The New Jersey Institute of Technology Experience in Fundamentals of Engineering Design (FED) and Freshman Engineering Courses

1994-1997

by
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Snowbird, Utah
August 1997
Disciplinary and Interdisciplinary Orientated Freshman Courses

By
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and
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Newark, NJ 07110

Summer School For Chemical Engineering Faculty
Chemical Engineering Division
American society of Engineering Education
Snowbird, Utah
August 11,1997
Handout of Course Lecture Notes and Overheads of Session Titled Teaching of Introductory Freshman Engineering and Freshman Engineering Design Courses
Background

In the Beginning

• Development of Freshman Engineering Design

Administrative concerns primary in developing interest in engineering, and engineering design concepts, student retention, and to initiate curriculum change.

Educational Research initiative by NSF Gateway Coalition of ten Universities
Objectives

• Overall Objective

To enable Freshman to work on real engineering problems at start of their education and not only in the traditional senior capstone design courses
Specific Objectives

Move Engineering Design to Freshman Year

Team approach to Problem Solving

Ignite Interest in Freshman About Engineering with hands on Experience

Improve Student Retention

Initiate Curriculum Change
Specific Objectives

(Continued)

• Couple Freshman Engineering Design with Computer Science and Humanities Courses

Learn Computer applications early

and

Learn to communicate both orally and in written reports early
GOALS

Administration

• Student Retention

• Curriculum Revision

• Engineering Design Upfront

• Expose Student to Various Engineering Disciplines
GOALS

Industry

• Technical Skills
• Communication Skills
  (a) Oral
  (b) Written

• Computer Abilities

• Team Player

• Off and Running
Goals

Instructor

• Teach Measurements Through Experimentation

• Technical Aspect of Experimentation

• Team Work Concepts

• Report Writing

• Oral Presentation

• Real Engineering Exposure
Goals

Student

• Interesting and Exciting Programs

• Exposure to Engineering early

• Acquire Experience with Minimal Effort
Disciplinary Development

- First Courses
  - Modules
    - Chemical Engineering
    - Civil Engineering
    - Electrical Engineering
    - Mechanical Engineering
Disciplinary Development

(Continued)

• Lecture-Laboratory Format
  Chemical Engineering
  Electrical Engineering
• Design Orientation Format
  Civil Engineering
  Mechanical Engineering

• All Modules
  Oral Final Report
  Written Final Report
Disciplinary Development

(Continued)

• Mechanical Engineering Module
  Full Fourteen Week Semester
  Required of all Students

• Chemical, Civil And Electrical
  Engineering Modules
  Seven Weeks
  Three hours per week
  Either 3 hours or
  Two, 1 1/2 hours blocks
  Students take two modules per semester
Program Structure

Engineering Component

• 14 weeks
  • 3 modules
    • One 14 week, ME module that is required, 3 hours per week
    • Two predetermined modules
      • 7 weeks each, 3 hours per week
      • From ChE. CE, EE
    • Small Class size, 15-18 students
    • 5-6 groups of 3 students
    • Instructor plus 1-2 Teaching Assistants

Humanities Component

• Three Hours per week
Chemical Engineering Module

• Lecture - 5 1/2 periods

• Laboratory -4 periods

• Final Report and Oral Presentation – 3 1/2 periods

• Final evaluation and Course Evaluation Survey -1 period
Courses Topics

• Theory of Measurements
• Definitions
• Basic Concepts
• Units
• Dimensions
• Standards
• Conversions
• Dimensional Analysis
• Correlations
• Linearization
  • Statistical Analysis
• Writing Reports
• Oral Presentation
## Courses Syllabus
### Fall 1994

<table>
<thead>
<tr>
<th>Week</th>
<th>Period</th>
<th>Subject</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 1</td>
<td>1</td>
<td>Orientation</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Film on Chemical Engineering</td>
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<td></td>
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<td>Pollution Prevention, pollution Abatement</td>
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<td></td>
<td>3</td>
<td>Measurement Lab</td>
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<td>4</td>
<td>Measurement Lab</td>
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<tr>
<td>Week 2</td>
<td>5</td>
<td>Computation Lab</td>
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<td>7</td>
<td>Measurement Lab</td>
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<td>8</td>
<td>Measurement Lab</td>
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<td>Week 3</td>
<td>9</td>
<td>Computation Lab</td>
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<td>Measurement Lab</td>
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<td>Measurement Lab</td>
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<td>Week 4</td>
<td>13</td>
<td>Computation Lab</td>
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<td>14</td>
<td>Computation Lab</td>
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<td>15</td>
<td>Measurement Lab</td>
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<td></td>
<td>16</td>
<td>Measurement Lab</td>
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<tr>
<td>Week 5</td>
<td>17</td>
<td>Computation Lab</td>
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<td>18</td>
<td>Computation Lab</td>
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<td></td>
<td>19</td>
<td>Computation Lab</td>
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<td></td>
<td>20</td>
<td>Final Report and Presentation</td>
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<tr>
<td>Week 6</td>
<td>21</td>
<td>Final Report and Presentation</td>
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<td>22</td>
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<td>24</td>
<td>Final Report and Presentation</td>
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<tr>
<td>Week 7</td>
<td>25</td>
<td>Oral Presentations</td>
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<tr>
<td></td>
<td>26</td>
<td>Oral Presentations</td>
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<tr>
<td></td>
<td>27</td>
<td>Course Review</td>
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<tr>
<td></td>
<td>28</td>
<td>Final Presentation</td>
</tr>
</tbody>
</table>
Lectures

- Nature of Chemical Engineering
- Concepts Involved in the Manufacture of Hazardous Substances
- Environmental Issues
- Pollution Prevention and Pollution
Laboratory

- Senior Chemical Engineering Unit
  Operations Laboratory and New FED Laboratory

- Groups of 3 or 4 Students

- Two Experiment by each group
Experiments

Pilot Plant Size Chemical Engineering Laboratory

• Calibration of Rotameter (All Groups)
• Pressure Drop in Pipes
  Calibration of Venturi Meter
• Pressure Drop in Fluidized Bed
• Pressure Drop in Packed Towers
• Efflux Time From Tanks

Bench Scale, New FED Laboratory

• Concentric Tube Heat Exchanger
• Bench Scale Temperature Measurement and Data Logger
• Fluid Friction Measurements
• Fluid Mixing Studies
• Pressure Drop in a Packed Towers and Fluidized Beds
A Laboratory Manual
For
Fundamentals of Engineering Design
Chemical Engineering Module;
Measurements Laboratory

by
Deran Hanesian
Angelo Perna
Department of Chemical Engineering, Chemistry and Environmental Science
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New Jersey Institute of Technology
Course Grading Module

- Final Quiz 25%
- Report 35%
- Oral 20%
- Homework 10%
- Class Evaluation, Lab Performance, Group Cooperation, and Effort 10%

Total 100%

- Grades from two modules (either ChE, CE; EE) weighted with ME module for final course grade

- Student must pass all modules to pass the course
Student Reaction

• Field to study and did this course help you to decide?
  • Helped 25-30 (50) percent of students to decide
  • For eleventh graders, it helped them all. They learned more about engineering as field to study.

• Were you Inspired by what you learned?
  • 60-70 percent were inspired
  • Inspiration is highly instructor related
  • All of the eleventh graders were inspired. They are more impressionable.
• Was your experience enjoyable?
• Would you recommend this course to others?

• About 75 (95) percent enjoyed the course and would recommend it.
• Very highly instructor related
• All eleventh graders liked the course
• Those that disliked the course stated:
  • Too difficult
  • Too much work-long report
    No interest in chemical engineering
  • Not their field and they resented being forced to take the course

Those that liked the course stated:

• Learned a great deal
• Experienced real engineering
• Group interactions and help from group
• Not boring - Fun - interesting
• Do you recall the term "Pollution Prevention" being used in the course?

  • 100 percent

• Do you know what the term means?

  • 60 - 70 (100) percent had heard the term and knew what it meant

  • Response was a highly instructor related, indicating some stressed these points, others did not
• Do you recall the term "Pollution Abatement" being used in the course?
  • 50 percent

• Do you know what the term means?
  • Fewer students had heard this term and 50 percent were not familiar with these terms
  • Most students had heard and knew about pollution prevention but much fewer knew about pollution abatement before taking the course
• **What did you enjoy most?**

  • Overwhelming majority stated hands-on laboratory experience during experimentation
  • Other enjoyable aspects of the course:
    • Working in Groups
    • The people I Met
    • Presentations
    • Everything

• **What did you enjoy least?**

  • Oral presentations
  • Lab Reports - lengthy
  • Analysis of Data and calculations without Background
• Other aspects of the course that were not enjoyed

• Homework
• Quiz (Final)
• Too Much Work
• Log-log Graphs
• Group problems
• Length of Course - too short
• Stress
• Uselessness of what was learned
Interdisciplinary Evolution

- Developed pilot courses - Spring 1996

  Interdisciplinary

  - Engineering Design and Manufacturing Integration
RATIONALE

In response to a perceived need for curriculum innovation in the freshman year, a philosophy of introducing "engineering up front", was developed. This approach involved the development of engineering design courses and introducing them in the freshman year. The course content was to introduce students to concepts of teamwork, "realistic engineering", independent work, oral and written communication aspects of technical reporting, and experimental measurements and analysis. One approach to meet this need was the development of four (4) interdisciplinary environmental based courses (modules) over the period 1995-97. The four courses and their description are as follows:
Background

The Need

• Students
  • Preliminary courses were well received
  • Wanted more of these types of courses

• Faculty
  • Expand experience for students to two semesters in Freshman Year
    • The first semester
      • Present traditional laboratory type courses
    • The second semester
      • Present scaled down capstone type design courses that freshman could handle with minimum faculty guidance
      • The courses were to be based upon interdisciplinary problems used in team building
  • Course to be for 14 weeks
Interdisciplinary Evolution

Courses Developed

Electrical-Mechanical Engineering
- Floppy Disk Drive

Electrical-Biomedical Engineering
- Emergency Medical Service
  Field Radio

Mechanical - Industrial and Manufacturing Engineering
- Lawn Sprinkler Design
Civil-Chemical Engineering

• Spring 1996

  Siting a Municipal Landfill in a Residential Community

• Fall 1996

  The Design and Siting of a Municipal Wastewater Facility

• Spring 1997

  The Design, Siting, and Environmental Analysis of a Major Connecting Highway

  The Design and Siting of a Hazardous Substance Manufacturing Facility
  (Aspirin Production)
"SHARED RESOURCES" MODULES TO SUPPORT ENVIRONMENTAL ENGINEERING EDUCATION

Investigators

Robert Dresnack, Ph.D.
Eugene Golub, Ph.D.
Deran Hanesian, Ph.D.
Hsin Neng Hsieh, Ph.D.
Angelo Perna, Ph.D.

New Jersey Institute of Technology
Newark, NJ 07102
"SHARED RESOURCES" MODULES TO SUPPORT ENVIRONMENTAL ENGINEERING EDUCATION

SITING A MUNICIPAL LANDFILL IN A RESIDENTIAL COMMUNITY

Prepared by:

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Angelo Perna, Ph.D., P.E.
Hsin Neng Hsieh, Ph.D., P.E.

