The Siting and Design of a Manufacturing Facility Using Hazardous Materials

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Abstract

A meaningful freshman engineering design experience course with an interdisciplinary environmental approach was offered at New Jersey Institute of Technology in Spring term 1997 and was taught by faculty from the Chemical and Civil Engineering Departments. The problem assigned was the Siting and Design of a Manufacturing Facility using Hazardous Materials and the process design was for a plant to manufacture aspirin. The project simulated a contract undertaken by a consulting firm to site and design the plant with the assignment given to entry level engineers. This approach does not require that the freshman students be well versed in the "traditional design concepts, background, and knowledge" required in the capstone design courses.

Students were grouped into four teams of four students each to site the facility and to perform mass balance calculations for the aspirin manufacturing plant. A USGS Quadrangle map and soil information (prepared by the Soil Conservation Service, U.S. Department of Agriculture) for Somerset County, New Jersey were provided to each group. Students were asked to prepare a work schedule, which should include the following: aspirin production estimate, plant size determination, preliminary site selection, sites and surrounding area study, research on environmental restrictions, research on political considerations, economic study, cost analysis, and report preparation. Each team had to select at least three sites for their detailed study and conduct a field recon of the project areas before selecting a final site.

At the end of the semester, with the completion of their study, each team submitted a written report and orally presented their recommendations regarding the selected site and the aspirin production requirements to the class and faculty.

Introduction

During the last five or six years the incorporation of design concepts into the freshman year has gained widespread acceptance in the United States. Spurred forward by the formation of numerous NSF sponsored Educational Coalitions the Freshman Engineering Design programs have become an integral part of the curriculum. The New Jersey Institute of Technology (NJIT), as part of the NSF sponsored Gateway Coalition, a consortium of ten engineering institutions, has instituted such a program and developed numerous discipline and interdisciplinary courses.

The basic intent of these programs is to move the traditional exposure to design concepts from senior year capstone courses into the entire undergraduate curriculum, beginning with entering freshmen. The overall objectives are to introduce freshmen to the open-ended nature of design problems, to give students "hands-on" experience, to expose students to team work and the solution of problems by a team, and to teach students the importance of both oral and written presentation of their results. These courses were part of an extensive development which paired courses in freshman engineering with Humanities and Computer Science. Faculty from all three disciplines coordinated their efforts.

Objectives

The objective of this program was to ignite interest in engineering as a profession in the freshman year, to facilitate curriculum reform, to expose entering students to engineering design problems early in their studies, to develop a team approach to problem solving, to couple engineering with Humanities and Computer Science and finally, to teach both effective oral and written communication.

Interdisciplinary Course Development

In the Spring of 1996 four interdisciplinary courses were developed by a team of Civil Engineering and Chemical Engineering Faculty. The other engineering departments also developed interdisciplinary course offerings. These courses all aimed at incorporating engineering design with manufacturing and augment the existing and continuing disciplinary freshman engineering courses.

The Design and Siting of a Hazardous Substance Manufacturing Facility

In the Spring of 1997, the Civil Engineering and Chemical Engineering faculty developed a meaningful, interdisciplinary course with an environmental approach. The design and siting of a hazardous substance manufacturing facility was based upon the production of aspirin. The students were given a contract to design and site an aspirin manufacturing facility. The students attended class two hours and 10 minutes per week for fourteen weeks. There were five lectures given by the interdisciplinary team. These lectures were an introduction to the course, siting the facility, the aspirin manufacturing industry, soil conditions and cost estimate, and finally effective written and oral communication. Simultaneous the students attended other classes with the Humanities and Computer Science faculty.

The students were divided into four groups of four each. The course outline is shown in Table 1.

a. Siting Studies

The Civil Engineering faculty focused on the siting aspects of the study. Students had to consider environmental, political and economic restrictions and were given minimum guidance by the faculty to encourage independent thought. Various health hazards were discussed. The Toxic Substances Control Act of 1976, the Resources Conservation Recovery Act (RCRA), Emergency Planning and Community Right to Know Act of 1986 and the Hazardous Materials Transportation Act (HMTA) of 1975 were presented to the

students for background information. Definitions of hazardous waste, F Waste (hazardous waste from non-specific source), K waste (hazardous waste from a specific source), and U/P waste (commercial chemical product) were discussed. In addition, planning, project feasibility, funding and site selection considerations were reviewed. As the project began, the Civil Engineering faculty met with each group to review their progress.

