ChE 280C
Spring 2000

Pollution Prevention

Instructor: Joseph A. Shaeiwitz
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Class: 9:30-10:45 T R

Course Goals:

1. Students will understand environmental issues affecting society and the chemical process industry.
2. Students will understand environmental regulations affecting the chemical process industry.
3. Students will understand the environmental risks associated with chemical plants.
4. Students will understand and appreciate the role of chemical engineers in pollution prevention.
5. Students will be able to evaluate the environmental risks of chemicals involved in a chemical process.
6. Students will be able to estimate potential chemical releases and exposures in a chemical process.
7. Students will understand the concept of and recognize opportunities for applications of green chemistry.
8. Students will be able to evaluate the environmental performance of unit operations and of a process flowsheet.
9. Students will be able to suggest strategies for pollution prevention in unit operations.
10. Students will be able to analyze flowsheets to suggest strategies for process-wide pollution prevention.
11. Students will be able to evaluate the economic consequences of pollution prevention.
12. Students will understand and be able to perform a rudimentary life-cycle analysis.
13. Students will understand the basics of and appreciate the importance of industrial ecology.

Course Policies (exceptions at discretion of instructor):

1. There are no make-up exams.
2. All problem sets are due at the beginning of class or at the stated time.
3. A late assignment = no assignment.
4. Exam grading appeals must be submitted in writing on the day the exam is returned. If you miss that class, you lose the opportunity for regrading.
5. Any classes canceled due to inclement weather (or any other reason) will be rescheduled.
6. You may (and are encouraged to) work in groups on problem sets. However, what you submit must be your own work except for assignments that are designated as group assignments. Assignments that are obviously copied will receive no credit.
7. Problem sets and exams should be neat and easy to follow. Each problem should start on a new page. Your answer should be boxed, have units as appropriate, and have the

correct number of significant figures. There will be a 20% deduction, per occurrence, for answers which significantly exceed the correct number of significant figures. Problems should be worked in the units provided (SI or American). No credit will be given for problems not worked in the units provided. No credit will be given for answers without work. Credit will be deducted for missing or incorrect units, sloppy work that is hard to follow, and for the incorrect number of significant figures. You should round off the final answer to the correct number of significant figures. If you round off intermediate calculations, thereby making your final answer inaccurate, significant credit will be deducted.

Grading:			
	Problem Sets	20%	
	Project	25%	due April 6, 2000
	Midterm Exam	25%	February 24, 2000
	Final Exam	30%	May 3, 2000 (11:00 a.m.– 1:00 p.m.)

Grades: The nominal grading scale is

≥90%	A
≥80%	B
≥70%	C
≥60%	D
<60%	F

At the instructor's discretion, this scale may be lowered, but not raised.

Text: Draft of book *Green Engineering*. (Cost $25 – can be purchased in Department office)

Related Texts: (on reserve in Evansdale Library)

Allen, D. T. and K. S. Rosselot, *Pollution Prevention for Chemical Processes*, Wiley-Interscience, 1997.

Anastas, P. T. and C. A. Farris, *Benign by Design. Alternative Synthetic Design for Pollution Prevention*, ACS Symposium Series # 577, ACS, Washington, DC, 1994

Anastas, P. T. and T. C. Williamson, *Green Chemistry. Frontiers in Benign Chemical Synthesis and Processes*, Oxford, 1998.

Bishop, P. L., *Pollution Prevention: Fundamentals and Practice*, McGraw Hill, 2000.

El-Halwagi, M. M. *Pollution Prevention through Process Integration*, Academic Press, 1997.

Wentz, C. A. *Hazardous Waste Management (2nd ed)*, McGraw Hill, 1995.

Approximate Course Outline

1. Introduction to Environmental Issues
2. Environmental Risk
3. Environmental Regulations
4 Role of Chemical Engineers
5. Evaluating Environmental Risks
6. Evaluating Environmental Releases and Exposures
7. Green Chemistry
8. Pollution Prevention in Process Synthesis
9. Unit Operations and Pollution Prevention
10. Flowsheet Analysis for Pollution Prevention
11. Evaluating the Environmental Performance of a Flowsheet
12. Evaluating Environmental Costs and Benefits
13. Life Cycle Assessment

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Problem Set 1
due 1/20/00

1. Information on toxicity of chemicals can be found from several sources. One is the NIOSH pocket guide (which some of you may have from safety class last year), which is available on line at http://www.cdc.gov/niosh/npg/pgdstart.html. Another is the EPA integrated risk information system (IRIS), available at http://www.epa.gov/ngispgm3/iris/index.html. Examine these sites (and possibly others of your choice) and evaluate the toxicity of the following. Be certain to report the risk-assessment parameters, if they are available.

   seniors – styrene, benzene, toluene, ethylbenzene, ethylene, methane
   juniors – substitute acetone and isopropyl alcohol for toluene and methane
   grad students – pick one of the above

2. The following web site has summaries and text of the laws (plus others) listed on page 3 of Chapter 3:

   http://www.epa.gov/epahome/laws.htm

   In your assigned group, examine the law you have been assigned. Try to interpret the legalese. Prepare a one- to two- page summary of your law. Also, prepare a 5-10 minute presentation. Each group (or designated individual) will present the group's findings, and then a discussion of each will follow. The content of your summary should have some more details than the summaries in the appendix to Chapter 3.