New Jersey Institute of Technology
Newark, NJ 07102

Sponsored by:

Gateway Coalition
National Science Foundation

March 1996
Civil - Chemical Engineering
Pilot Module

Siting of a Municipal Landfill in a Residential Community

- Fourteen Weeks
- 2 hours and 10 minutes
- Groups of 2-4 students

Twelve Students
Civil Engineering Faculty (2)  
Chemical Engineering Faculty (1)

All three professors met individually with each group

- Lectures
  - Solid Waste Management
  - Existing New Jersey Solid Waste Management
  - Siting a Municipal Landfill

- Site Visitations
  - Gloucester County Landfill
  - Hackensack Meadowland
  - Development Commission Landfill

- Minimum Guidance and Independent Research
  - Environmental Restrictions
  - Political Restrictions
  - Economic Aspects of Site
  - Cost Analysis
  - Site Selection
Department of Civil & Environmental Engineering  
New Jersey Institute of Technology

FED 101- Freshmen Engineering Design (Spring 1996)  
Instructors:  
Dr. Eugene Golub  
Office: 302A, Campbell Hall  
Tel: (201)596-2448  e-mail: golub@admin1.njit.edu

Dr. Angelo Perna  
Office: 376 Tiernan Hall  
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Dr. Hsin-Neng Hsieh  
Office: 228 Otto Yorker CEES Bldg.  
Tel: (201)596-5859  e-mail: hsieh@admin1.njit.edu

Purpose of the course: Through basic engineering calculation and data analysis, students are working in groups to site a municipal landfill

<table>
<thead>
<tr>
<th>Week</th>
<th>Topic</th>
<th>Assignment*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lecture: Introduction of the course</td>
<td>Assignment I</td>
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<tr>
<td>2</td>
<td>Lecture: Introduction to solid waste management</td>
<td>Assignment II</td>
</tr>
<tr>
<td>3</td>
<td>Lecture: Local solid waste management (Existing New Jersey solid waste management)</td>
<td>Assignment III</td>
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<tr>
<td>4</td>
<td>Lecture: Considerations in siting a municipal landfill</td>
<td>Assignment IV</td>
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<tr>
<td>5</td>
<td>Map study and preliminary sites selection</td>
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<td>6</td>
<td>Site visitation (preliminary investigation)</td>
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<td></td>
<td>Field trip: Gloucester County Landfill</td>
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<td>7</td>
<td>Development of design criteria for the study</td>
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<td></td>
<td>Field trip: Hackensack Meadowland Development Commission Landfill</td>
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<tr>
<td>8</td>
<td>Sites and surrounding area study</td>
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<td>9</td>
<td>Research on environmental restrictions</td>
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<td>10</td>
<td>Research on political restrictions</td>
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<tr>
<td>11</td>
<td>Economics study</td>
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<td>12</td>
<td>Cost analysis</td>
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<td>13</td>
<td>Report preparation</td>
<td></td>
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<tr>
<td>14</td>
<td>Students oral presentation</td>
<td></td>
</tr>
</tbody>
</table>

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

Group 1

- Serve 45,000 Households
- Daily Load, 20 pounds/day
  (assume no recycling and recycling)
- Allowable Height, 20 feet
- Life of Landfill, 20 years
- Compactor trucks,
  28,000 pounds capacity
Siting

Based upon a United States Geological Survey (USGS) map of New Jersey, the students

• Chose three-five possible sites

• Made final choice of one
"SHARED RESOURCES" MODULES TO SUPPORT ENVIRONMENTAL ENGINEERING EDUCATION

SITE SELECTION AND ANALYSIS OF A WASTEWATER TREATMENT PLANT FACILITY

Prepared by:

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Deran Hanesian, Ph.D., P.E.
Hsin Neng Hsieh, Ph.D., P.E.
Angelo Perna, Ph.D., P.E.

New Jersey Institute of Technology
Newark, NJ 07102

Sponsored by:

Gateway Coalition
National Science Foundation

June 1997
Civil-Chemical Engineering Pilot Module

The Design and Sitting of a Municipal Wastewater Facility

• Fourteen Weeks
• Two Hours and Ten Minutes per Week
• Two Hours and ten Minutes CAD and Software Applications Class
• Humanities Component
  - Three hours per Week
• Groups of four
Civil Engineering Faculty(2)

• Siting of Facility Minimum Guidance
  Independent Research
  Site Visits
• Environmental restrictions
• Political Restrictions
• Economic Aspects of Site
New Jersey Institute of Technology

FED 101 - Freshmen Engineering Design (Fall 1996)

Instructors: Dr. Eugene Golub
Office: 302A, Campbell Hall
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Dr. Angelo Perna
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Tel: (201)596-3616 e-mail: perna@admin.njit.edu

Purpose of the course: Through basic engineering calculation and data analysis, students work in groups to analyze and site a municipal wastewater treatment plant

<table>
<thead>
<tr>
<th>Week</th>
<th>Topic</th>
<th>Assignment*</th>
</tr>
</thead>
</table>
| 1    | Lecture 1: Introduction to the course  
Video tape: “Who are engineers? You” | Assignment 1 |
| 2    | Lecture 2: Water Quality  
Video tape: “One Drop at a Time” | Assignment 2 |
| 3    | Lecture 3: Introduction to Wastewater Treatment  
Lecture 4: Siting a Wastewater Treatment Facility | Assignment 3 |
| 4    | Lecture 5: Concepts of Mass Balance | |
| 5    | Lecture 6: Soil Conditions and Cost Estimate | |
| 6    | Site visitation (preliminary investigation) | |
| 7    | Field trip: Passaic Valley Sewerage Authority Wastewater Treatment Plant | |
| 8    | Sites and surrounding area study  
Mass balance (flow rate and composition of streams) | |
| 9    | Research on environmental restrictions  
Mass balance Calculation (continued) | |
| 10   | Research on political restrictions  
Mass balance Calculation (continued) | |
| 11   | Economics study  
Estimate size of equipment needed | |
| 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
Design Basis

• Serve 45,000 Households

• Average Three People per Household

• Eighty Gallons per Day per Capita Consumption

• Locate Plant in New Jersey
  - South Branch of Raritan River
  - Highway 202
  - Township of Branchburg

• Influent Stream
  - BOD, 250 mg/L
  - Suspended Solids, 250 mg/L

• Effluent Stream
  - BOD, 30 mg/L (max)
  - Suspended Solids, 30 mg/L (max)
Field Trip

• Passaic Valley Wastewater Treatment Facility, Newark, NJ.

• Serves 100 square miles of Northern New Jersey

• Capacity, 330 million gallons per day

• Serves 36 Municipalities

• 1.3 million people

• Discharges effluent into New York Harbor

• 156 acre site

• Largest in Eastern United States

• Processes about one fourth of all wastewater in New Jersey
Siting

- Each group isolated three to five possible sites
- Made final choice of one
- Two of four groups recommended the same site
- Others were different
Process Design

- Performed Material Balances
- Determined Number and Size of Various Units
- Performed Process Cost Calculations Including Inflationary Factors
- Student Results Varied
  - Construction Cost
    $6 - 7.6 million
  - Operating and Maintenance Costs
    $450,000 - $500,000 per year
  - Plant Size
    30-35 acres
"SHARED RESOURCES" MODULES TO SUPPORT ENVIRONMENTAL ENGINEERING EDUCATION

THE PLANNING AND SITING OF A MANUFACTURING FACILITY USING HAZARDOUS MATERIALS

Prepared by:

Eugene Golub, Ph.D., P.E.
Deran Hanesian, Ph.D., P.E.
Hsin Neng Hsieh, Ph.D., P.E.
Angelo Perna, Ph.D., P.E.

New Jersey Institute of Technology
Newark, NJ 07102

Sponsored by:

Gateway Coalition
National Science Foundation

June 1997
Civil - Chemical Engineering Pilot Module

The Siting of a Hazardous Material Manufacturing Facility in a Residential Community - The Manufacture of Aspirin

- Fourteen weeks
- Class - 2 hours and 10 minutes
- Groups of 5 students
- Twenty students
- Students were also assigned to Computer Applications Class (2 hours and 10 minutes)
- Course is paired with Eng 099-004
New Jersey Institute of Technology

FED 101 - Freshmen Engineering Design (Spring 1997)

Instructors:

- Dr. Eugene Golub
  Office: 302A, Campbell Hall
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  Tel: (201)596-3616  e-mail: perna@admin1.njit.edu

Purpose of the course: Through basic engineering calculation and data analysis, students are working in groups to site a pharmaceutical manufacture plant.

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<tbody>
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<td>Lecture 1: Introduction to the course</td>
<td>Assignment 1</td>
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<tr>
<td></td>
<td>Video tape: “Opportunities in Environmental Engineering”</td>
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<tr>
<td>2</td>
<td>Lecture 2: Siting a Facility</td>
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<tr>
<td>3</td>
<td>Lecture 3: Aspirin Manufacturing Industry</td>
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<tr>
<td>4</td>
<td>Lecture 4: Soil Conditions and Cost Estimate</td>
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<tr>
<td>5</td>
<td>Lecture 5: Written and Oral Communication</td>
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<td>6</td>
<td>Site visitation (preliminary investigation)</td>
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<tr>
<td>7</td>
<td>Field trip: Hoffman LaRoche Pharmaceutical Manufacture Plant</td>
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<td>8</td>
<td>Sites and surrounding area study</td>
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<td></td>
<td>Literature search on Aspirin</td>
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<tr>
<td>9</td>
<td>Research on environmental restrictions</td>
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<td>Production and plant size estimate</td>
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<td>10</td>
<td>Research on political restrictions</td>
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<td></td>
<td>Mass balance</td>
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<td>11</td>
<td>Economics study</td>
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<td></td>
<td>MSDA search</td>
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<tr>
<td>12</td>
<td>Cost analysis: construction cost, operation and maintenance cost</td>
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<tr>
<td>13</td>
<td>Report preparation</td>
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</table>

*Students are requested to conduct literature search for the assigned homework.
Civil Engineering Faculty (2)

- Siting of the Hazardous Materials Facility
  - Minimum Guidance
  - Independent Research
  - Site Visits
- Environmental Restrictions
- Political Restrictions
- Economics Aspects of Site
- Site Selection
Chemical Engineering Faculty (2)

- Introduction to the Problem, History, Background Film
- Manufacture of Aspirin

Step I  Salicylic Acid From Phenol
  • Block Diagram
  Input - Output
  • Flow Diagram

Step II  Acetyl Salicylic Acid From
Salicylic Acid with
Acetic Anhydride
  • Block Diagram
  • Flow Diagram

- Plant Tour
  Hoffmann-LaRoche, Nutley, NJ
Chemical Engineering Faculty (2)
(Continued)

• Chemistry of Processes
  Kolbe-Schmitt Synthesis

• Chemicals used in Processes

• Materials Safety Data Sheets for all Chemicals Used
  Identify Health Hazards
Chemical Engineering Faculty (2)
(Continued)

The Problem

• Determine the size of the Production Facility
  • Determine and plant the growth of U.S. population
  • Determine and plant the growth of U.S. Aspirin production
  • Estimate the amount of Aspirin Needed in the U.S. in 2007 AD
  • Estimate what share of this market you will capture
  • Determine the production capacity of the Facility
The Problem (Continued)

• Determine the quantities of all products and by-products formed and all of the raw material required
  • Assume
    • 100% Conversion in each step
    • 95% Yield in each step

• Specify the waste streams, the quantities of these streams and suggest a method of disposal

• What pollution prevention improvements can you make to the process to reduce the waste streams
Siting

- Groups isolated 3-4 possible sites
- Made final choice of one site
- Two of the groups picked sites in Hillsborough NJ near Route 206
- Two of the groups picked sites near Readington NJ near the Hunterdon County and Sumerset County boundary near Route 202
"SHARED RESOURCES" MODULES TO SUPPORT ENVIRONMENTAL ENGINEERING EDUCATION

THE SITING OF A ROADWAY TO MINIMIZE AIR POLLUTION

Prepared by:

Robert Dresnack, Ph.D., P.E.
Eugene Golub, Ph.D., P.E.
Deran Hanesian, Ph.D., P.E.
Angelo Perna, Ph.D., P.E.

