Section 3251

Software Applications in Solid and Hazardous Waste

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Abstract

As part of a program supported by the Gateway Engineering Education Coalition, faculty from seven universities developed a set of case studies, collectively known as "Shared Resources: Modules to Support Environmental Engineering Education." The "Shared Resources" were developed as modules. That is, they were designed to be used as supplements in existing environmental engineering courses. Each module contains all of the materials the students will need to complete the exercise (except the software if it is licensed) and detailed information for the instructor on the use of the materials, including some sample results and discussion points.

This paper describes a series of modules related to solid and hazardous waste. Five modules deal with the application of software. These modules are built around the following software packages: (1) BIO1D, a one-dimensional mass transport code which is useful for introducing students to the basic processes and approaches to bioremediation, (2) BIOPULME II and BIOPLOT, a two-dimensional mass transport code used for bioremediation design, (3) SWPlan which can help students evaluate fundamental strategies for solid waste management, (4) HELP 3.04 and HELP Model for Windows which can be used to analyze hydraulic barriers for solid waste facilities, and (5) AIRFLOW/SVE, a code that automates the two-dimensional analysis of the multi-component gas-phase transport of contaminants in the vicinity of a single vapor extraction well. Many of these software packages can be used for class demonstrations as well as for student exercises.

Two additional modules are case studies dealing with radioactive waste. In the first case study, students are given basic information on radiation and methods for handling radioactive material. They are then asked to identify and evaluate options for cleaning up a plutonium spill. In the second case study, students receive basic information on low-level radioactive waste and disposal facilities for it. They are then asked to assess a site selected for a low-level radioactive waste disposal facility. The basic information needed to complete the case studies is provided in both written and electronic form.

Introduction

In environmental engineering courses, faculty strive to present the principles important in dealing with a wide variety of environmental problems and to teach students to solve the types of problems they are most likely to encounter. However, because the environmental field is so diverse and the type of problems environmental engineers face on the job is ever-changing, it is important for students to learn how to approach unfamiliar problems.

Case studies can be used in environmental engineering courses to encourage students to think through problems they may not otherwise have an opportunity to investigate. Completing the case studies, with the guidance of the instructor, gives students insight into what types of questions ought to be asked, what data are required, and what alternatives should be considered.

Case studies built around software packages allow students to investigate specific situations and develop a feel for the range of values they might expect to see for various scenarios. While not a perfect substitute for field experience, exploring "real-world" problems with a good educational software package can provide students with a knowledge base that can be useful on the job. Surprisingly, some of the software packages that a student would use on the job are not effective educational tools. Characteristics of a good educational software package include:

- narrow focus to reduce the expertise required of the student user,
- flexibility in defining the problem,
- user-friendly front end,
- blunder control to disallow unreasonable input values,
- able to be mastered in a short time,
- rapid run times,
- visual display of results (and perhaps input),
- detailed results documentation,
- processing feedback,
- low cost,
- machine flexibility,
- detailed technical documentation, and
- information rich examples. 1

Faculty members often do not have the time to develop their own set of detailed case studies or to investigate the wide array of software packages available to determine whether they are effective educational tools. Case studies developed by others are an alternative. However, such case studies are most helpful if (1) they allow a faculty member to determine quickly what concepts they illustrate and (2) they are essentially self-contained so that they can be given to the students with minimal introduction by the instructor. "Shared Resources: Modules to Support Environmental Engineering Education" is a collection of environmental engineering case studies that was designed to be easy for instructors to review and use. Seven of these case studies in the area of solid and hazardous waste are briefly described in the remainder of this paper.

Modules Built Around Software

Five modules built around proprietary software packages are described below. The extensive documentation with each module includes a brief description of the software, set up hints, three or four applications of the software that students can explore, known problems and "bugs" encountered when using the software, and reading and reference lists.

Solid Waste Management - SWPlan™

Solid waste management planning requires an understanding of the characteristics of the solid waste stream, including long term trends in composition and volume. This module[3] gives faculty and students a tool to develop a municipal solid waste management plan and explore the impact of waste reduction options such as source reduction, recycling, yard waste composting, and incineration. The module is based on SWPlan™ 2.0, a proprietary software product developed by Recycling Insights™. In addition to development of an integrated municipal solid waste management plan, the software can be used to evaluate an existing system, prepare or compare vendor proposals, and simulate a variety of management scenarios.