A USGS Quadrangle map and soil information from the Soil Conservation Service, US Department of Agriculture for Somerset County, New Jersey were provided to the students. The students were also encouraged to visit the sites and to speak to government officials in Somerset County. The students then determined three possible site locations and finally recommended the best site. All through the study, the students reported their progress to the Civil Engineering faculty.

b. Process Design

The students were taken on a field trip to the Hoffman-LaRoche Pharmaceutical plant to gain a visual knowledge of a chemical manufacturing facility. The students were then given an introduction to the problem, were presented the history of aspirin manufacture and were shown a background film. The manufacture of aspirin was from the two step process:

- Salicylic Acid from Phenol

and

- Acetyl Salicylic Acid from Salicylic Acid Using Acetic Anhydride

They were given lectures on the reactions in the Kolbe-Schmitt process, the chemicals used, and were given the design problem.

1. The Problem

The problem presented to the students required the calculations of the size of the production facility. The students were asked to determine the growth of U.S. population, the growth of U.S. aspirin production, make an estimate of the aspirin need in the year 2007AD, estimate the market share that can be captured, and hence determine the design production capacity of the plant. Students were asked to identify all health hazards from the chemicals used in the process using the Material Safety Data Sheets available on the computer. Mass balance calculations were made to determine the quantities of all products and by-products formed and of all raw materials required. Waste streams were specified along with suggested disposal methods. Finally, they were guided into the concepts of pollution prevention in chemical process design. The results were presented with process flow sheets and block diagrams. Their results were presented in both written and oral reports. The written report discussed the background, history, hazardous materials and health. The plant siting part of the report included environmental, political, and economic restrictions in addition to the overall site evaluations and recommendations. The process design part of the report included the chemistry of aspirin manufacture, the Kolbe-Schmitt synthesis, process flow sheets, block diagrams and material balances, U.S. population growth, U.S. aspirin production growth, estimate of aspirin needs in your 2007AD, estimate of plant production

capacity, stream specification and waste disposal methods and pollution prevention recommendations. The simplified flowsheets developed by the students are included.

Conclusions

The major conclusions of this study were:

1. Students enjoyed working on project, and the course was well received.
2. Students disliked oral presentations but did an excellent job.
3. The written report required a great deal of effort by both the students and the instructors.
4. Initial offering of the course led to the development of the workbook concept.
5. The students gained important insights into the engineering profession.

Recommendations

This type of effort should be integrated at the freshman level by all institutions.

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Biographies

DERAN HANESIAN served as chairman of the Dept. of Chem. Eng., Chem., and Env. Sci. from 1975-1988 and is Professor of Chem. Eng.. He came to NJIT in 1963. He received a bachelor of Chem. Eng. in 1952 and a Ph.D. in Chem. Eng. in 1961, both from Cornell Univ. Dr. Hanesian worked for DuPont from 1952-1957 and 1960-1963. He taught at the Algerian Petroleum Inst., Yerevan Poly. Inst., Armenia as a Fulbright Scholar, the Univ. of Edinburgh, Scotland, and Rutgers, the State Univ. of NJ. He was the recipient of the Robert Van Houten award for Teaching Excellence in 1977 at NJIT, the ASEE, Midlantic AT&T Foundation Award for Excellence in Instruction in Eng. in 1986, the John Fluke Award, ASEE, 1994, the Outstanding Tenured Faculty Award, NJIT, 1994, and the Distinguished Teaching Award, Middle Atlantic Section, ASEE in 1997. He is a Fellow and Emeritus Member of the American Institute of Chemical Engineers and a Fellow and Life Member of the American Society of Engineering Education.