New Jersey Institute of Technology
Newark, NJ 07102

Sponsored by:

Gateway Coalition
National Science Foundation

June 1997
Civil - Chemical Engineering Pilot Module

The Siting of a Roadway To Minimize Air Pollution

• Fourteen weeks
• Class - 2 hours and 55 minutes
• Groups of 4-5 students
• Nineteen students
• Students were assigned to ME module
• Course is paired with Eng 099-004
<table>
<thead>
<tr>
<th>WEEK</th>
<th>TOPIC</th>
<th>DELIVERABLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction to the project &lt;br&gt;Introduction to air pollution &lt;br&gt;Film - opportunities in Env. prot</td>
<td>assigned homework</td>
</tr>
<tr>
<td>2</td>
<td>Establish schedule for the project &lt;br&gt;Chemistry &amp; physics of air pollut. &lt;br&gt;Chem reactions - gasoline diesel &lt;br&gt;smog - dispersion - health effects</td>
<td>Project schedule with individual assignments</td>
</tr>
<tr>
<td>3</td>
<td>Establish report outline use of computer models</td>
<td>Report outline</td>
</tr>
<tr>
<td>4</td>
<td>Field recon to the proposed site area</td>
<td>Report on field recon</td>
</tr>
<tr>
<td>5</td>
<td>Model description &lt;br&gt;outside speaker</td>
<td>Report on field recon</td>
</tr>
<tr>
<td>6</td>
<td>Individual meetings &lt;br&gt;outside speaker</td>
<td>Update on schedule and outline</td>
</tr>
<tr>
<td>7</td>
<td>Preliminary selection of possible alignments</td>
<td>Map with preliminary selections and justifications- update on report</td>
</tr>
<tr>
<td>8</td>
<td>Report on environmental restrictions of prelim alignments</td>
<td>Report on environmental restrictions of prelim alignments- update on report</td>
</tr>
<tr>
<td>9</td>
<td>Report on political constraints of prelim alignments</td>
<td>Report on political constraints of prelim alignments- update on report</td>
</tr>
<tr>
<td>11</td>
<td>Site evaluation &amp; selection</td>
<td>update on report</td>
</tr>
<tr>
<td>12</td>
<td>Reports - oral preparation</td>
<td>Reports - oral preparation</td>
</tr>
<tr>
<td>14</td>
<td>Student oral presentations</td>
<td>Student oral presentations</td>
</tr>
</tbody>
</table>
January 15, 1997

FED 101-008

Angelo J. Perna
Deran Hanesian

1. Week 1
   *Introduction to Project
   *Film - Opportunities in Environmental Protection

2. Week 2
   Chemistry and Physics of Air Pollution
   *Chemical Reactions
   *Gasoline
   *Diesel
   *Smog
   *Dispersion
   *Health Effects
   *Film - Exxon

3. Week 5-6
   Speakers on Air Pollution

4. Week 10-11-12
   Discuss and Teach Written and Oral Reports
Civil Engineering Faculty (2)

- Siting of Highway
  - Minimum Guidance
  - Independent Research
  - Site Visits
  - Application of Computer Model CAL3QHC

- Environmental Restrictions
- Political Restrictions
- Economics Aspects of Site
- Site Selection
USER'S GUIDE TO CAL3QHC VERSION 2.0: A MODELING METHODOLOGY FOR PREDICTING POLLUTANT CONCENTRATIONS NEAR ROADWAY INTERSECTIONS (REVISED)
USER'S GUIDE
to
MOBILES
(MOBILE SOURCE EMISSION FACTOR MODEL)

May 1994
"User's Guide to MOBILE5 (Mobile Source Emission Factor Model)"

U.S. Environmental Protection Agency, Office of Mobile Sources, Emission Planning and Strategies Division, Air Quality Analysis Branch

EPA-AA-AQAB-94-1

MOBILE5 is the latest update to the emission factor model for highway vehicles. It updates and supersedes MOBILE4.1, released in 1991.

MOBILE5 is the latest version of EPA's highway vehicle emission factor model. It estimates fleet average in-use emission factors for hydrocarbons (HC), carbon monoxide (CO), and oxides of nitrogen (NOx) for eight types of gasoline-fueled and diesel highway vehicles. Relative to MOBILE4.1, it has been extensively revised on the basis of additional test data, and includes the effects of new regulations under the 1990 Clean Air Act Amendments on future emission levels.
Chemical Engineering Faculty (2)

• Air Pollution
  • History of Problem
• Automobiles - Motor Vehicles
  • Gasoline Engine
  • Diesel Engine

• Major Legislation
• Chemistry
  • Combustion
  • Photochemical Smog
• Dispersion
  • wind
  • Turbulence
  • Lapse Rates and Atmosphere Stability
  • Topography
• Health
Design Basis

Connecting Highway to be located between Highway 22 and Highway 202 at the Hunterdon-Somerset County boundary in Branchburg, NJ

- Peak Hour Vehicle Rates
  - Each group assigned a different rate
  - Range was 1200 - 2000 vehicles per hour

- Four lane Highway, two lanes in each direction

- Speeds to be maintained

- 55 mph max on main highway lanes
  15 mph at the highway ramps
Siting

- Groups isolated possible sites
- Made a final choice of one
- All four groups recommended different, but similar routes
Student Evaluation

- Students were impressed with the course
- Enjoy the experience
- Enjoy team effort
- Too much work
- Disliked being forced to take a course in an area not of their choice
FACULTY REACTION

• Exciting
  • Educational Development Working with Interested Faculty
  • Change Curriculum
  • Changes in Teaching Methodology

• Challenging
  • Take Complex Problems and Simplify Them for Freshman in a Lecture/Laboratory Environment

• Rewarding
  • Positive Impact on Students Development
  • Four Year Remembrance by Students
CONCLUSIONS

• Did not help them decide on a career
• Students were inspired by course
• Enjoyed hands-on experimentation the most
• Disliked oral presentations the most
  • Lengthy Lab reports
  • Analysis of data and
    Calculation without background
• Developed some mind-set on pollution prevention and abatement
• Experience was very enjoyable
• Reaction to course is very highly related to instructor
• Course is worthwhile developing
• Best instructors in the department should be assigned to the course
Acknowledgments

• Financial Support for Program Development
  • The NFS-Gateway Coalition
  • The State of New Jersey
  • New Jersey Institute of Technology
  • The Fluke Corporation
  • The NSF Technical Reinvestment Program (TRP)

• Special thanks - Deans William Swart and Steve Tricamo

  - Encouragement
  - Commitment
  - Enthusiasm

for entire Freshman Engineering Design Program
Acknowledgment

• Their Students
  Hugo Fernandez, Jenny Lin, Janina Alvarez and Peniel Ortega
  for their dedicated assistance throughout the program

• Their colleagues in Civil engineering
  Dr. H.N. Hsieh, Dr. E. Golub and Dr. R. Dresnack
Appendix
Course Material

Siting a Municipal Landfill in a Residential Community
Definitions of Solid Wastes

Food Waste - Residues of animal, fruit or vegetables resulting from the handling, preparation cooking and eating of food. These waste are highly putrescible and decompose rapidly. This waste is called garbage.

Rubbish - Consists of combustible (i.e. paper, rubber, plastics, textile, wood, etc.) and non-combustible (i.e. aluminum cans, glass, ferrous, and non-ferrous metals, etc.) solid wastes of household, institutions, commercial activities, etc.

Ashes and Residues - Remnants from the burning of wood, coal, coke and other combustible waste on homes, stores, institutions, and industrial and municipal facilities for heating, cooking, and disposing of combustible waste. (Does not include ashes from power plant).

Demolition and Construction Wastes - Materials from construction, repairing and remodeling of building. Include dust, bricks, stones, plaster, plumbing fixture, etc. Often call rubbish.

Special Waste - Include street sweepings, dead animals, litter, abandoned vehicles, etc.

Treatment Plant Wastes - Solid and semi-solid wastes from water, wastewater, and industrial treatment plants.

Agricultural Wastes - Wastes from diverse agricultural activities.

Hazardous Waste - Waste that possess a substantial damages to human, plant, or animal life.
Population - Solid Waste (MSW) Data

<table>
<thead>
<tr>
<th>Year</th>
<th>Population</th>
<th>MSW* (ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960</td>
<td>180,671,000</td>
<td>81.7 x 10^6</td>
</tr>
<tr>
<td>1970</td>
<td>205,052,000</td>
<td>112.5 x 10^6</td>
</tr>
<tr>
<td>1980</td>
<td>227,757,000</td>
<td>129.2 x 10^6</td>
</tr>
<tr>
<td>1986</td>
<td>241,613,000</td>
<td>140.8 x 10^6</td>
</tr>
</tbody>
</table>

*MSW Discard after material recovery
The big can
The national average of what goes in our landfills.

- Plastic: 15%
- Metal: 10%
- Wood: 10%
- Organic Material: 10%
- Textiles: 5%
- Paper: 40%
- Glass: 2%
- Other: 9%
<table>
<thead>
<tr>
<th>Materials</th>
<th>1970</th>
<th>1986</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper and Paperboard</td>
<td>36.5</td>
<td>50.1</td>
</tr>
<tr>
<td>Glass</td>
<td>12.5</td>
<td>11.8</td>
</tr>
<tr>
<td>Metals</td>
<td>13.5</td>
<td>12.6</td>
</tr>
<tr>
<td>Plastics</td>
<td>3.0</td>
<td>10.3</td>
</tr>
<tr>
<td>Rubber and Leather</td>
<td>3.0</td>
<td>3.9</td>
</tr>
<tr>
<td>Textiles</td>
<td>2.0</td>
<td>2.8</td>
</tr>
<tr>
<td>Wood</td>
<td>4.0</td>
<td>5.8</td>
</tr>
<tr>
<td>Other</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Food Wastes</td>
<td>12.8</td>
<td>12.5</td>
</tr>
<tr>
<td>Yard Wastes</td>
<td>23.2</td>
<td>28.3</td>
</tr>
<tr>
<td>Miscellaneous Inorganics</td>
<td>1.9</td>
<td>2.6</td>
</tr>
</tbody>
</table>

**TOTALS**

<table>
<thead>
<tr>
<th>1970</th>
<th>1986</th>
</tr>
</thead>
<tbody>
<tr>
<td>112.5</td>
<td>140.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Products</th>
<th>1970</th>
<th>1986</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durable Goods</td>
<td>13.9</td>
<td>19.2</td>
</tr>
<tr>
<td>Nondurable Goods</td>
<td>21.4</td>
<td>35.4</td>
</tr>
<tr>
<td>Containers and Packaging</td>
<td>39.3</td>
<td>42.7</td>
</tr>
<tr>
<td>Other Wastes**</td>
<td>17.8</td>
<td>43.4</td>
</tr>
</tbody>
</table>

**TOTALS**

<table>
<thead>
<tr>
<th>1970</th>
<th>1986</th>
</tr>
</thead>
<tbody>
<tr>
<td>112.5</td>
<td>140.8</td>
</tr>
</tbody>
</table>

---

* Wastes discarded after materials recovery and before energy recovery.