Module users can specify characteristics of the municipality being studied such as the population and number of waste management employees, the percentage of the waste stream contributed by each of 19 types of material, waste collection methods, waste transportation data, amount of waste managed by each of several methods (e.g. incineration, recycling, landfilling), and costs. An example problem has been defined and three simulations related to the example problem are presented. The simulations allow students to explore some of the software's options. All simulations are based on the Cleveland, Ohio, metropolitan area, and data for that area are provided on a disk. The three simulations are:

1. Municipal solid waste (MSW) collection and landfilling
2. MSW collection + curbside recycling and landfilling
3. MSW collection + curbside recycling + waste management and landfilling.

Bioremediation - BIO1D

Built around the proprietary software product BIO1D developed by Geotrans, Inc., this module [4] gives faculty and students the ability to model bioremediation of contamination in groundwater. The software models the simultaneous transport of two interacting chemical species. Since the material is reasonably advanced and requires some understanding of pollution transport and biological reactions, the module is probably most useful for upper division students.

Four example simulations are presented, and input files and results are included. All of the simulations are related to phenol contamination of groundwater. However, each simulation allows the students to explore a different aspect of the problem. Those aspects are:

1. Potential impact of aerobic biological activity,
2. Potential impacts of a sorptive interaction along with aerobic biological activity,
3. Potential impacts of allowing anaerobic metabolism to take over within the domain at any location where the oxygen concentration drops below the minimum value of oxygen to sustain aerobic metabolism (no sorption), and
4. Potential impacts of eliminating the contamination source.

2-Dimensional Groundwater Remediation - BIOPLUME II ^{EM} and BIOPLOT

The introduction to the manual for this module [5] states:

"The BIOPLUME II ^{EM} model simulates the transportation and oxygen influenced biodegradation of hydrocarbons in groundwater. It solves a two-dimensional solute transport equation coupled with the groundwater flow equation. The solution of the groundwater flow equation is based on a finite difference approximation, while the transport equation uses a method of characteristics solution [2].

BIOPLUME II ^{EM} is capable of simulating reaeration and anaerobic biodegradation by assuming a first order decay of the hydrocarbon concentration. It also has the ability to provide an option for in-situ biorestoration by using an injection well as a source of oxygen and a production well as a source of contaminated water. In addition, BIOPLUME II ^{EM} can be used to simulate 'pump and treat' remediation in the presence or absence of biological activity."

BIOPLUME II ^{EM}, version 2.6, and BIOPLOT, version 1.2, are proprietary software products of TECSOFT, Inc. A public domain version of BIOPLUME is available from the EPA. However, the proprietary version was used for this module since it can be used with BIOPLOT which has much improved visualization capabilities. An early section in the module documentation compares BIOPLUME II ^{EM} with BIO1D.

Five simulations using BIOPLUME II ^{EM} are provided with the module. Input data and results are included. All simulations are related to a single hydrocarbon source being released at a point within an aquifer. The simulations consider:

1. Natural aerobic biodegradation
2. In-situ biorestoration using three injection wells in a straight line
3. Three injection wells with a better distribution
4. Impact of an extraction well
5. Combination of pump and treat and bioremediation techniques.

Landfill Water Balance - HELP 3.04 and HELP for Windows

A water balance analysis is commonly used to estimate potential leachate production and liner/drain system performance when designing a solid waste disposal facility. Decisions about the size of the leachate collection system and leachate treatment methods depend upon estimates of leachate production.

The water balance analysis takes into consideration the effects of hydrogeologic processes on water movement at the landfill site. Two ways to analyze this water movement are hand calculations (Thornthwaite Method) and the HELP model. Two HELP models are available. HELP 3.04 (Hydrologic Evaluation of Landfill Performance)is an EPA public domain software package. HELP Model for Windows v2.05 is a proprietary software package available from Grace Dearborn, Inc., and is more user-friendly. This case study uses both versions of HELP. Since some understanding of hydraulics, geotechnical engineering, and landfill design are needed to run HELP, this module [6] is probably best suited for students in upper division courses.

HELP contains a one-dimensional vertical drainage model and a one-dimensional lateral drainage model. Input to the model includes weather, soil and design data. The software models the effects of surface storage, snow melt, runoff, infiltration, evapotranspiration, vegetative growth, soil moisture storage, lateral subsurface drainage, leachate recirculation, unsaturated vertical drainage, and leakage through soil, geomembrane or composite liners.

Three example simulations are provided in the module. All are related to the performance of a municipal solid waste landfill. Results of each simulation are provided. The simulations model the following:

1. A system of three layers (vegetative, lateral drainage, and barrier soil)
2. A system of six layers (the three in simulation 1 plus municipal solid waste layer, lateral drainage layer, and barrier layer with liner at the bottom)
3. Potential impact of a geomembrane liner.

