about 30 minutes to look up the required parameters, punch the data cards, submit their deck, and then pick up the output. This was in contrast to about four hours to do a single design by hand.

It was interesting to discover that only eight out of thirty-four students had taken a computer science course. Nearly all of the class had a working knowledge of how to submit a deck with data and get the results from the computer. Some had learned this from using the computer in physical chemistry laboratory and from a fluid flow and heat transfer course.

A set of oscilloscope subroutines has been added to the original program so that the results can be displayed visually as the student operates the computer (an SDS 930) from a keyboard. The display on the cathode ray tube includes the Y-X coordinates, the equilibrium line, and the operating line. The transfer units are constructed between the operating and equilibrium lines using the approximate method of White and Baker[2]. The numerical answers are also displayed on the oscilloscope. In this way, the operator can explore the effects of numerous variations in just a few minutes time. The student response to this modified program has been even more enthusiastic than it was with the printed output only.

The authors wish to emphasize that the program should not be made available to the students until they first have learned to complete a full design by hand calculation. The program is such a timesaver that one is tempted to use it before it is understood. Readers may obtain copies of the program notation, flowchart, and Fortran listing from the authors.

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PROGRAMS IN WATER POLLUTION CONTROL

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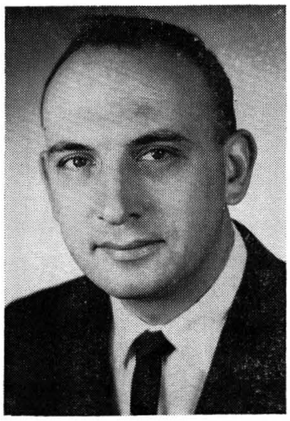
During the last three years, the University of Connecticut ChE Department has offered a program of study in water pollution control. The treatment of industrial and municipal wastes requires a variety of techniques and processes involving unit operations, transfer processes, reaction kinetics, and process control. Thus, the chemical engineer has substantial background that is applicable to pollution problems. To contribute effectively to a broad range of pollution problems, the chemical engineer needs additional training in biological processes and sanitary engineering.

Training programs are offered on both the undergraduate and graduate level. Students in these programs are educated as chemical engineers with specialized background in environmental engineering. Graduates from these programs meet all requirements for a degree in chemical engineering. In addition, they take a sequence of courses and conduct research in water pollution control.

Undergraduate Program

Although the major emphasis is on graduate activities, we feel industry needs BS degree chemical engineers with a background in pollution control. These engineers would be of special value to smaller chemical firms that could not justify a full-time pollution engineer.

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The undergraduate program is incorporated into the present chemical engineering curriculum by simply choosing the recommended courses as electives. These courses give the student background in microbiology, sanitary engineering, and the separation methods developed primarily by chemical engineers. All students, both undergraduate and graduate, are expected to conduct research in the waste management field. We feel that research experience is important to the student in developing his ability to analyze and solve problems in the pollution field.

Table 1. Recommended Electives for Undergraduate Program

SEMESTER	COURSE
Second, Junior Year	Introduction to Microbiology
First, Senior Year	Water and Sewage Treatment (Sanitary Engineering Course)
	Introduction to Research
Second, Senior Year	Rate Processes in Water Treatment Systems, ChE 281
	Introduction to Research

Graduate Program

The MS program consists of 27 to 33 credit hours of work, including 6 to 9 hours of thesis research. Students in this program are required to take chemical engineering graduate courses in thermodynamics, reaction kinetics, and transfer processes. For electives, they are expected to take courses in microbiology, sanitary engineering, and environmental chemical engineering. The electives outside of chemical engineering provide the students with needed scientific material in the biological field and acquaint them with the current procedures of sanitary engineering. For an entering graduate student with no previous background in the area of pollution control, ChE 281 is also required.

The program at the doctorate level is flexible and is designed to meet the needs and interests of the individual student. Although there are no specific course requirements for the PhD degree, courses are usually selected in biochemistry, microbiology, process control, optimization, and systems analysis.

Table 2. Recommended MS Curriculum

First Semester
- Advanced Chemical Engineering Thermodynamics
- Advanced Transfer Operations I
- Fundamentals of Microbiology
- Research

Second Semester
- Reaction Kinetics
- Environmental Elective
- Sanitary Engineering Elective
- Research

Summer
- Environmental Systems Analysis, ChE 381
- Research

Chemical Engineering Courses

The major contribution of chemical engineers to water pollution control has been in the areas of rate processes and systems analysis. Classically, the water pollution field has been dominated by civil and sanitary engineers, who are more concerned with flow and structural aspects. The basic course in our program, "Rate Processes in Water Treatment Systems" (ChE 281), applies chemical engineering principles to sanitary engineering problems. As mentioned previously, this course is normally taken by seniors or first year graduate students. Material for this course is drawn from the fields of microbiology, chemistry, sanitary engineering. Since no completely satisfactory textbook exists and since the literature is expanding rapidly, the course is based mainly on recent published articles. An outline

The chemical engineer has a background that is applicable to pollution problems.

of the course and some selected references are listed in Table 3.