** The "Other Wastes" category includes food wastes, yard wastes, and other miscellaneous inorganic wastes.

Details may not add to totals due to rounding.
Table 2

Gross Discards, Recovery, and Net Discards of Municipal Solid Waste

(In millions of tons)

<table>
<thead>
<tr>
<th>Year</th>
<th>Gross Discards</th>
<th>Materials Recovery</th>
<th>Discards After Materials Recovery</th>
<th>Energy Recovery</th>
<th>Net Discards</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960</td>
<td>87.5</td>
<td>5.3</td>
<td>81.7</td>
<td>--</td>
<td>81.7</td>
</tr>
<tr>
<td>1965</td>
<td>102.3</td>
<td>6.2</td>
<td>96.1</td>
<td>0.2</td>
<td>95.9</td>
</tr>
<tr>
<td>1970</td>
<td>120.5</td>
<td>8.0</td>
<td>112.5</td>
<td>0.4</td>
<td>112.1</td>
</tr>
<tr>
<td>1975</td>
<td>125.3</td>
<td>9.1</td>
<td>116.2</td>
<td>0.7</td>
<td>115.5</td>
</tr>
<tr>
<td>1980</td>
<td>142.6</td>
<td>13.4</td>
<td>129.2</td>
<td>2.7</td>
<td>126.5</td>
</tr>
<tr>
<td>1981</td>
<td>144.8</td>
<td>13.2</td>
<td>131.6</td>
<td>2.3</td>
<td>129.3</td>
</tr>
<tr>
<td>1982</td>
<td>142.0</td>
<td>12.9</td>
<td>129.1</td>
<td>3.5</td>
<td>125.6</td>
</tr>
<tr>
<td>1983</td>
<td>148.4</td>
<td>13.9</td>
<td>134.5</td>
<td>5.0</td>
<td>129.5</td>
</tr>
<tr>
<td>1984</td>
<td>153.6</td>
<td>15.3</td>
<td>138.3</td>
<td>6.5</td>
<td>131.8</td>
</tr>
<tr>
<td>1985</td>
<td>152.5</td>
<td>15.3</td>
<td>137.3</td>
<td>7.6</td>
<td>129.7</td>
</tr>
<tr>
<td>1986</td>
<td>157.7</td>
<td>16.9</td>
<td>140.8</td>
<td>9.6</td>
<td>131.2</td>
</tr>
</tbody>
</table>

Details may not add to totals due to rounding.
<table>
<thead>
<tr>
<th>Source</th>
<th>lb/capita/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combined residential and commercial</td>
<td>4.29</td>
</tr>
<tr>
<td>Industrial</td>
<td>1.90</td>
</tr>
<tr>
<td>Institutional</td>
<td>0.16</td>
</tr>
<tr>
<td>Demolition and construction</td>
<td>0.72</td>
</tr>
<tr>
<td>Street and alley cleanings</td>
<td>0.25</td>
</tr>
<tr>
<td>Tree and landscaping</td>
<td>0.18</td>
</tr>
<tr>
<td>Park and beach</td>
<td>0.15</td>
</tr>
<tr>
<td>Catch basin</td>
<td>0.04</td>
</tr>
<tr>
<td>Sewage treatment plant solids</td>
<td>0.50</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>8.19</strong></td>
</tr>
</tbody>
</table>

* Adapted from Ref. 4.
† As reported in Table 4-12, the corresponding total per capita quantities for all areas (7.92 lb capita.day) are somewhat lower than those from urban areas.

Note: 1 lb capita.day x 0.4536 = kg capita.day
DISPOSAL METHODS

(I) Sanitary Landfilling - An engineered method of disposing of solid wastes on land in a manner that protects the environment, by spreading the wastes in thin layers, compacting it to the smallest practical volume, and covering it with soil by the end of each day.

(II) Incineration - The controlled process by which solid, liquid, or gaseous combustible wastes are burned and changed into gases and the residue product contains little or no combustible material.

(a) Mass Burn - Waste combusted without any pre-processing other than the removal of items to large to go through the feed system.

(b) Refuse Derived Fuel (RDF) - Units which burn sorted refuse which can vary from simple removal of bulky items accompanied by shredding to extensive processing to produce finely divided fuel suitable for co-firing in pulverized coal boilers. Processed MSW, regardless of the degree of processing performed is broadly referred to as RDF.

(I) Landfills in U.S.A.:

(a) 10,000 active landfills
(b) 1/3 will reach design capacity in 5 to 7 years
How is Our Waste Managed?  
(millions of tons per year)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>volume</td>
<td>%</td>
<td>vol.</td>
<td>%</td>
<td>vol.</td>
<td>%</td>
<td>vol.</td>
<td>%</td>
</tr>
<tr>
<td>Landfills/Other</td>
<td>81.7</td>
<td>93</td>
<td>12.1</td>
<td>93</td>
<td>124.6</td>
<td>76</td>
<td>119.6</td>
<td>69</td>
</tr>
<tr>
<td>Recycling</td>
<td>5.8</td>
<td>7</td>
<td>8.0</td>
<td>7</td>
<td>17.7</td>
<td>11</td>
<td>19.5</td>
<td>11</td>
</tr>
<tr>
<td>Waste-to-Energy</td>
<td>—</td>
<td>—</td>
<td>0.4</td>
<td>1</td>
<td>20.3</td>
<td>13</td>
<td>33.4*</td>
<td>19</td>
</tr>
<tr>
<td>Total</td>
<td>87.5</td>
<td>100</td>
<td>130</td>
<td>100</td>
<td>162.6</td>
<td>100</td>
<td>172.5</td>
<td>100</td>
</tr>
</tbody>
</table>

*Includes only operating facilities or those under construction as of July 1, 1989.

INCINERATION

<table>
<thead>
<tr>
<th>Year</th>
<th>Capacity (TPD)</th>
<th>No. of Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>pre-1980</td>
<td>15,000</td>
<td>-</td>
</tr>
<tr>
<td>1986</td>
<td>48,000 (approx.)</td>
<td>111</td>
</tr>
<tr>
<td>1989</td>
<td>80,000 (approx.)</td>
<td>172*</td>
</tr>
</tbody>
</table>

* 122 waste to energy plants (68,000 TPD)
  50 New waste to energy plants (12,000 TPD)

WASTE TO ENERGY

<table>
<thead>
<tr>
<th>Year</th>
<th>Capacity (TPD)</th>
<th>No. of Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1980</td>
<td>10,175</td>
<td>-</td>
</tr>
<tr>
<td>1986</td>
<td>35,365</td>
<td>73</td>
</tr>
<tr>
<td>1989</td>
<td>68,000</td>
<td>122</td>
</tr>
</tbody>
</table>
Sanitary landfilling is an engineered method of disposing of solid wastes on land by spreading them in thin layers, compacting them to the smallest practical volume, and covering these with soil each working day in a manner that protects the environment. By definition, no burning of solid waste occurs at a sanitary landfill. A sanitary landfill is not only an acceptable and economic method of solid waste disposal. It is also an excellent way to make otherwise unsuitable or marginal, land valuable.
In the progressive slope or ramp method of sanitary landfilling, solid waste is spread and compacted on a slope. Cover material is obtained directly in front of the working face and compacted on the waste.

In the area method of sanitary landfilling, a bulldozer spreads and compacts the waste on a natural surface of the ground, and a scraper is used to load the cover material at the end of the day's operation.

In the trench method of sanitary landfilling, the collection truck deposits its load into a trench where a bulldozer spreads and compacts it. At the end of the day, the trench is extended, and the soil is used as daily cover material.
Cross-section of a cell

Water runoff goes to a water treatment system

80ml high-density polyethylene liner

60ml high-density polyethylene liner

Leak detection system

18" of filter sand

18" of filter sand

3' layer of compacted clay

Manholes are maintained for inspection and taking samples of the water collection system.

Source: Middlesex County Utilities Authority, University of Arizona
Gas Movement Control

Gravel vents or gravel-filled trenches can be used to control lateral gas movement in a sanitary landfill.
Determining the yearly volume of compacted solid waste generated by a community of 10,000 people.
Solid waste disposal costs
Price per ton, as of April 1994

Connecticut $64.59
Delaware 58.5
Maine 52.25
Maryland 56.28
Massachusetts 65.92
New Hampshire 43.35
New Jersey 93.84
New York 81.22
Pennsylvania 56.26
Rhode Island 33.60
Vermont 52.89

Edgeboro Landfill
Unloading fees - per ton

General waste $59.54
Special handling $103.06
Mixed loads & out of county loads $68.50
Construction & demolition $68.50

Includes taxes of $16.38 per ton
WHAT IS A HAZARDOUS WASTE

KEY POINTS:

• The RCRA statute broadly defines hazardous waste. Note that RCRA defines hazardous wastes in terms of properties of a solid waste. Therefore, if a waste is not a solid waste, it cannot be a hazardous waste. EPA specified in regulations (40 CFR Part 261) that a solid waste is hazardous if it:
  - Is listed in the regulations
  - Exhibits one of four characteristics
  - Is a mixture containing a hazardous waste
  - Is derived from a hazardous waste.

• The specific lists of hazardous waste are composed of wastes from:
  - Non-Specific sources (e.g., industrial spent solvents (40 CFR Part 261.31))
  - Specific sources (e.g., wastewater treatment sludges (40 CFR Part 261.32))
  - Discarded commercial chemical products (e.g., benzene, dieldrin (40 CFR Part 261.33(e) and (f)).
KEY POINTS: (continued)

- **RCRA** defines four hazardous characteristics in 40 CFR Parts 261.20 - 261.24
  - Ignitability (flashpoint 140° F or 60° C)
  - Corrosivity (corrode 1/4 inch of steel in a year)
  - Reactivity (reactive with water or air)
  - Toxicity (measured by EPA's EP Toxicity test). This test, however, will soon be replaced by the toxicity characteristic leaching process (TCLP).

- Wastes not regulated as hazardous by RCRA (excluded wastes) include:
  - household wastes
  - mining wastes
  - agricultural wastes
  - fly ash
  - oil and gas wastes
  - small quantity generator waste
  - certain recycled materials.

