DEVELOPMENT OF SOLID WASTE MANAGEMENT COURSES AT THE UNDERGRADUATE AND GRADUATE LEVEL

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ABSTRACT

Management of solid wastes in a cost effective and environmentally sensitive manner has become one of the most challenging infrastructure issues facing municipalities today. The problem is exacerbated by a shortage of qualified engineers. In this paper, both undergraduate and graduate courses in solid waste management that have been taught by the authors at their respective universities for over 20 years are described and available textbooks and reference materials are discussed.

INTRODUCTION

Solid waste management is an integral part of the environmental engineering profession. Depending on the departmental structure of the institution, it is generally taught within a civil engineering or environmental engineering department. In most institutions, an introduction to solid waste management is taught as part of an environmental engineering survey course dealing with water and wastewater treatment, air pollution, and solid wastes. At California Polytechnic State University (Cal Poly), solid waste management is taught as a required course in an undergraduate environmental engineering curriculum. A second graduate course in solid waste management is also offered as a technical elective to graduate and undergraduate students. At the University of California, Davis (UCD), the undergraduate course in solid waste management is taught as a technical elective. The graduate course is also offered as technical elective. At both institutions, research projects offer students the opportunity to participate in advanced research and development in the solid waste management field.

SOLID WASTE MANAGEMENT COURSES AT CAL POLY

Cal Poly is one of the largest undergraduate engineering programs in the United States with an enrollment of over 4000 engineering students out of a total campus enrollment of 17,500. Environmental engineering has been an established department within the University for over 20 years. The department has a total enrollment of 670 students, 500 undergraduate civil engineering majors, 150 environmental engineering majors, and 20 graduate students. Both majors have a common core of engineering science and mathematics in the lower division. The two majors also have a common core of hydraulics, fluid mechanics, and geotechnical engineering in the upper division. As part

TABLE 1 LECTURE SCHEDULE FOR UNDERGRADUATE COURSES IN SOLID WASTE MANAGEMENT

Week	Topic	Reading
	Cal Poly[a]	
1	Introduction/Solid Waste Composition	Chaps. 1,2, and 3
2	Solid Waste Generation	Chap. 4
3	Statistical Analysis / Storage	Chap. 5, Appendix C
4	Collection/Transfer/Transport	Chap. 6 and 7
5	Resource Recovery and Recycling	Chap. 8
6	Energy Recovery I (Physical)	Chap. 9
7	Energy Recovery II (Biological)	Chap. 9
8	Landfill Disposal	Chap. 10
9	Landfill Disposal (continued)	Chap. 10
10	Planning Issues	Chap. 12 and 16
	University of California, Davis[b]	
1	Integrated Waste Management/Characteristics of MSW	Chaps. 1,2, and 3
2	Physical, Chemical, and Biological Transformations/ Characteristics of Hazardous Wastes Found In MSW	Chap. 4 Chap. 5
3	Solid Waste Generation and Collection Rates/Waste Handling and Separation, Storage, and Processing at the Source	Chap. 6 Chap. 7
4	Collection of Solid Waste	Chap. 8
5	Separation and Processing and Transformation of Solid Waste	Chap. 9
6	Separation and Processing and Transformation of Solid Waste (cont.)	Chap. 9
7	Transfer and Transport/Disposal of Solid Wastes and Residuals	Chaps. 10 and 11
8	Disposal of Solid Wastes and Residuals	Chap. 11
9	Disposal of Solid Wastes and Residual Matter/ Closure, Restoration, and Recycling of Landfills	Chap. 11 Chaps. 16 and 17
10	Management Issues: Meeting Mandated Diversion Goals	Chaps. 18, 19, and 17

[a] Text: Ref. [6]
[b] Text: Ref. [7]

TABLE 2 LABORATORY SCHEDULE FOR UNDERGRADUATE COURSES IN SOLID WASTE MANAGEMENT

Week	Topic	Reading/Requirements
	Cal Poly[a]	
1	Graphical Analysis of Solid Waste Data	Laboratory Report
2	Computer Analysis of Solid Waste Data	Laboratory Report
3	Field Sorting and Composition Study	Memorandum to the File
4	Proximate Analysis	Laboratory Report
5	Proximate Analysis (cont.)	
6	Calorimeter Analysis	Laboratory Report
7	Calorimeter Analysis (cont.)	
8	Computer Aided Solid Waste Planning	Laboratory Report
9	Computer Aided Solid Waste Planning (cont.)	
10	Field Trip - TBA (all day)	Memorandum to the File
	University of California, Davis[b]	
1	Statistical Analysis of Solid Waste Data	Spreadsheet Program
2	Field Sorting of Residential MSW	Memorandum to the File
3	Routing of Solid Waste Collection Vehicles	Completed Routes
4	Field Trip To Recycling Center	Memorandum to the File
5	Introduction Of Term Projects (Landfill Design/Preparation of RFP)	
6	Design of MSW Landfill (Earthwork and Volume Analysis)	
7	Development of Landfill Gas Production Model	Spreadsheet Model
8	Development of Landfill Leachate Generation Model	Spreadsheet Model
9	Design of Landfill Gas Recovery System	Spreadsheet Program
10	Work On Term Projects (Landfill Design/Preparation of RFP)	Design Report