Vapor Extraction Remediation - AIRFLOW/SVE

Vapor extraction is a method used for remediation of contaminated, unsaturated soil when a significant air flow can be induced. Normally volatile contaminants with low water solubilities are treated in this way. AIRFLOW/SVE (Soil Vapor Extraction), a proprietary software package developed by Waterloo Hydrologic Software, can be used to model vapor phase pressure distribution, vapor phase velocity pathways, volatile NAPL (non aqueous phase liquids) concentration profiles, and residual phase NAPL burden profiles around a single, axisymmetric vapor extraction well.

In the example problem for this module [7], organic contamination has been detected under a relatively small building on an industrial site. The building has a concrete floor which cannot be removed, but enough space is available to allow for the installation of a vapor extraction well. Additional information is given about the soil beneath the building and the location of the water table. The module contains four simulations related to the example problem, along with results and discussions of the results. The four simulations are:

1. Vapor extraction using a 2 meter well screen
2. Vapor extraction using an extended well screen
3. Vapor extraction of gas phase plus residual NAPL source
4. Vapor extraction of gas phase plus multicomponent residual NAPL source.

Modules Dealing With Radioactive Waste

The two modules dealing with radioactive waste were designed for instructors and students who have little familiarity with radiation and radioactive materials. Thus, they are intended to help students understand the fundamental concepts related to radioactive environmental contamination and develop an appreciation for the many factors that must be considered when planning the remediation of such a site - or the siting of a facility where radioactive materials will be used or stored. Some quantitative examples are provided, but the primary focus is on the types of questions that must be answered rather than on the range of quantitative results that might be expected.

Remediation of a Site Contaminated with Plutonium

This module [8] consists of a student handbook containing some basic information on radiation and radioactive contamination, a PowerPoint presentation that summarizes the information in the handbook, four problems that illustrate some key concepts, complete solutions to those problems, a case study for student groups to consider, and a faculty discussion guide. The student handbook covers topics such as radioactive decay and half-life, biological effects of ionizing radiation, methods for detecting radioactive contamination, and techniques for remediation and control of contaminated sites. The four problems include a dose calculation, a study of risk due to radiation exposure, a radioactive decay calculation, and a shielding problem. The faculty discussion guide provides a discussion of topics that students should address when preparing the case study.

In the case study, a site contaminated with plutonium is described. Students are asked to identify and evaluate options for cleaning up or isolating the site. They are to consider exposure pathways, impacts of area geology, hydrogeology, and meteorology, risks associated with both the radiation exposure and the remediation methods, costs, schedules, and public concerns.

Siting of a Low-Level Radioactive Waste Disposal Facility

Contents of this module [9] include a set of fact sheets on topics related to low-level radioactive waste and its treatment and disposal, a PowerPoint presentation of the key information in those fact sheets, a case study on the siting of a low-level radioactive waste (LLRW) disposal facility, and faculty discussion guide.

The fact sheets on LLRW were developed as part of a public education program and have been extensively reviewed by nuclear scientists, science educators, representatives of national environmental groups, and many members of the public. They are designed to convey accurate, unbiased technical information in terms that people with no training in nuclear science can readily understand. Topics covered include sources, volumes, and characteristics of LLRW, minimization and treatment of LLRW, transportation of the waste, design of disposal facilities, effects of geology and hydrogeology on the selection and performance of a LLRW disposal site, and regulations governing the handling of low-level waste.

In the case study, it is assumed that a host community for a LLRW disposal facility has been chosen. The students are retained by the community to provide an independent, unbiased assessment of risks associated with the facility and to suggest conditions and benefits the community should demand in return for hosting the disposal facility. Students are given a list of considerations including risks to human health and safety, transportation issues, infrastructure improvements required, new community services needed, geological suitability of the site, environmental monitoring and protection measures, and economic impacts. They are to consider an extended time frame stretching from facility construction through operation and at least one hundred years of the post-operation period. Discussion points for each of the topics are provided in the faculty discussion guide, along with a proposed list of benefits to be recommended to the community.

Module Availability

The seven modules discussed in this paper are listed in the references and are available through the Gateway Engineering Education Coalition. (Note to reviewers: the person to whom requests would be addressed has not yet been identified. Additional information will be provided in when this paper is submitted in final form for publication.)

Acknowledgment

This is a project of the Gateway Engineering Education Coalition, (NSF Award EEC-9444246), is supported in part by the Engineering Education and Centers Division of the National Science Foundation.

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