Spring 2021 — University of South Florida
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Design Project 2021

1. Regulatory Background

The United States Environmental Protection Agency (USEPA) maintains a list of contaminated sites that are believed to pose the highest risk to public health. This list is called the National Priorities List (NPL). Sites listed on the NPL are sometimes called "Superfund" sites, because the NPL is established under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), which is better known as the "Superfund" legislation (for reasons that we needn't discuss here). New sites may be added to the NPL if the USEPA determines that they pose a significant enough risk; old sites may be deleted (de-listed) from the NPL once the USEPA determines that they have been cleaned up sufficiently.

When a site is added to the NPL, a *remedial investigation* is conducted to assess the level of contamination and the risks to public health associated with that contamination. Following the remedial investigation, a *feasibility study* is conducted to consider a range of potential options for cleaning the site. These two stages together are known as the RI/FS. Following completion of the RI/FS, the general public is given a chance to comment on the clean-up options under consideration, and then the USEPA issues a *record of decision* (ROD). The record of decision describes the method that is to be implemented for cleaning the site, explains why that method was chosen from among the candidates considered, and provides an estimated cost for the site clean-up.

2. General Description of Your Assignment

In this design project, your team of students will assess three potential clean-up options for a fictitious site where the groundwater is contaminated with hazardous organic chemicals. This activity will mimic what you might perform in engineering practice if you worked for a consulting firm performing the *feasibility study* for a NPL site, or perhaps the early stages of the design process for a company proceeding with clean-up after the ROD has been issued. You will be given information about the contaminated groundwater and the clean-up requirements, similar to the type of information that might result from a remedial investigation in a "real" clean-up project.

In actual engineering practice, a wide range of clean-up options would probably be considered, including both above-ground (pump-and-treat) treatment options and below-ground (in situ) treatment options. In this project, you will consider only three above-ground treatment options for the contaminated groundwater: granular activated carbon (GAC), air stripping with GAC for off-gas control, and advanced oxidation by O_3/H_2O_2. If you wish, you can also consider combinations of the three. These are three realistic treatment options that probably would be considered at a real site clean-up, along with others (such as in situ bioremediation) that are beyond the scope of ENV 6519. Thus, the activity that you will perform in this project is like a sub-set of what you might perform for a real NPL site in engineering practice. (GAC and air stripping are, in fact, two of the most common clean-up techniques for contaminated groundwater sites.)

The record of decision frequently reports the estimated capital cost, the estimated operating and maintenance (O&M) cost, and the equivalent present worth for each treatment option considered. Therefore, in this project, you will need to estimate and report these costs for each of your three treatment options. This cost estimation will require you to optimize the design for each of the three treatment options; e.g., for air stripping, you will need to determine the air flow rate and tower height that result in the lowest overall cost while still meeting treatment requirements. In practice, if all treatment options are deemed technically feasibly, the USEPA would probably select the lowest-cost option, unless some other factor was deemed more important; e.g., if one option resulted in a significantly faster clean-up, it might be selected even if more expensive than the other options.

You can consider that your team of students is acting as a project team for an environmental engineering consulting firm, and your instructor is playing the role of your client at either the USEPA or the company responsible for the contamination. In the spirit of healthy competition, you can consider that other teams of students represent competing consulting firms who want to out-perform your team in the eyes of the client. The firm that presents the best feasibility study to the client would be most likely to get repeat business in the future. The best feasibility study is the one that includes optimum technical designs for each treatment option, along with accurate cost estimates of each option. Thus, two of your most important goals in completing this assignment are (1) to develop the best engineering designs, and (2) to develop the best cost estimates.

3. Relevant Project Parameters

Your hypothetical contaminated site is a facility at which old motors and engines were refurbished and recycled. Solvents were used to remove oil, grease, and tar from the motors and engines. The primary solvent used was trichloroethene (TCE), but 1,1,2,2-tetrachloroethane (1,1,2,2-TeCA) was also used to a lesser extent. For many years, spent solvents were dumped in an unlined pond, until this practice was deemed unacceptable from an environmental perspective. By the time the practice ceased, the soil and groundwater underlying the pond were heavily contaminated. To the extent possible, non-aqueous-phase liquid (NAPL) sources have been removed from the site, but it is believed that some residual NAPL remains behind, and will likely serve as a continuing source of contamination for many years.

