a point value. A description of three possible assignments follows.

Pre-Assignments

Students are typically given the case documents ahead of time to prepare for the in-class discussion. To facilitate student preparation, we assign pre-case questions to help focus reading of the case at a level necessary to engage in substantive discussion in class.

Case Questions and Problem Solving

During the case, students complete pieces of the analysis either in class or as homework, individually or in groups. For example, if the case is conducted over three or more class periods, students can complete the analysis in discrete steps as homework between class sessions. The laboratory experiments and results may also be graded.

Post-Assignments

As a final project, students are asked to make a recommendation to the homeowners regarding their well water and septic system. This could be done in group or individual class presentations or written essays.

Student Assessment

By way of assessment of student learning and engagement, students in an upper-level course at Drew University were asked to respond in writing to the following question as part of their post-assignment:

“What one or two concepts from this case are you likely to be able to recall at a later point in time (for instance, after the semester is over), if any? Sit back and consider this question—what piqued your curiosity or had relevance to YOU?”

Here are some representative student responses:

“This case certainly started me thinking about my own family’s situation. We have both a well and septic tank, but until we received the information on this case in class, I never even considered the connection between the two. I was immediately intrigued, I spoke with my parents soon after, asking if/when we had our water tested. They said that we don’t have our water tested, sometimes it’s better not to know…for educated and intelligent adults, I felt that was a fairly unconcerned position to take. So, now I am curious, and a bit concerned, about my well situation at home.”

“I will take away the idea of environmental concentration notation. I have converted so many numbers between molarity...
and parts per million, these calculations are not something I will soon forget.”

“After working on this case, I learned some of the health effects related to high levels of nitrate in drinking water. Since our family does not use a septic system, the concept of how a septic system works and what some of the concerns were for those who use this type of system was entirely new and also a memorable one. Also, I personally never considered the negative aspects of using chemical fertilizers on lawns. This case has shown that people should be considerate of what they put into their soils since it might contaminate their own drinking water.”

**Supplemental Material**

A full set of case study materials is available in this issue of *JCE Online*. A brief description of these materials is listed below.

- Well Wishes Case: The written case scenario on which the classroom and laboratory activities are based
- Pamphlet on Septic Systems: Supporting material to be given out to students in conjunction with the case
- Complete Case Teaching Notes: A document that details different ways the case can be used, strategies for leading the case discussion, student assignments, a complete analysis of the case dilemma, and background material on septic systems, well water, and other pertinent topics
- Optional Laboratory Experiments: Protocols for nitrate and chloride determination

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**Literature Cited**