- CERCLA regulates hazardous substances *which* include RCRA hazardous wastes, in addition to other hazardous materials.
Partial List of References for the Case Study


Course Material

Site Selection and Analysis of a Wastewater Treatment Plant Facility
Process Design of a Wastewater Facility

In the process design of a wastewater facility, the important steps are:

1. Selection of the process for design

2. Development of the Material Balances for the Process
   a. Flow Rates
   b. Composition of Streams

3. Estimating the Size of the Equipment Needed
   a. Size of each unit
   b. Number of Units

   a. Overall estimated construction cost
   b. Annual operating and maintenance cost

I. Selection of the Process Design

Processes for wastewater treatment can be much too complex for students in the freshman year to comprehend. Hence, a simplified process is discussed which shows the essential aspects of the system. One such simplified process is shown in Figure 1. It entails

1. Screen
   • Remove large objects

2. Primary Sedimentation
• Remove particulates by settling

3. Primary Vacuum Filter
  • For solids removal

4. Aeration System
  • Convert BOD material to sludge

5. Secondary Sedimentation
  • Remove sludge by settling

6. Secondary Vacuum Filter
  • Remove sludge

II. Development of Material Balances for the Process

Based upon a design basis which established:

1. Influent Flow Rate
2. Influent Composition
3. Maximum Tolerable Effluent Specification of the Components

material balance calculations are made. Basic assumptions are made, where necessary, using literature recommendations. These calculations are shown and are summarized in the following table.

III. Estimation of the Size of Equipment Needed

Based upon the material balances, data and sizing recommendations in the literature, the number, size, and dimension of each unit are determined. These data are shown and can be summarized. (See Section IV, Sizing of Equipment)
IV. Cost Estimated for the Process.

   Literature correlations are used to estimate the process.

   1. Construction cost

   2. Annual operation and maintenance cost Based upon the Engineering News Record Index, the effect of inflation is incorporated into the initial estimate from the literature and current cost are arrived at.
Material Balance Calculation

Input + Generation - Output - Consumption = Accumulation (+) or Depletion (-)

Example: Your checking account

Deposit + Interest - Withdrawal - Bank Fees = Accumulation (+) or Depletion (-)

There are three components (water, BOD₃ and S.S.) in the system, therefore, we can have only three independent equations to describe the system.

I. Influent:

Given Information:

- 80 gal/cap-day
- 45,000 households
- 3 people/household
- Influent BOD₃ = 250 mg/l
- Influent S.S. = 250 mg/l

- Effluent BOD₃ = 30 mg/l
- Effluent S.S. = 30 mg/l

Stream 1 Calculation

Flow rate = (80 gal/cap-day)(45,000 households)(3 people/household)
= 10,800,000 gal/day

Water

(10,800,000 gal/day)(8.31 lb/gal) = 90,072,000 lb/day

BOD₃

(250 mg/l)(1 liter/1000 g)(1g/1000 mg) = 0.00025 = 0.025 wt. %
(90,072,000 lb/day)(0.00025 wt fraction BOD) = 22,518 lb/day

S.S.

(90,072,000 lb/day)(0.00025 wt fraction S.S.) = 22518 lb/day

II. Primary Sedimentation Tank and Primary Vacuum Filter:

1. Design Information:
a. Primary Sedimentation Tank

Surface Overflow Rate: 16 - 48 m³/m²-d (400 - 1,200 gpd/ft²)
Solids Loading: 49 - 147 kg/d-m² (10 - 30 lb/ft²-d)
Detention time: 1 - 4 hours
Removal: 40 - 65% of Suspended Solids (S.S.)
25 - 50% BOD₅

Primary Solids Concentration: 4 - 10%

b. Primary Vacuum Filter

Diameter: 5 m (16.4 ft)
Length: 6 m (20 ft)
Vacuum: 20 in Hg (686 Pa) compressible sludge
Filter Yield: 20 - 60 kg/hr-m² (4 - 12 lb/ft²-hr)
Cake Solids: 10-25%

2. Calculation Basis

a. Primary Sedimentation Tank

Surface Overflow Rate: 600 gpd/ft²
Solids Loading: 49 kg/d-m² (10 lb/ft²-d)
Removal: 40 % of S.S.
25 % BOD₅
Primary Solids Concentration: 4 %

b. Primary Vacuum Filter

Cake Solids: 25%

3. Overall Balance for Primary Sedimentation Tank and Primary Vacuum Filter

Total Flow Balance

Total lb/day In = Total lb/day Out

Stream 1 (lb/day) = Stream 5 (lb/day) + Stream 6 (lb/day)
This equation is used for water balance, BOD₅ balance and S.S. balance.

Stream 1:

Total Flow Rate = 10,800,000 gal/day
Water = 90,072,000 lb/day
BOD₃ = 22,518 lb/day
S.S. = 22518 lb/day

Stream 5: 40% S.S. removal and cake solids = 25%

S.S. = (22,518 lb/d)(0.4) = 9007.2 lb/d
Flow = 9007.2/0.25 = 36,029 lb/d
BOD₃ = (22,518 lb/day)(0.25) = 5629.5 lb/d
Water = 36,029 - 5629.5 - 9007.2 = 21,392.3 lb/d

Concentration:

BOD₃ = 5629.5/36,029 = 156,249 mg/l
S.S. = 9007.2/36,029 = 249,998 mg/l = 0.25 = 25%
Water = 1,000,000 - 156,249 - 250,000 = 593,965 lb/d

Stream 6

Stream 6 = Stream 1 - Stream 5

Total Flow = 90,070,000 - 36,029 = 90,034,000 lb/day
BOD₃ = 22,518 - 5629.5 = 16,888.5 lb/d = 16,885.5/90,033,971 = 187.58 mg/l
S.S. = 22,518 - 9007.2 = 13,510.8 lb/d = 13,510.8/90,033,971 = 150 mg/l
Water = 90,033,971 - 16,885 - 13,510.8 = 90,003,572 lb/d or 999,662 mg/l

Stream 4

Solids in Stream 4 = Solids in Stream 5
Solids In = Solids OUT

Assume Filtrate has 0% solids
Let Stream 4 = X Total lb/d = 4% solids

S.S. In = 0.04X lb/d

Assume Stream 3 = 0% S.S.
Stream 5 S.S. Out = 9007.2
0.04X = 9007.2
Stream 4 = X = 225,180 lb/d Total

BOD₃ and S. S. in Stream 4 = BOD₃ and S. S. in Stream 5
Water in Stream 4 = 210,542 lb/d

Stream 3
Stream 3 = Stream 4 - Stream 5 = 225,180 - 36,029 = 189,151 lb/d Total

Total Flow in Stream 4 = Total Flow in Stream 3 + Total Flow in Stream 5
225,180 = Stream 3 + 36,029
Total Flow Stream 3 = 189,151 lb/d

Assume Stream 3 BOD₃ concentration is 3 mg/l
BOD₃ in Stream 3 = (3 lb/1,000,000 Total)(189,151) = 0.5674 lb/d

Stream 2

Stream 2 = Stream 1 + Stream 3

Total Flow = 90,259,181
BOD₃ = 22,518.6 lb/d = 22518.6/90,259,181 = 249.5 mg/l
S.S. = 22,518/90,259,181 = 249.5 mg/l
Water = 90,214, 115 lb/day = 90,214,115/90,259,181 = 999,501 mg/l

III. Activated Sludge System

1. Design Information:

a. Effluent Water Concentration, S

\[ S = K_a (1 + K_d \theta_a )/[ \theta_a (K_a - K_d ) - 1] \]

b. Kinetic Constants: The following kinetic constants are commonly used for complete mix process with sludge recyle:

- \( K_a = 0.1 - 0.3 \text{ hr}^{-1} \)
- \( K_d = 50 - 120 \text{ mg/l} \)
- \( Y = 0.5 - 0.67 \text{ mg MLSS/mg waste (yield coefficient)} \)
- \( K_d = 0.002 - 0.003 \text{ hr}^{-1} \) (decay coefficient)
- \( \theta_a = 3 - 14 \text{ days (sludge age, or mean cell residence time)} \)

c. Process Loading Factor

\[ F/M \text{ Ratio} = \frac{\text{Food (BOD₃)/microorganisms (mass of S.S.)}}{\text{Usually F/M is in the range of 0.2 - 0.6 kgBOD₃/kg MLSS-d}} \]

Volumetric loading: 0.02 to 0.04 lb BOD₃/ft³ -d

d. Active Biomass in Reactor

Concentration of active biomass in reactor, X, can be expressed as:
\[ X = Y \left( S^o - S \right) \frac{\theta \theta_s}{\left[ 1 + K_s \theta_s \right]} \]

- \( X \) = active biomass (solids) in aerator (1000 - 3000 mg/l)
- \( S^o \) = influent BOD concentration, mg/l
- \( S \) = effluent BOD concentration, mg/l
- \( \theta \) = hydraulic residence time, hr. (4 - 8 hours)
- \( \theta_s \) = sludge age

e. Sludge Production

Sludge (solids) generation rate, \( P_t \), can be calculated by the following equation:

\[ P_t = \frac{VX}{\theta_s} \]

f. Recycle Ratio, R

Recycle ratio, R, can be calculated by the following equation:

\[ R = \frac{(1 + \theta / \theta_s)(X / X - 1)}{\text{where } X_s \text{ is the solid concentration in the recycle flow}} \]

Recycle ratio = 0.15 - 0.75

g. Oxygen Demand

Oxygen Demand (OD) = \( [(S^o - S)(1 - aY) / \theta] + 0.9 a K_s X \)

\[ a = 1.44 \text{ mg BOD}_5/\text{mg MLSS} \]

h. Secondary Sedimentation

Settled solids concentration: 0.5 - 2.0%
Underflow solids: 2.0 - 3.0%
Surface overflow rate: 800 - 1200 gpd/ft²
Solids loading: 4 - 6 lb/d-ft²
Secondary treatment removal efficiency: 85 - 95\% S.S. and 85 - 95\% BOD₅

i. Activated Sludge Vacuum Filter

Diameter: 5 m (16.4 ft)
Length: 6 m (20 ft)
Filter Yield: 5 - 20 kg/hr-m² (1 - 4 lb/ft²-hr)
Cake Solids: 10-15\%

2. Design
a. BOD\textsubscript{3} in Stream 11

BOD\textsubscript{3} in Stream 6 = S\textsuperscript{o} = 187.5 mg/l

The following equation is used for calculation:

\[ S = K_m (1 + K_d \theta_e) \left/ \left( \theta_e (K_o - K_d) - 1 \right) \right. \]

with the selection of the following constants:

\[ K_o = 0.2 \text{ hr}^{-1} \]
\[ K_m = 60 \text{ mg/l} \]
\[ Y = 0.6 \text{ mg MLSS/mg waste} \]
\[ K_d = 0.0025 \text{ hr}^{-1} \]
\[ \theta_e = 5 \text{ days or 120 hours} \]