Systems analysis is introduced into the program in a project type graduate level course. In this course, we emphasize dynamics, control, and optimization of environmental systems. Typical project topics have included "Response and Stability of an Activated Sludge Reactor" and "Design and Control of an Activated Carbon Recovery Process."

Unfortunately, our water resources have only recently received the attention which they deserve. Since the quantity of fresh water in many areas is severely limited, we will have to do a better job in managing the available supply. The quality of our water in the future will be determined by the extent to which chemical engineers and others succeed in their effort to improve our water purification technology.

Table 3. Course Outline for Rate Processes in Water Treatment Systems

I. Fundamental Principles
  A. Nature of aqueous solutions
    1. Eisenberg, D., Kauzmann, W., The Structure and Properties of Water, Oxford Univ. Press, 1969.
    2. Gould, R. F., ed., Equilibrium Concepts in Natural Water Systems, American Chemical Society, 1967.
  B. Mass transfer and chemical reaction in heterogeneous systems
    1. Astarita, G., Mass Transfer with Chemical Reaction, American Elsevier, 1967.
    2. Den Hartog, H. J., and Beek, W. J., Local Mass Transfer with Chemical Reaction, *Appl. Sci. Res.*, **19**, 338 (1968).
    3. Wen, C. Y., Noncatalytic Heterogeneous Solid-Fluid Reaction Models, *Ind. Eng. Chem.*, **60** (9), 34 (1968).

II. Biological Phenomena
  A. Mass transport to the biological floc
    1. Calderbank, P. H., Mass Transfer in Fermentation Equipment, Ch. 5 in Blakebrough, N., ed., Biochemical and Biological Engineering Science, Vol. 1, Academic Press, 1967.
    2. Gulevich, W., Renn, C. E., and Liebman, J. C., Role of Diffusion in Biological Waste Treatment, *Environ. Sci. Technol.*, 2, 113 (1968).
    3. Swilley, E. L., et al., Significance of Transport Phenomena in Biological Oxidation Processes, *Purdue Univ. Eng. Bull., Ext. Ser.* **117**, 821 (1964).
  B. Reaction kinetics in aerobic and anaerobic systems
    1. Aiba, S., et al., Biochemical Engineering, Academic Press, 1965.
    2. Gates, W. E., et al., A Rational Model for the Anaerobic Contact Precess, *J. Water Pollut. Cont. Fed.*, **39**, 1951 (1967).
    3. Luedeking, R., Fermentation Process Kinetics, Ch. 6 in Blakebrough, N., ed., Biochemical and Biological Engineering Science, Vol. 1, Academic Press, 1967.
  C. Design of biological reactors
    1. Bischoff, K. B., Optimal Continuous Fermentation Reactor Design, *Can. J. Chem. Eng.*, **44**, 281 (1966).
    2. Eckenfelder, W. W., Ford, D. L., Economics of Wastewater Treatment, *Chem. Eng.* **76** (19), 109, (1969).
    3. Erickson, L. E., et al., Modeling and Optimization of Biological Waste Treatment Systems, *Chem. Eng. Prog. Symp. Ser.*, **64** (90), 97 (1968).

III. Physical Methods of Separation
  A. Adsorption
    1. Weber, W. J., Morris, J. C., Kinetics of Adsorption on Carbon from Solution, *Am. Soc. Civil Eng. Proc., San. Eng. Div.*, **89**, 31, Apr. 1963.
    2. Weber, W. J., Morris, J. C., Equilibria and Capacities for Adsorption on Carbon, *Am. Soc. Civil Eng. Proc., San. Eng. Div.*, **90**, 79, June 1964
  B. Foam fractionation
    1. Lemlich, R., Principles of Foam Fractionation, in E. S. Perry, ed., Process in Separation and Purification, Vol. 1, Interscience, 1968.
    2. Rubin, E., Gaden, E. L., Foam Separation, Ch. 5 in H. M. Schoen, ed., New Chemical Engineering Separation Techniques, Interscience, 1962.
  C. Membranes
    1. Merten, U., Desalination by Reverse Osmosis, MIT Press, 1968.
    2. Michaels, A. S., and Bixler, J. J., Membrane Permeation: Theory and Practice, in E. S. Perry, ed., Progress in Separation and Purification, Vol. 1, Interscience, 1968.

IV. Chemical Methods of Separation
  A. Coagulation
    1. Packham, R. F., Polyelectrolytes in Water Clarification, *Proc. Soc. Water Treat, Exam.*, **16** (2), 88 (1967).
    2. Stumm, W., and O'Melia, C. R., Stoichiometry of Coagulation, *J. Amer. Water Works Assn.*, **60**, 514 (1968).
  B. Combustion
    1. Corey, R. C., Principles and Practices of Incineration, Wiley, 1969.
    2. Spalding, D. B., Some Fundamentals of Combustion, Butterworths, 1955.
  C. Ion Exchange
    1. Applebaum, S. B. Demineralization by Ion Exchange, Academic Press, 1968.
    2. Arden, T. V., Water Purification by Ion Exchange, Plenum Press, 1968.