ENVIRONMENTAL ENGINEERING

Director of undergraduate studies: John Fortner (john.fortner@yale.edu), 521 17 Hillhouse Ave.; seas.yale.edu/departments/chemical-and-environmental-engineering

Environmental engineering encompasses the scientific assessment and development of engineering solutions to environmental problems affecting land, water, and air (the biosphere). The field embraces broad environmental concerns, including the safety of drinking water, groundwater protection and remediation, wastewater treatment, indoor and outdoor air pollution, solid and hazardous waste disposal, cleanup of contaminated sites, the prevention of pollution through product and process design, and strategies for sustainable water and energy use and production.

Environmental engineers must balance competing technical, social, and legal issues concerning the use of environmental resources. Because of the complexity of these challenges, environmental engineers need a broad understanding not only of engineering disciplines but also of chemistry, biology, geology, and economics. Accordingly, the program allows students in the major to select an emphasis on environmental engineering technology, sustainability, global health, economics, or energy and climate change. The program prepares students for leadership positions in industry and government agencies or for further studies in engineering, science, business, law, and medicine.

Two degree programs are offered: the B.S. in Environmental Engineering, and the B.A. in Engineering Sciences (Environmental). The B.S. degree program in Environmental Engineering is designed for students who desire a strong background in environmental engineering leading to a career in the field. The B.A. degree program in Engineering Sciences (Environmental) is intended for students whose careers will involve, but not be dominated by, the skills of environmental engineering. The B.A. program is appropriate for those contemplating a career in which scientific and technological problems can play an important role, as is often the case in law, business, medicine, or public service.

PREREQUISITES

B.A. degree program in Engineering Sciences (Environmental)  The B.A. degree program requires MATH 112 and 115; a two-term lecture sequence in chemistry; and PHYS 170, 171.

B.S. degree program in Environmental Engineering  The B.S. degree program has the following prerequisites in mathematics and basic sciences: MATH 112, 115; MATH 120 or ENAS 151; ENAS 194; a two-term lecture sequence in chemistry, with corresponding labs; PHYS 180, 181; and BIOL 101 and 102 or BIOL 103 and 104.

REQUIREMENTS OF THE MAJOR

B.A. degree program  The B.A. degree program requires nine term courses beyond the prerequisites, including the senior requirement. Students take ENVE 120, 360, and either ENVE 373 or 377. Five electives must be chosen in consultation with the director of undergraduate studies (DUS).

B.S. degree program  The B.S. degree program requires at least twelve term courses beyond the prerequisites, including the senior requirement. Students take CENG 300 or MENG 211, ENVE 120, 360, 373, 377, 315 or 448, EVST 444 or ENVE 438, and MENG 361 or F&ES 714. At least three technical electives must be chosen in consultation with the DUS.

Credit/D/Fail  No course taken Credit/D/Fail may count toward the major, including prerequisites.

SENIOR REQUIREMENT

B.A. degree program  Students in the B.A. program must pass ENVE 416 or ENVE 490 in their senior year.

B.S. degree program  Students in the B.S. program must pass ENVE 416 or ENVE 490 in their senior year.

REQUIREMENTS OF THE MAJOR

ENGINEERING SCIENCES (ENVIRONMENTAL), B.A.

Prerequisites  MATH 112, 115; two-term lecture sequence in chemistry; PHYS 170, 171

Number of courses  9 term courses beyond prereqs (incl senior req)

Specific courses required  ENVE 120, 360; ENVE 373 or 377

Distribution of courses  5 electives approved by DUS

Senior requirement  ENVE 416 or ENVE 490

ENVIRONMENTAL ENGINEERING, B.S.

Prerequisites  MATH 112, 115; MATH 120 or ENAS 151; ENAS 194; two-term lecture sequence in chemistry, with labs; PHYS 180, 181; BIOL 101 and 102 or BIOL 103 and 104

Number of courses  12 term courses beyond prereqs (incl senior req)

Specific courses required  CENG 300 or MENG 211; ENVE 120, 360, 373, 377; ENVE 315 or 448; EVST 444 or ENVE 438, and MENG 361 or F&ES 714

Distribution of courses  3 technical electives approved by DUS
Senior requirement ENVE 416 or ENVE 490

Environmental engineers are involved with many aspects of society's interaction with the environment. The field embraces broad environmental concerns, including the safety of drinking water, groundwater protection and remediation, wastewater treatment, indoor and outdoor air pollution, solid and hazardous waste disposal, cleanup of contaminated sites, preservation of sensitive wetlands, energy and the environment, and prevention of pollution through product and process design. Environmental engineers must balance technical, social, economic, and legal issues concerning the use of environmental resources. Consequently, they need a broad understanding not only of engineering disciplines but also of chemistry, biology, geology, economics, and management.