ANGELO J. PERNA received his B.S. ChE degree from Clemson University in 1957 and his M.S. degree from there in 1962. He received his Ph.D. from the University of Connecticut in 1967. He worked as a production and development engineer with Union Carbide Nuclear Company in Oak Ridge, TN, and taught at VPI, and the University of Connecticut. He is currently Professor of Chemical Engineering, Chemistry and Environmental Engineering at New Jersey Institute of Technology. In 1997. he received the NJIT Alumni Award for Teaching Excellence. He is a Fellow in both the American Institute of Chemical Engineers and the American Society of Engineering Education.

Table 1

Course Outline

Week	Topic
1	Lecture 1: Introduction to the course Video Tape: “Opportunities in Environmental Engineering”
2	Lecture 2: Siting a Facility
3	Lecture 3: Aspirin Manufacturing Industry
4	Lecture 4: Soil Conditions and Cost Estimate
5	Lecture 5: Written and Oral Communication
6	Site Visitation (Preliminary Investigation)
7	Field Trip: Hoffman LaRoche Pharmaceutical Manufacture Plant
8	Sites and surrounding area study Literature search on Aspirin
9	Research on environmental restrictions Production and plant size estimate
10	Research on political restrictions Mass Balance
11	Economics study MSDS search
12	Cost analysis: construction cost, operation and maintenance cost
13	Report preparation
14	Students’ oral presentation

* Students are requested to conduct literature search for the assigned homework.

Figure 1
Simplified Process Flow Sheet for Salicylic Acid Manufacture

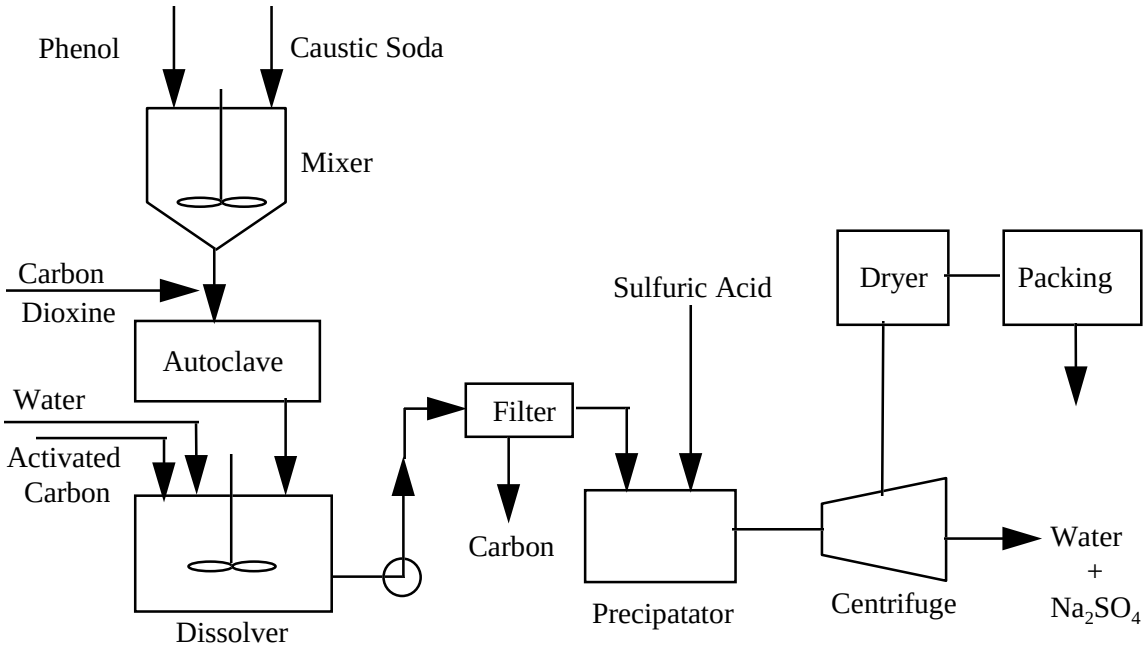

Figure 2
Simplified Process Flow Sheet for Acetyl Salicylic Acid Manufacture