   Your written summary should be neat and in your best grammar since copies will be made and circulated to everyone in the class. Your grade on this part of the assignment will be a combination of technical content, oral presentation, and written report.

   The Clean Air Act
   The Clean Water Act
   The Toxic Substances Control Act
   The Occupational Safety and Health Act
   The Resource Conservation and Recovery Act
   The Pollution Prevention Act
   the following two, which go together:
      Comprehensive Environmental Response, Compensation, and Liability Act
      The Superfund Amendments and Reauthorization Act

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Problem Set 2
due 1/25/00

There have been several famous, some infamous, and some local chemical releases affecting the environment and humans. Some of these are:

Kepone – Hopewell, VA
Love Canal – near Buffalo, NY
Times Beach, MO
W. R. Grace – Woburn, MA – subject of movie *A Civil Action*
GE Plastics – Morgantown, WV – within last 5 years
Controversy over waste incinerator (which was never built) in East Liverpool, OH
Controversy over power plant next to Seneca Center

There are varying amounts of information on these topics available on the web. For some, you may have to search local newspapers, which I was unable to do successfully on the web. Some of the references on the reserve list may also have information on one or more of these. In your assigned groups, prepare a one- to two-page summary of one of these items plus a 5-10 minute presentation. Each group (or designated individual within the group) will present the group's findings, and then a discussion of each will follow.

Your written summary should be neat and in your best grammar since copies will be made and circulated to everyone in the class. Your grade on this part of the assignment will be a combination of technical content, oral presentation, and written report.

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Problem Set 3
due 2/8/00

all problems are from Green Engineering textbook

1. 5.1

2. 5.5

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Problem Set 4
due 2/15/00

Analyze a process flowsheet to estimate fugitive emissions. This may be done and submitted in your groups. Juniors should do the acetone process. Seniors should do the styrene process. Mixed groups should analyze the process of the majority. The group including graduate students may choose either of these two processes, or you may choose the acrylic acid process. For process flows, use the stream tables on the first major for acetone or acrylic acid, and the stream tables on the second major for styrene.

You should analyze for total organics and hydrogen separately. Assume that each process stream has at four valves in addition to those shown on your PFD. Also, to get a conservative estimate, assume that all organic liquids are "light liquids."

Is your process classified as a major source?

note: the styrene and acetone processes can be found at

http://www.cemr.wvu.edu/~wwwche/publications/projects/index.html

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Project

Look at the books on Green Chemistry on reserve in the Library. There are also examples of Green Chemistry in Chapter 7 of the text and in the chapters of a book on Green Chemistry the library does not have, which I have put in the folder in the computer room. Your group should choose a topic from one or more of these chapters. Alternatively, you may research and identify your own topic. This will be your semester project. The progression of events will tentatively be as follows:

identify Green Chemistry process to manufacture a product – compare to "old" process
synthesize base cases of both flowsheets
analyze the environmental impact of both flowsheets
suggest improvements to either or both flowsheets

The first assignment is to identify your group's process and understand the inherent chemistry. You should use the chapter or chapters in these books as a starting point. You are also expected to investigate the references cited. Explain the inherent chemistry of both processes. Take a first pass at a PFD for the new process. Also, try to find a PFD for the old process. The *Kirk Othmer Encyclopedia of Chemical Technology* and *The Encylcopedia of Chemical Processing Design* are good references for process flow diagrams for the "old" process. Both of these are in the permanent reference section of the Evansdale Library.

Perform an environmental risk analysis (Chapter 5) on the chemicals involved in both processes. Also, perform the analysis illustrated in Example 8.1 on the chemicals involved in both processes. Is the new process indeed "greener" than the old process, based on these analyses? Each group will give a brief presentation describing their "old" and "new" processes plus results to date on February 29, 2000.

For the final project, complete the analysis of both flowsheets, analyze the environmental impact of the flowsheets, and suggest process improvements to both flowsheets. Then, make a recommendation as to which flowsheet is environmentally superior, the original with modifications or the best one you could developed based on green chemistry.

Much of the flowsheet analysis will be learned in Chapters 9-12. Therefore, it is possible that the final due date of the semester project will be after April 6, 2000, as was stated on the syllabus. It depends on when we complete the material necessary for you to do the project. The due date will definitely be prior to the due dates for the junior and senior designs.

Some ideas for these projects are listed below. This list is not exhaustive; you may research and identify your own idea for this project.

Synthesis of adipic acid from d-glucose (*Benign by Design*, Chapter 3)
Alternatives to phosgene (*Benign by Design*, Chapters 4, 10)
Alternative styrene process (*Benign by Design*, Chapter 9)
Supercritical carbon dioxide applications (*Benign by Design*, Chapter 8; Chapter 11 in other Green Chemistry book) – note: there could be multiple projects here

Alternative route to polycarbonates (Chapter 2 in other Green Chemistry book)
Alternative route to production of dimethyl carbonate (Chapter 6 in other Green Chemistry book)
Use of dimethyl carbonate as an alternative feedstock (Chapter 7 in other Green Chemistry book)