Students majoring in Environmental Engineering select an emphasis on environmental engineering technology, sustainability, global health, energy and climate change, or economics. The major prepares students for leadership positions in industry and government agencies. Graduates may also continue with further studies in engineering, science, business, law, and medicine.

Students interested in the major should take the following course during the first year:

- ENVE 120, Introduction to Environmental Engineering

One of the following math courses:

- MATH 112, Calculus of Functions of One Variable I
- MATH 115, Calculus of Functions of One Variable II
- MATH 120, Calculus of Functions of Several Variables

One of the following chemistry sequences:

- CHEM 161, General Chemistry I and CHEM 165, General Chemistry II
- CHEM 163, Comprehensive University Chemistry I and CHEM 167, Comprehensive University Chemistry II

Information can be found on the Chemical and Environmental Engineering website. The director of undergraduate studies (DUS) welcomes consultation with students about the program at any time.

FACULTY ASSOCIATED WITH THE PROGRAM IN ENVIRONMENTAL ENGINEERING

Professors Paul Anastas (Forestry & Environmental Studies), Michelle Bell (Forestry & Environmental Studies), Ruth Blake (Geology & Geophysics), Menachem Elimelech (Chemical & Environmental Engineering), Edgar Hertwich (Forestry & Environmental Studies), Edward Kaplan (School of Management), Jaehong Kim (Chemical & Environmental Engineering), Jordan Peccia (Chemical & Environmental Engineering), Lisa Pfefferle (Chemical & Environmental Engineering), Julie Zimmerman (Chemical & Environmental Engineering)

Associate Professors John Fortner (Chemical & Environmental Engineering), Drew Gentner (Chemical & Environmental Engineering)

Courses

* ENVE 120b / CENG 120b / ENAS 120b, Introduction to Environmental Engineering  John Fortner

Introduction to engineering principles related to the environment, with emphasis on causes of problems and technologies for abatement. Topics include air and water pollution, global climate change, hazardous chemical and emerging environmental technologies.

Prerequisites: high school calculus and chemistry or CHEM 161, 165 or CHEM 163, 167 (may be taken concurrently) or permission of instructor. QR, SC

ENVE 314a / CENG 314a, Transport Phenomena I  Kyle Vanderlick

First of a two-semester sequence. Unified treatment of momentum, energy, and chemical species transport including conservation laws, flux relations, and boundary conditions. Topics include convective and diffusive transport, transport with homogeneous and heterogeneous chemical reactions and/or phase change, and interfacial transport phenomena. Emphasis on problem analysis and mathematical modeling, including problem formulation, scaling arguments, analytical methods, approximation techniques, and numerical solutions. Prerequisite: ENAS 194 or permission of the instructor. QR, SC RP

ENVE 315b / CENG 315b, Transport Phenomena II  Amir Haji-Akbari

Unified treatment of momentum, energy, and chemical species transport including conservation laws, flux relations, and boundary conditions. Topics include convective and diffusive transport, transport with homogeneous and heterogeneous chemical reactions and/or phase change, and interfacial transport phenomena. Emphasis on problem analysis and mathematical modeling, including problem formulation, scaling arguments, analytical methods, approximation techniques, and numerical solutions. Prerequisite: ENAS 194 or permission of instructor. QR, SC

ENVE 360b / ENAS 360b, Green Engineering and Sustainable Design  Julie Zimmerman

Study of green engineering, focusing on key approaches to advancing sustainability through engineering design. Topics include current design, manufacturing, and disposal processes; toxicity and benign alternatives; policy implications; pollution prevention and source reduction; separations and disassembly; material and energy efficiencies and flows; systems analysis; biomimicry; and life cycle design, management, and analysis. Prerequisites: CHEM 161, 165 or 163, 167 (or CHEM 112, 113, or 114, 115), or permission of instructor.
ENVE 373a / CENG 373a, Air Pollution Control  Drew Gentner
An overview of air quality problems worldwide with a focus on emissions, chemistry, transport, and other processes that govern
dynamic behavior in the atmosphere. Quantitative assessment of the determining factors of air pollution (e.g., transportation and other
combustion–related sources, chemical transformations), climate change, photochemical "smog," pollutant measurement techniques, and
air quality management strategies. Prerequisite: ENVE 120. QR, SC RP