Then, effluent BOD\textsubscript{3} concentration (BOD\textsubscript{3} in Stream 11)

\[ S = 60 \left[ 1 + (0.025)(120) \right] \left/ \left[ 120(0.2 - 0.025) - 1 \right] \right. = 3.44 \]

b. Volume of Reactor:

\[ V = Q t \]
\[ Q = \text{Total Flow in Stream 6} \]
\[ t = 7 \text{ hours} \]

\[ Q = (90,034,000 \text{ lb/d}) \left( 1 \text{ d/24 hr} \right) (0.45 \text{ kg/lb})(1 \text{ liter/1 kg})(35.3 \text{ ft}^3/1000 \text{ liter}) \]
\[ = 60,145.65 \text{ ft}^3/\text{h} \]

\[ V = (60,145.65 \text{ ft}^3/\text{h})(7 \text{ hours}) = 421,019.55 \text{ ft}^3 \]

c. Active biomass (MLSS) in aerator

\[ X = Y(S^o - S)(\theta_e / \theta)/[1 + K_d \theta_e] \]

Use \( \theta = 7 \text{ hours} \) and \( Y = 0.6 \)
\[ X = 1456.3 \text{ mg/l solids in aerator} \]

d. Recycle Ratio

\[ R = \text{Total flow in Stream 10/Total flow in Stream 6} \]
\[ \text{Assume } R = 0.3 \]
\[ \text{Flow in Stream 10} = 0.3(90,034,000 \text{ lb/d}) = 27,010,200 \text{ lb/d} \]
\[ R = \frac{1+\theta_2}{(X_r/X-1)} \]
\[ 0.3 = \frac{1 + (7/120)}{((X_r/1456.3) - 1)} \]
\[ X_r = 6593.8 \text{ mg/l MLSS (solids in Stream 10)} \]

e. Sludge Production:

\[ P_1 = \frac{VX}{\theta_e} = \frac{(421, 019.55 \text{ ft}^3) (1000 \text{ liter/35.3145 ft}^3) (1456.3 \text{ mg/l})}{3,471.79 \text{ kg/d}} = 7639 \text{ lb/d} \]

f. Oxygen Consumption rate:

\[ \text{Oxygen Demand (OD)} = [(S^o - S)(1 - aY)/6] + 0.9 a K_d X \]

\[ a = 1.44 \]

\[ \text{OD} = [(187.5 - 3.44)(1 - 1.44*0.6) + 0.9 (1.44) (0.0025)(1456.3)] / 7 = 8.29 \text{ mg/l-h} \]

3. Mass Balance for Streams 7 - 14

\[ \text{S.S. in Stream 7} = \text{S.S. in Stream 6} + \text{S.S. generated} \]
\[ = 13, 510.5 \text{ lb/d} + 7, 639 \text{ lb/d} \]
\[ = 21, 149.5 \text{ lb/d} \]

\[ \text{Total Flow in Stream 7} = \text{Total Flow in Stream 6} + 7, 639 \text{ lb/d} \]
\[ = 90, 034, 000 \text{ lb/d} + 7, 639 \text{ lb/d} \]
\[ = 90, 041,639 \text{ lb/d} \]

\[ \text{BOD}_3 \text{ in Stream 7} = \text{BOD}_3 \text{ in Stream 11} \]
\[ \text{BOD}_3 \text{ in Stream 7} = 3.44 \text{ mg/l} \]
\[ \text{BOD}_3 \text{ fraction} = \frac{3.44}{1,000,000} = 0.00000344 \]

\[ \text{Wt fraction} = \frac{\text{BOD}_3 \text{ in Stream 7}}{\text{Total Flow in Stream 7}} \]
\[ \text{BOD}_3 \text{ in Stream 7} = (90,041, 634 \text{ lb/d})(0.00000344) \]
\[ \text{BOD}_3 \text{ in Stream 7} = 309.7 \text{ lb/d} = \text{BOD}_3 \text{ in Stream 11} \]

\[ \text{Wt. Fraction of S.S. in Stream 7} = \frac{21,149.5}{90,041,639} = 0.0002349 \]
\[ \text{Concentration of S.S. in Stream 7} = 234.9 \text{ mg/l} \]

\[ \text{Water in Stream 7} = \text{Total Flow Stream 7} - \text{BOD}_3 \text{ Stream 7} - \text{S.S. Stream 7} \]
\[ \text{Water in Stream 7} = 90, 041, 639 \text{ lb/d} - 309.7 - 21, 149.5 = 90, 020, 179.8 \text{ lb/d} \]

Assume 94% solids are removed in second sedimentation tank
\[ \text{S.S. in Stream 9} = 0.94 \text{ S.S. in Stream 7} \]
\[ = (0.94)(21,149.5) = 12, 689.7 \text{ lb/d} \]
4% solids in Stream 9
S.S. in Stream 9 = 19,799.6 lb/d = (0.04) (Water in Stream 9)
Water in Stream 9 = 494,990 lb/d
Since BOD is very small
Total Flow in Stream 9 = Water in Stream 9 + S.S. in Stream 9
Total Flow in Stream 9 = 494,990 lb/d + 19,799.6 lb/d = 514,789.6 lb/d

Wt. Fraction + S.S. in Stream 9/Total Floe in Stream 9
Wt. Fraction = 19,799/514,789 = 0.038462
Concentration in Stream 9 = 38,462 lb/d

The Recycle Ratio is 0.3 in Stream 10
S.S. in Stream 10 = (0.3)(S.S. in Stream 9) = (0.3)(19,799.6) = 5939.9 lb/d
Total Flow in Stream 10 = (0.3)(Total Flow in Stream 9) = (0.3)(514,789.6) = 154,436.9 lb/d
Water in Stream 10 = (0.3)(Water in Stream 9) = (0.3)(494,990) = 148,497 lb/d
All concentrations are the same as in Stream 9

Stream 13 = Stream 9 - Stream 10
S.S. in Stream 13 = S.S. Stream 9 - S.S. Stream 10
S.S. in Stream 13 = 19,799.6 - 5,939.9 = 13,859.7 lb/d

Water in Stream 13 = Water in Stream 9 - Water in Stream 10
Water in Stream = 494,990 - 148,497 = 346,493 lb/d

Total Flow in Stream 13 = Total Flow in Stream 9 - Total Flow in Stream 10
Total Flow in Stream 13 = 514,789.6 - 154,436.9 = 360,352.7 lb/d

S.S. in Stream 14 = S.S. in Stream 13
S.S. in Stream 14 = 13,859.7 lb/d
25% solids in Stream 14
S.S. in Stream 14 = (0.25) Water in Stream 14
Water in Stream 14 = 13,859.7/0.25 = 55,438.8 lb/d
Total Flow in Stream 14 = S.S. in Stream 14 + Water in Stream 14
Total Flow in Stream 14 = 13,859.7 + 55,438.8 = 69,298.5 lb/d

S.S. in Stream 14/ Total Flow in Stream 14 = Wt. fraction

Wt. Fraction = 13,589.7/69,298.5 = 0.196104
Concentration of S.S. in Stream 14 = 196,103.8 mg/l

Water in Stream 12 = Water in Stream 13 - Water in Stream 14
Water in Stream = 222,069.75 - 35,531 = 12,186,538.55 lb/d
Assume no suspended solids or BODs in this recyle Stream
Water in Stream 8 = Water in Stream 7 + Water in Stream 12
Water in Stream 8 = 890, 020, 179.8 + 186, 539.55
= 90, 206, 718.35 lb/d

Total Flow in Stream 8 = Water in Stream 8 + S.S. in Stream
= 90, 206, 718.35 + 21, 149.5
= 90, 227, 867.85 lb/d

BOD₃ in Stream 8/Total Flow in Stream 8 = Wt. Fraction
Wt. Fraction = 309.7/90,227,867.85 = 0.0000343
Concentration BOD₃ in Stream 8 = 3.43 mg/l

S.S. in Stream 8/Total Flow in Stream 8 = Wt. fraction

Wt. fraction = 21, 149.5/90, 227, 867.85 = 0.0002344
Concentration of S.S. in Stream 8 = 234.4 mg/l

Stream 11 + Stream 14 + Stream 5 = Stream 1
Total Flow in Stream 11 + 44, 414 + 36, 029 = 90, 072, 000
Total Flow in Stream 11 = 89, 991, 557 lb/d
S.S. in Stream 11 = S.S. in Stream 8 - S.S. in Stream 9
S.S. in Stream 11 = 21, 149.5 - 19,799.6 = 1349.9 lb/d

S.S. in Stream 11/ Total Flow Stream 11= Wt. fraction
1349.9/89, 991, 557 = 0.000015
Concentration of S.S. in Stream 11 = 15 mg/l

Water in Stream = 89, 991, 557 - 1349.9 = 89, 990, 207.1 lb/d
# Mass Balance Calculation Summary

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IV. Sizing of the Equipment

a. Primary Sedimentation Tank

Surface Area = Total flow rate / Surface overflow rate = 10,800,000 / 600 = 18,000 ft$^2$

Use four tanks, each with a surface area of 4,500 ft$^2$
Use length 100 ft, with 45 ft, and depth 8 ft

b. Aeration Tanks

Use Volumetric loading = 0.03 lb BOD$^5$/ ft$^3$ -d

BOD = 16,665.5 lb/d

Volume = BOD load / volumetric loading = 16,665.5 / 0.03 = 555,520 ft$^3$

Use 4 tanks, each has a volume of 138,880 ft$^3$
Use length 120 ft, width 60 ft, and depth 20 ft

c. Secondary Sedimentation Tank

Surface Area = Total flow rate / Surface overflow rate = 10,800,000 / 800 = 13,500 ft$^2$

Use three tanks, each with a surface area of 4,500 ft$^2$
Use length 100 ft, with 45 ft, and depth 8 ft

d. Primary Vacuum Filter

Solids = 9007.2 lb/d
Solids loading = 4 lb/ ft$^2$ -d
Area of filter required = Solids / Solids loading = 9007.2 / (24 x 4) = 93.8 ft$^2$

The Filter available:
Diameter = 16.4 ft
Length = 20 ft
Filter area supplied = \( \pi dl = \pi (16.4)(20) = 1030.4 \) ft$^2$

Use one unit.

d. e. Activated Sludge (Secondary) Vacuum Filter

Solids = 19,809 lb/d
Solids loading = 1 lb/ft²-d
Area of filter required = Solids/Solids loading = 19,809/(24*1) = 825 ft²

The Filter available:
Diameter = 16.4 ft
Length = 20 ft
Filter area supplied = πdl = π(16.4)(20) = 1030.4 ft²

Use one unit.