Concentrations of TCE and 1,1,2,2-TeCA in groundwater monitoring wells have been measured as high as 30 mg/L for TCE and 0.25 mg/L for 1,1,2,2-TeCA. In addition, cis-1,2-dichloroethene (cis-DCE) has been detected at concentrations as high as 10 mg/L, even though it was not one of the solvents used originally. This is because cis-DCE can be formed when TCE (or, perhaps, 1,1,2,2-TeCA) biodegrades anaerobically. These concentrations could pose a significant health risk if the groundwater migrates to drinking-water wells which are about 1 km downgradient. Below is a table of drinking water maximum contaminant levels (MCLs) and public health goals (PHGs) according to the state of California. (Federal MCLs are less stringent than those in California; for the purposes of this assignment, assume the contaminated site is in California.)

Chemical	MCL (mg/L)	PHG (mg/L)	
TCE	0.005	0.0017	
1,1,2,2-TeCA	0.001	0.0001	
cis-DCE	0.006	0.013	[unclear why MCL < PHG for cis-DCE]

The USEPA is considering a remedial action plan in which groundwater is pumped out of the contaminated aquifer using a pulsed pumping strategy; extracted water will be pumped to an equalization basin. From the equalization basin, contaminated water will be treated by one of the three technologies that you are evaluating. For purposes of conducting the feasibility study, the USEPA has stipulated the following.

- Design flow rate: 120 gallons per minute (time-averaged rate of groundwater extraction)
- Assumed concentrations in contaminated water:
  TCE: 2 mg/L   1,1,2,2-TeCA: 0.018 mg/L   cis-DCE: 0.5 mg/L
- Treatment requirement: treated water must adhere to California drinking water standards (i.e., the MCLs given in the table above), in order to provide sufficient flexibility for subsequent usage of the treated water. *Use the MCLs, not the PHGs*.
- Operation period: 15 years (estimated time until site can be de-listed from NPL)

4. Deliverables

Your project team will be responsible for delivering the following three items to the "client":

1. a written report describing your evaluation of the three treatment options, including your designs and cost estimates, due on April 29;
2. an oral presentation to the class on April 27 or April 29, approximately 30 minutes long, in which you summarize the findings of your report; and
3. a team interview with the instructor on May 6, approximately 30 minutes long, in which you will answer follow-up questions about your designs and cost estimates.

Together, the three deliverables will constitute 33% of your semester grade. Guidelines for the written report and oral presentation will be provided later, either in class or in separate written documents. Interviews will be held during the time designated by the registrar for the final exam, i.e., May 6 from 12:30–2:30 PM; the interview takes the place of a final exam.

5. Pedagogical Benefit

This course covers physical and chemical processes in environmental engineering. Because that topic is too broad to cover comprehensively, this semester we will emphasize physical and chemical processes that are used in remediation but that are based on principles which appear throughout the discipline of environmental engineering. This design project is intended to require that students synthesize the concepts that will be studied throughout the semester, and apply those concepts in the solution of a realistic environmental engineering problem. This “problem-based learning” (different from, but related to, “project-based” learning) is intended to require students to exhibit critical thinking skills at all levels of Bloom’s taxonomy (knowledge, comprehension, application, analysis, synthesis, evaluation).

If you are interested in the pedagogical theory of problem-based learning or Bloom’s taxonomy, there are, of course, Wikipedia entries. While I generally caution students not to over-rely on web sites for information, Wikipedia does tend to be pretty good in most cases. The Wikipedia entry for problem-based learning has been modified over the years, but back in 2012 it gave the following description, which I like pretty well.

> Problem-based learning (PBL) is a student-centered pedagogy in which students learn about a subject in the context of complex, multifaceted, and realistic problems (not to be confused with project-based learning). The goals of PBL are to help the students develop flexible knowledge, effective problem solving skills, self-directed learning, effective collaboration skills and intrinsic motivation…. Working in groups, students identify what they already know, what they need to know, and how and where to access new information that may lead to resolution of the problem. The role of the instructor (known as the tutor in PBL) is that of facilitator of learning who provides appropriate scaffolding and support of the process, modelling of the process, and monitoring [of] the learning…. The tutor must build students [*sic*] confidence to take on the problem [and] encourage the student[s], while also stretching their understanding….
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> The [s]ix core characteristics of problem based learning [are]: [it] consists of student-centred learning; learning occurs in small groups; teachers act as facilitators or guides (referred to as tutors); a problem forms the basis for organized focus and stimulus for learning; problems stimulate the development and use of problem solving skills; new knowledge is obtained through means of self-directed learning.
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> In PBL, students are encouraged to take responsibility for their group and organize and direct the learning process with support from a tutor or instructor. Advocates of PBL claim it can be used to enhance content knowledge while simultaneously fostering the development of communication, problem-solving, critical thinking, collaboration, and self-directed learning skills.