* ENVE 377a / CENG 377a, Water Quality Control  Jaehong Kim
Study of the preparation of water for domestic and other uses and treatment of wastewater for recycling or discharge to the environment.
Topics include processes for removal of organics and inorganics, regulation of dissolved oxygen, and techniques such as ion exchange,
electrodialysis, reverse osmosis, activated carbon adsorption, and biological methods. Prerequisite: ENVE 120 or permission of instructor. SC RP

ENVE 416b / CENG 416b, Chemical Engineering Process Design  Yehia Khalil
Study of the techniques for and the design of chemical processes and plants, applying the principles of chemical engineering and
economics. Emphasis on flowsheet development and equipment selection, cost estimation and economic analysis, design strategy and
optimization, safety and hazards analysis, and environmental and ethical considerations. Enrollment limited to seniors majoring in
Chemical Engineering or Environmental Engineering. QR, SC RP

* ENVE 420b, Rethinking Urban Sanitation: The United States and Peru  Staff
This interdisciplinary course examines the challenges posed by the growing volumes of human excreta that are generated daily in cities
around the world. Topics to be covered include: environmental, engineering, and public-health aspects of sanitation; the history of
sanitation; innovation in sanitation; sewage reuse; cultural and social considerations; and case studies of different centralized and
decentralized solutions. The course is organized around two alternative final projects: 1) a spring-break trip to Lima, Peru, where
students observe first-hand some of the components of this complex sanitation system, and meet with stakeholders ranging from
government officials to slum-dwellers to non-profits pursuing innovative sanitation solutions; and 2) a U.S.-based analysis of a
comparable sanitation system. Enrollment in the class is limited to 10 students each from the School of Forestry & Environmental
Studies, the School of Public Health, and the Department of Chemical and Environmental Engineering. Participation in the Peru field
trip/project is limited to five students from each school. Applications for enrollment and participation in the Peru field trip are due in
December 2019. Prerequisite: ENVE 120.

ENVE 438a, Environmental Organic Chemistry  John Fortner
This course examines major physical and chemical attributes and processes affecting the behavior of organic compounds in environmental
systems, including volatilization, sorption/attachment, diffusion, and reactivity. Emphasis is placed on legacy pollutants (e.g. TCE,
PCBs, DDT) and along with emerging contaminants of concern (e.g. pharmaceuticals, explosives, etc). The course reviews basic
concepts from physical chemistry and examines the relationships between chemical structure, properties, and environmental behavior of
organic compounds. Physical and chemical processes important to the fate, treatment, and transformation of specific organic compounds
are addressed including solubility, volatilization, partitioning, sorption/attachment, bioaccumulation, and bulk environmental
transformation pathways. Equilibrium and kinetic models based on these principles are used to predict the fate and transport of organic
contaminants in the environment. Priority given to seniors or permission of instructor. QR, SC

ENVE 444a, Biological Processes in Environmental Engineering  Jordan Peccia
Fundamental aspects of microbiology and biochemistry, including stoichiometry, kinetics, and energetics of biochemical reactions,
microbial growth, and microbial ecology, as they pertain to biological processes for the transformation of environmental contaminants;
principles for analysis and design of aerobic and anaerobic processes, including suspended- and attached-growth systems, for treatment
of conventional and hazardous pollutants in municipal and industrial wastewaters and in groundwater. Prerequisites: CHEM 161, 165, or
163, 167 (or CHEM 112, 113, or 114, 115, or 118); MCDB 290 or equivalent; or with permission of instructor. SC

ENVE 448a, Environmental Transport Processes  Menachem Elimelech
Analysis of transport phenomena governing the fate of chemical and biological contaminants in environmental systems. Emphasis
on quantifying contaminant transport rates and distributions in natural and engineered environments. Topics include distribution of
chemicals between phases; diffusive and convective transport; interfacial mass transfer; contaminant transport in groundwater, lakes,
and rivers; analysis of transport phenomena involving particulate and microbial contaminants. Prerequisite: ENVE 120 or permission of
instructor. QR, SC

ENVE 473b, Air Quality and Energy  Drew Gentner
The production and use of energy explored as a source of air pollution worldwide. Assessment of emissions and physical/chemical
processes; the effects of emissions from energy sources; the behavior of pollutants in energy systems and in the atmosphere. Topics
include traditional and emerging energy technology, climate change, atmospheric aerosols, tropospheric ozone, and transport/modeling/
mitigation. Prerequisite: ENVE 373 or equivalent. SC

* ENVE 490a or b, Senior Project  John Fortner
Individual research and design projects supervised by a faculty member in Environmental Engineering, or in a related field with
permission of the director of undergraduate studies.