Reference:

Course Material

Siting of a Hazardous Manufacturing Facility in a Residential Area
The Manufacture of Aspirin

The Kolbe-Schmitt Synthesis
Manufacture of Aspirin
Step I - Salicylic Acid

Phenol → Caustic Soda → Mixer

Carbon → Dioxine → Autoclave

Water → Activated Carbon → Dissolver

Sulfuric Acid → Filter → Carbon

Dryer → Packing → Technical Grade Salicylic Acid

Centrifuge → Water + Na₂SO₄
Manufacture of Aspirin  
Step I  Salicylic Acid

**Process Input**

- Phenol
- Caustic Soda
- Carbon Dioxide
- Water
- Activated Carbon
- Sulfuric Acid

**Process Output**

- Sulfuric Acid
- Sodium Sulfate
- Water
- Activated Carbon
Process Description

Schmitt Modification of the Kolbe Reaction
Austin, George T., Schreve's Chemical Process industries, 5th Ed, p 809-805
McGraw-Hill Book Co 1984

1. Mixer Phenol is mixed with Caustic Soda
   (sodium hydroxide)

Reaction:

\[
2 \text{C}_6\text{H}_5\text{OH} + 2\text{NaOH} \rightarrow 2 \text{C}_6\text{H}_5\text{ONa} + 2\text{H}_2\text{O}
\]

Phenol     Caustic Soda     Sodium Phenolate

2. Autoclave The sodium phenolate is dried in an autoclave to finely divided powder. The autoclave is a revolving, heated ball mill. It operates under vacumm and 130 deg C. The sodium phenolate is complete, carbon dioxide gas is introduced under pressure (700 kPa) and temperature (100 deg C). Sodium phenol carbonate is formed and this isomerizes to sodium salicylate. Phenol is regenerated and recovered.
Reaction:

\[ 2 \text{C}_6\text{H}_5\text{ONa} + \text{CO}_2 \rightarrow \text{ONaC}_6\text{H}_4\text{COONa} + \text{C}_6\text{H}_5\text{OH} \]

sodium phenolate \hspace{2cm} \text{carbon dioxide} \hspace{2cm} \text{sodium salicylate} \hspace{2cm} \text{phenol}

3. Dissolver

Water dissolves the sodium salicylate and activated carbon is added to remove color by adsorption. The solid activated carbon is removed in a filter.

4. Precipitator

The sodium salicylate solution is mixed with sulfuric acid which precipitates the salicylic acid.

Reaction:

\[ \text{ONaC}_6\text{H}_4\text{COONa} + \text{H}_2\text{SO}_4 \rightarrow \text{OHC}_6\text{H}_4\text{COOH} + \text{Na}_2\text{SO}_4 \]

sodium salicylate \hspace{2cm} \text{sulfuric acid} \hspace{2cm} \text{salicylic acid} \hspace{2cm} \text{sodium sulfate}
5. Centrifuge

The precipitated salicylic acid is removed from the sodium sulfate solution in and sent to a drier.

6. Drier

the salicylic acid is purified by sublimation sent to packing and sold.

Overall Reactions

1. \[2 \text{C}_6\text{H}_5\text{OH} + 2\text{NaOH} \rightarrow 2 \text{C}_6\text{H}_5\text{ONa} + 2\text{H}_2\text{O}\]

2. \[2 \text{C}_6\text{H}_5\text{ONa} + \text{CO}_2 \rightarrow \text{ONaC}_6\text{H}_4\text{COONa} + \text{C}_6\text{H}_5\text{OH}\]

3. \[\text{ONaC}_6\text{H}_4\text{COONa} + \text{H}_2\text{SO}_4 \rightarrow \text{OHC}_6\text{H}_4\text{COOH} + \text{Na}_2\text{SO}_4\]

Overall

\[\text{CO}_2 + \text{C}_6\text{H}_5\text{OH} + 2\text{NaOH} + \text{H}_2\text{SO}_4 \rightarrow \text{OHC}_6\text{H}_4\text{COOH} + \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}\]
Manufacture of Aspirin
Step II - Acetyl Salicylic Acid

- acetic anhydride
- toluene
- salicylic acid

Reactor

88 - 92 deg C
20 hours

Cooling tanks

Filter to recovery

Acetylsalicylic acid

Washer

Water

Packaging

Drier
Manufacture of Aspirin

Step II  Acetyl Salicylic Acid

**Process Input**

- Acetic Anhydride
- Toulene
- Salicylic Acid
- Water

**Process Output**

- Acetylic Acid
- Water

**Process**

Step II
Process Description

1. Reactor Salicylic acid is mixed with toluene and acetic anhydride and reflux at 88 -92 deg C for 20 hours.

Reaction:

\[
\text{OHC}_6\text{H}_4\text{COOH} + (\text{CH}_3\text{CO})_2\text{O} \rightarrow \text{Toluene} \quad 88\text{-}92\text{ deg C}
\]

\[
\text{CH}_3\text{COOC}_6\text{H}_4\text{COOH} + \text{CH}_3\text{COOH}
\]

salicylic acid  acetic anhydride
acetyl salicylic acid  acetic acid
Structural Reaction

(1) \[ 2 \text{OH} + 2 \text{NaOH} \rightarrow 2 \text{ONa} + 2 \text{H}_2\text{O} \]

(2) \[ 2 \text{ONa} + \text{CO}_2 \rightarrow \text{ONaCO}_2\text{Na} + \text{OH} \]

(3) \[ \text{ONaCO}_2\text{Na} + \text{H}_2\text{SO}_4 \rightarrow 2 \text{OH} \text{CO}_2\text{H} + \text{Na}_2\text{SO}_4 \]

(4) \[ \text{OHCO}_2\text{H} + \text{CH}_3\text{C}^\equiv\text{O} \rightarrow \text{O}_2\text{CCH}_3 \text{CO}_2\text{H} + \text{CH}_3\text{COOH} \]
References

1. Kirk and Othmer, "Encyclopedia of Chemical Technology"


Problem

1. Develop Material Safety Sheets for all Chemical reactants and products in the manufacture of Aspirin

2. Determine the Size of the Production Facility
   a. Determine growth of U. S population
   b. Determine growth of U. S Aspirin Production
   c. Estimate aspirin needed in year 2007 AD
   d. Estimate what share of this market you will capture
   e. Determine the production capacity of your facility
3. Determine the quantities of all raw materials needed and all by-products formed. Assume 100 percent conversion in each step and a process yield of 95 percent in each step.

4. Specify the waste streams, the quantities, and suggest a method of disposal.

5. What pollution prevention improvements can you make to process a reduce the waste streams.
Report Outline

1. Background - History

2. Hazardous Materials and Health

3. Siting
   a. Environmental Restrictions
   b. Political Constraints
   c. Overall Site evaluation-and Recommendation

4. Process
   a. Chemistry of Aspirin
      Manufacture - Kolbe - Schmitt Synthesis
   b. Process Flow Sheet
   c. Block Diagram and Material Balance
   d. Growth Curve For U. S Population
e. Growth Curve For U. S Aspirin Production

f. Estimate Aspirin Needs in year 2007 AD

g. Estimate and Recommend Production Rate for Plant

h. Specify waste streams and recommended disposal method

I. Discuss possible pollution prevention and pollution abatement methods

5. Conclusion

6. Recommendation

7. References

8. Appendix a Material Safety Sheets
References


4. Chemical Engineering 55 March 1948 p 136 - 139 Flowsheet

5. Chemical Engineering 60 June 1953 p 116- 120

7. Kirk and Othmer, "Encyclopedia of Chemical Technology"
Course Material

Siting of a Roadway to Minimize Air Pollution
AIR POLLUTION
BACKGROUND
I. HISTORY of the PROBLEM

1. Before the Industrial Revolution

   .61 AD      Roman Philosopher complains about stink and smoke in Rome

   .1157 AD     Eleanor of Aquitaine
               Wife of Henry B of England complains burning wood in Tutbury Castle "Unendurable" moves out

   .1273 AD     Wood burning prohibited in London

   .1306 AD     Edward I issues royal proclamation and enjoins the use of "sea coal" in furnaces

   .1661 AD     Pollution in London bad
               John Evelyn submits brochure on air and smoke to Charles II and Parliament

2. The Industrial Revolution

   .1700's    Steam Engine by coal and wood burning

   .1848      Great Britain- Public Health Act

   1866

   1875

   .1880's    U.S. Legislation against black smoke and ash

   .Feb 1880   1000 excess deaths in London
2. Twentieth Century

1900 - 1925  Steam Locomotives in cities
           Electric power generating stations

1925 - 1950
Disasters ( 1950 - 1970 )

Dec 1 1930  Belgium Meuse Valley 65
deaths ( excess )
factories steel mills
chemical plants

Oct 26 1948  Five days of atmospheric .fog and inversion
Oct 31 1948 20 deaths

Nov 1950  Poca Rica Mexico
Release of H2S for 25 minutes
22 deaths

London England  Dec 1952  5 days- 4000 deaths
  Atmospheric conditions and inversion
  high pressure, poor dispersion high
  concentration Jan 1956 1000 deaths
Dec 1957 700 - 800 deaths
Dec 1962 700 deaths
New York  Nov 1953

1962 - 1963
200 - 400 deaths,
1966 Highest SO2 in nation
   Adverse weather
   Hundreds of excess deaths
Dec 1962 inversion
   296 Death in excess
   of 3 standard deviation
   of expected mortality rates

Pasadena CA  1949 First National Air Pollution
   Symposium in the United States
II. AUTOMOBILES - Motor Vehicles

Developed 1892 Charles Duryea
Made Available to masses by mass production
Henry Ford
Depression
Post war - suburban sprawl
    Baby boom

Los Angeles-1960's

Los Angeles - Mediterranean climate
    Sunlight + exhaust
    gases = smog

Cyclone - Counterclockwise

Anticyclone - clockwise
    100 - 1000 km
Subtropical anticyclones - high pressure
    over oceans

Los Angeles, West Coast
    Pacific Ocean anticyclones, Subtropical, Inversion - hot air above
    cool air from ocean below
    Mountains on three sides
    Prevailing winds from West
    Air pollutants dropped
Sources of Pollution - Gasoline Engines

- Exhaust - Difficult
- Fuel Tank and Carburetor - Controlled - 1971
- Crankcase - Controlled - 1963
- The Atoms - C, H, N, O, S

- Exhaust - CO
  - Hydrocarbons
  - NO\textsubscript{x}
  - CO\textsubscript{2}
  - SO\textsubscript{x}

- Diesel Engine
  1. Odor - unburned hydrocarbons
  2. Smoke - unburned carbon
  - (least but most noticeable)
  3. CO
  4. Hydrocarbons
  5. NO\textsubscript{x}
  6. Particulates
  7. SO\textsubscript{x}

Table 8.3 Comparison of Gaseous Emission Levels for Automobile and Diesel Engines

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Automobile</th>
<th>Diesel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrocarbons, ppm</td>
<td>900</td>
<td>150 - 500</td>
</tr>
<tr>
<td>Carbon Monoxide, vol. %</td>
<td>3.5</td>
<td>0.2</td>
</tr>
<tr>
<td>Nitrogen oxides, ppm</td>
<td>1500</td>
<td>2000 - 3000</td>
</tr>
</tbody>
</table>

Source: U.S. Dept. Of Commerce, Ref. 2
Fig. 6.9 Approximate distribution of automobile emissions by source. (AP-68, 1970.)