[a] Text: Ref. [6] and Laboratory Notes
[b] Text: Ref. [7] and Laboratory Notes

of their major requirements, environmental engineering students take a broad based series of courses in air pollution, water pollution, hazardous waste management, and solid waste management. Some of these courses are also taken by civil engineering majors as technical electives. Recently, environmental engineering courses have also been taken by mechanical and agricultural engineering majors as technical electives.

Undergraduate Course

The required solid waste management course, ENVE-439 Solid Waste Management, is described in Tables 1 and 2. The emphasis of the course is on providing the environmental engineering student with a broad overview of the solid waste management field. The laboratory portion of the course offers both traditional benchtop experiments such as proximate and calorimeter experiments, as well as a waste composition experiment conducted at a local landfill. Statistical data analysis is introduced in two experiments, using both graphical and computer techniques. Finally, students are introduced to the use of specialized software for cost estimating and planning of integrated waste management systems. The software, developed by Cal Poly for the California Integrated Waste Management Board, is described in Ref. [1].

TABLE 3 LECTURE SCHEDULE FOR GRADUATE COURSES IN SOLID WASTE MANAGEMENT

Week	Topic	Reading
	Cal Poly[a]	
1	Key Issues in Reuse and Recycling	9-1 to 9-3, Chap. 15
2	Mechanical Separation Technology	9-4, 12-1 to 12-5
3	Materials Processing and Handling	12-6 to 12-8
4	Material Recovery Facilities (MRFs)	9-5, 9-6, 12-9
5	Fundamentals of Pyrolysis and Gasification	4-3, 9-7, 13-1 to 13-4
6	Environmental Control Systems	13-5
7	Energy Recovery Systems	13-6
8	Anaerobic Biological Systems	14-1, 14-3 to 14-5, and 11-4
9	Aerobic Biological Systems	9-8, 14-2
10	Financing of IWM Systems	Handout
	University of California, Davis[a]	
1	Intergrated Waste Management: Concepts and Issues	Chaps 1 and 2
2	Characteristics of MSW/ Solid Waste Generation and Collection Rates	Chaps 3 and 6
3	Issues In Waste Handling and Separation, Storage, and Processing at the Source/Collection/Transfer and Transport	Chap. 7, 8, and 10
4	Issues In Material Recovery Facilities (MRFs)	Chaps. 9, 12, and 15
5	Issues In The Disposal of Solid Wastes and Residual Matter	11-1 to 11-10, Chap. 11
6	Issues In The Closure, Restoration, and Recycling of Landfills	Chaps. 16 and 17
7	Strategies For Selecting Proper Mix Of Technologies	Chaps. 18, 19, and 17
8	Strategies For Selecting Proper Mix Of Technologies	Chaps. 18, 19, and 17
9	Strategies For Selecting Proper Mix Of Technologies	Chaps. 18, 19, and 17
10	Management Issues: Meeting Mandated Diversion Goals	Chaps. 18, 19, and 17

[a] Text: Ref. [7]

Graduate Course

Because of the time limitations of the quarter system (10 weeks), a second course was developed as part of a master's degree program in environmental engineering. The course focuses on materials and energy recovery from solid wastes. Outlines for the lecture and laboratory portion of the course are given in Tables 3 and 4. A unique feature of the course is the completion of a major design report. The class is divided into consulting

TABLE 4 LABORATORY SCHEDULE FOR GRADUATE COURSE IN SOLID WASTE MANAGEMENT AT CAL POLY

1. *Term Project:*

The major assignment of the course will be the preparation and presentation of a team project (in lieu of a Final Examination). The project will be presented before a judging panel of professional engineers and planners. The written presentation will be in a formal engineering report format and will be graded by the instructor. Projects will be graded on the basis of both individual and team performance. Some of the laboratory periods will be available for discussion of the project and team organization.

Milestone	Laboratory Period
Team Assignments	Week 2
Project Assignment	Week 3
Project Outline (typed)	Week 6
Project Draft and Rehearsal	Week 10
Project Presentation (oral and written)	Finals Week

2. *Field Trip*

A Field Trip will be scheduled during the quarter to a major resource recovery facility. A short trip report will be required.

"companies" which compete against each other. The project assignments are different each year and based on actual projects. This year's project will be the conceptual design of a MRF. Prior assignments have included designs of composting systems, MSW combustion systems, and development of a county integrated waste management plan. The design report is presented in both oral and written form and graded not only by the instructor, but also by a volunteer panel of locally prominent engineers and planners. This project is an introduction to the "real world" of competition and teamwork. It has proven to be highly successful and of great benefit to graduates of the program as confirmed by alumni interviews.

SOLID WASTE MANAGEMENT COURSES AT UCD

Historically, the University of California at Davis was the principal agricultural campus of the University of California. Civil engineering has been an established department at the Davis campus for about 27 years. The Department of Civil Engineering has a total enrollment of 540 students, 420 undergraduate and 120 graduate students. The department is divided into five major discipline areas: environmental, geotechnical, structural mechanics, transportation, and water resources. As part of their major requirements, all civil engineering students must take a series of design electives. The two elective courses in the environmental engineering area deal with the design of water and wastewater treatment facilities and solid waste management. These courses have been popular with students in all of the discipline areas, especially the solid waste management course.

Undergraduate Course

The undergraduate elective solid waste management course, ECI-147 Solid Waste Management, is described in Tables 1 and 2. The emphasis of the undergraduate course is on providing the student with both an overview of the field and an understanding of the engineering aspects of solid waste management. The laboratory portion of the course is designed to enhance the students understanding of the engineering computations involved. The first two laboratory sessions are devoted to the statistical analysis of waste generation rates and to the sorting of wastes in the field. The remaining laboratory periods are devoted to the computational aspects of solid waste management (see Table 2). Whenever possible, spreadsheets are used in the analysis of the problems. Two term projects are normally assigned. The first deals with the preparation of an RFP for a materials recovery facility. The second project involves the complete design of a sanitary landfill for MSW. The students work in groups of three on the second project.

Graduate Course

The focus of the graduate course in solid waste management is on management and policy issues (see Table 3). The specific topics covered will vary somewhat from year-to-year, depending on the student's interests. Although the specific topics may vary, the central theme of the graduate courses is the process that communities and waste managers use to make decisions concerning the proper mix of technologies to use to achieve waste management objectives, and the basis for their selection. The components of integrated waste management namely: source reduction, recycling, waste transformation, and disposal serve as a basis for assessing technology decisions. The key idea is to define the interrelationships that exist between the various options that are available to a community (e.g., waste transformation through combustion or composting) and the impacts of selecting one or another on the waste management system in the context of Integrated Waste Management. The work product for this class will vary depending on the focus of the class. In recent years spreadsheet programs have been the principal product.

REFERENCE MATERIALS

Textbooks that have been used to teach environmental engineering survey courses that incorporate solid waste management include Refs. [2–4]. One of the early books that was suitable for use as a classroom text in solid waste management, Ref. [5], went out of print shortly after it was published, due primarily to lack of interest and the limited number of universities that offered courses in solid waste management at that time. For the past 15 years, the only suitable text for undergraduate classroom use was Ref. [6]. This text has been used by Cal Poly and UCD for a number of years in the undergraduate course as well as by over 100 other universities for similar undergraduate courses. Reference [7], to be published in the fall of 1992, will supersede Ref. [6]. Several other textbooks suitable for undergraduate courses in solid waste management have also recently been published, including Refs. [8, 9]. The availability of these texts provides instructors with a wide variety of approaches that can be adapted and tailored to the specific requirements of the institution.

Over the past 20 years, a number of specialty books, Refs. [10, 11], Environmental Protection Agency documents such as Ref. [12], and handbooks, Refs. [13–16] have been published. Although quite useful for specialized graduate courses, and as reference books for practitioners, these books were unsuitable for use as a textbook for a general undergraduate course dealing with solid waste management.

Because of the number of changes that have occurred in the field of solid waste management over the past 10 years, it was also common practice in many institutions to supplement textbooks with reprints from trade magazines, journals, and proceedings such as the ASME National Waste Processing Conferences. Recent changes in the copyright law have made this approach extremely expensive, as copyright fees must be charged to each student ($0.50–$2.00 per reprint) in addition to reproduction costs. Hopefully a compromise will be negotiated in the future so that more realistic fees can be collected. Unfortunately many University libraries are cutting back on subscriptions to highly specialized, relatively low use publications, such as solid waste journals. These cutbacks, coupled with the current copyright policy, make selection of a comprehensive textbook extremely important.

SUMMARY

As the field of integrated waste management evolves, there will be an increasing need for trained engineers. Courses taught in civil and environmental engineering departments, such as described in this paper, will be an integral part of the education of these engineers. Because more usable textbooks and other teaching materials have become available, it is anticipated that more undergraduate and graduate courses will be developed in the future.

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