Fig. 23-11. Emissions from controlled and uncontrolled automobiles; gm/mile. (Controlled automobile at 1976 E.P.A. standards.)
III. MAJOR LEGISLATION

1. Air Pollution Control Act 1955
   Public Law 84 - 159

2. Public Law 86 - 493  1960

3. Public Law 87 - 761  1962

4. Clean Air Act 1963
   Public Law 88 - 206

5. Motor Vehicle Air Pollution Control Act
   Public Law 89 - 272  1965

6. Air Quality Act  1967
   Public Law 90 - 148  1967

7. Clean Air Act Amendments
   Public Law 91 - 604  1970

8. Clean Act Amendments Act
   Public Law 95 - 95  1977
IV. CHEMISTRY

Theory

\[ \text{C}_8\text{H}_{18} + 12.5\text{O}_2 + 47\text{N}_2 \rightarrow 8\text{CO}_2 + 9\text{H}_2\text{O} + 47\text{N}_2 \]
Iso-octane

Actual

\[ \text{HC} + \text{O}_2 + \text{N}_2 \rightarrow \text{CO}_2 + \text{CO} + \text{NO}_x + \text{HC} \]
HC = Hydrocarbons

1. CO

\[ \text{C}_8\text{H}_{18} + \text{O}_2 \rightarrow \text{CO} + \text{CO}_2 + \text{H}_2\text{O} \]
1500 F

CO forms from incomplete combustion

\[ \text{CO} + \text{O}_2 \rightarrow \text{CO}_2 \]
Catalytic Convertor (Platinum / Palladium)

Catalyst converts HC and CO to CO\(_2\) and H\(_2\)O

1300 F at exhaust better combustion of hydrocarbons
2. NO\textsubscript{x}

\[ 0.5\text{N}_2 + 0.5\text{O}_2 \leftrightarrow \text{NO} \]
\[ \text{O} + \text{N}_2 \leftrightarrow \text{NO} + \text{N} \]
\[ \text{N} + \text{O}_2 \leftrightarrow \text{NO} + \text{O} \]
\[ \text{N}_2 + \text{O}_2 \rightarrow 2\text{NO} \]
\[ \text{NO} + 0.5\text{O}_2 \rightarrow \text{NO}_2 \]
\[ 2\text{NO} + \text{O}_2 \rightarrow 2\text{NO}_2 \]

3. SO\textsubscript{x}

\[ \text{S} + \text{O}_2 \rightarrow \text{SO}_2 \]
\[ \text{SO}_2 + 0.5\text{O}_2 \rightarrow \text{SO}_3 \]
\[ \text{SO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4 \text{ (Acid Rain)} \]
V. PHOTOCHEMICAL SMOG

Smog   Smoke   Fog

- High Level of Oxidants
  - Irritate eyes and throat
  - Damage plants
  - Rubber Cracks
    Tires - Ozone

\[ A + h\nu \rightarrow A^* \]
\[ A^* \rightarrow B + C \]

\( h = \) Plank's Constant
\( \nu = \) Frequency

Species A + Photon \( \rightarrow \) Active Complex A*
Very Reactive

\[ A^* \rightarrow B + C \]

Active complex Could be highly reactive
Chain reaction
Photochemical Smog

Ultraviolet
**Ozone Formation**

\[ \text{O}_2 + h\nu \rightarrow 2\text{O} \]

Above 50 mi

Sunlight

Ultraviolet Rays

Lower Levels

\[ \text{M} + \text{O} + \text{O}_2 \rightarrow \text{O}_3 + \text{M} \text{ ozone} \]

\[ \text{O}_3 + h\nu \rightarrow \text{O}_2 + \text{O} \]

\[ \text{M} \text{ is energy} \]

Absorbing molecule \( \text{N}_2 \text{ or } \text{O}_2 \)

Ozone layer above earth 10 - 20 miles

**Nitrogen NO\textsubscript{x}**

\[ 2\text{NO} + \text{O}_2 \rightarrow 2\text{NO}_2 \]

\[ \text{NO}_2 + h\nu \rightarrow \text{NO} + \text{O} \]

\[ \text{O} + \text{O}_2 + \text{M} \rightarrow \text{O}_3 + \text{M} \]

\[ \text{O}_3 + \text{NO} \rightarrow \text{NO}_2 + \text{O}_2 \]
Others

\[
\begin{align*}
O + \text{NO}_2 & \rightarrow \text{NO} + \text{O}_2 \\
O + \text{NO}_2 + \text{M} & \rightarrow \text{NO}_3 + \text{M} \\
O + \text{NO} + \text{M} & \rightarrow \text{NO}_2 + \text{M} \\
\text{NO}_3 + \text{NO}_2 & \rightarrow 2\text{NO}_2 \\
\text{NO}_2 + \text{O}_3 & \rightarrow \text{NO}_3 + \text{O}_2 \\
\text{NO}_3 + \text{NO}_2 + \text{M} & \rightarrow \text{N}_2\text{O}_5 + \text{M}
\end{align*}
\]

Water in atmosphere - rain or vapor

\[
\begin{align*}
\text{O}_2 + 4\text{NO}_2 + 2\text{H}_2\text{O} & \rightarrow 4\text{HNO}_3 \text{ (Acid Rain)} \\
3\text{NO}_2 + \text{H}_2\text{O} & \rightarrow 2\text{HNO}_3 \text{ (Acid rain)} + \text{O}_2
\end{align*}
\]

Hydrocarbons - Very complex

\[
\begin{align*}
\text{O} + \text{Olefin} & \rightarrow \text{R} \cdot + \text{RO} \cdot \\
\text{O} + \text{CH}_2=\text{CH}_2 & \rightarrow \text{CH}_2 \cdot + \text{CH}_2\text{O} \cdot \\
\text{O}_3 + \text{RCH}=\text{CHR} & \rightarrow \text{RCHO} + \text{RO} \cdot + \text{HCO} \\
& \quad \text{Aldehyde} \\
& \quad \text{Pollutant}
\end{align*}
\]

\[
\begin{align*}
\text{R} \cdot + \text{O}_2 & \rightarrow \text{ROO} \cdot \\
\text{ROO} \cdot + \text{NO} & \rightarrow \text{NO}_2 + \text{RO} \cdot \\
\text{ROO} \cdot + \text{O}_2 & \rightarrow \text{RO} \cdot + \text{O}_3
\end{align*}
\]
Numerous other organics
Ketones
Aldehydes
Alcohols

\[ \text{R} + \text{NO}_2 \rightarrow \text{CH}_2\text{COOONO}_2 \text{ (PAN)} \]

\[ \text{PAN} = \text{Peroxy Acetyl Nitratoe} \]

Eye irritant

\[ \text{O} \]
\[ \uparrow \]
\[ \text{CH}_3 - \text{C} - \text{O} - \text{O} - \text{NO}_2 \]

\[ \text{CH}_3\text{O} + \text{NO}_2 \rightarrow \text{CH}_3\text{ONO}_2 \text{ (PAN)} \]
\[ \text{CH}_3\text{COO}_2 + \text{NO}_2 \rightarrow \text{CH}_3\text{COOONO}_2 \text{ (PAN)} \]

\[ \text{PBN} = \text{Peroxy Benzoyl Nitratoe} \]

\[ \text{O} \]
\[ \uparrow \]
\[ \text{C}_6\text{H}_5 - \text{C} - \text{O} - \text{O} - \text{NO}_2 \]

Eye irritant

100x greater than PAN
VI. DISPERSION

Fig. 8.2 Coordinate system showing gaussian distributions in the horizontal and vertical.

Fig. 30-8. Schematic diagram of the Gaussian plume from a continuous elevated point source. The origin of coordinates is at the base of the stack. Crosswind diffusion exceeds vertical at downwind distance \( x_1 \). At distance \( x_2 \), vertical exceeds crosswind in the case depicted.
Factors

1. Wind
   Horizontal speed
   . Since source is constant doubling wind speed reduces concentration by half

2. Turbulence
   . Thermal
     Clear - sunny days - light winds
   . Mechanical
     Movement of air past obstruction
     Dominant on windy nights
     Neutral atmospheric stability
3. Lapse rates and Atmospheric Stability

Lapse Rate - Temperature Decrease with height
- 0.65 °C / 100m
- 6.5 °C / km

Inversion causes pollutants to not disperse effectively
- Poor dispersion with inversion
4. Topography

**Figure 3.9** Flow of slope and valley winds at night.

**Figure 3.10** Nocturnal inversion conditions in a river valley.
VII. HEALTH

• Asthma - Nashville 1961 - SO2
  New Orleans 1962 -

• Bronchitis - Emphysema
  Chronic cough

• Lung Cancer - HC
  Exhausts
  Cigarette smoke
  Industrial Combustion

• Central Nervous System

• Heart Attacks

• Pulmonary Changes

  CO + Hemoglobin → Carboxy Hemoglobin
  CO ties up site were O₂ would use
  O₂ is depleted
  CO is 200 times more active with hemoglobin
  2 - 5% - central nervous system usual activity
  Impairment of time interval discrimination
  >5% cardiac and pulmonary affects
  Los Angeles CO 10 - 15 ppm (24 hr. avg.)
REFERENCES


10. Would you rather have the course organized such that the first seven weeks are devoted to the siting problem only and the second seven weeks for the process design part only?  Yes _____  No _____

Comments:

11. On the following scale, please rank this course
   0 — failure
   1 — marginal
   2 — average
   3 — above average
   4 — excellent

12. Are there any recommendations you would like to make to improve this course?

III. Evaluation of Faculty and Staff

1. As a student, how would you rate your instructor in terms of their ability to relate their disciplines?

   Dr. D. Hanesian:  a) excellent  b) very good  c) average  d) fair  e) poor

   Dr. A. Perna:  a) excellent  b) very good  c) average  d) fair  e) poor

2. If you were given a choice, which of your instructors would you like to have again in the future?

   Dr. D. Hanesian  Yes _____  No _____
   Dr. A. Perna  Yes _____  No _____
   Both  _____
3. Do you feel that the services provided by the faculty were adequate for your individual needs?
   Dr. D. Hanesian  Yes _____ No_____
   Comments: ____________________________

   Dr. A. Perna  Yes _____ No_____
   Comments: ____________________________

4. On the following scale, rank your instructors
   0 – failure
   1 – marginal
   2 – average
   3 – above average
   4 – excellent

   Overall rank for instructors
   Dr. D. Hanesian _____ Dr. A. Perna _____

5. Are there any recommendations you would like to make in regards to improving faculty rapport with students?  Yes _____ No _____
   Explain: __________________________________________

IV. General

1. Generally speaking, did you find your experience enjoyable?
   Please comment: ________________________________________

2. Would you recommend the program to others?  Yes _____ No _____
   Explain: ____________________________________________
3. Have you made any decisions regarding a career goal?  Yes ______  No ______
   If Yes, please explain.

4. Did this course result in a better understanding of the engineering profession and
   engineering design?  Yes ______  No ______
   Comments:

5. Have your experiences affected your ideas in any way about a possible career in
   science or engineering?  Yes ______  No ______
   Explain

6. Do you feel that assembling and writing a technical report was a useful and
   developing exercise?  Yes ______  No ______
   Comments:

7. Do you feel that preparing and presenting your oral report was a useful and
   developing exercise?  Yes ______  No ______
   Comments:

8. Do you feel that the class discussions on subjects related to the profession but not
   related to this specific problem were useful for your development and understanding
   of engineering?  Yes ______  No ______
   Comments:

Please use this space for additional comments you may have concerning the program.
For additional space, please use the back of the page.
PERTINENT PUBLICATIONS


