ENVIRONMENTAL ENGINEERING

**Director of undergraduate studies:** Jordan Peccia, 523 17 Hillhouse, 432-4385, jordan.peccia@yale.edu; 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 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 373 or 377. Five electives must be chosen in consultation with the director of undergraduate studies.

**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, and either 315 or 448, EVST 344, and MENG 361 or F&ES 714. At least three electives must be chosen in consultation with the director of undergraduate studies, preferably within one of the following tracks: environmental engineering technology, sustainability, global health, economics, or energy and climate change.

**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 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 344; MENG 361 or F&ES 714

**Distribution of courses** 3 electives as specified
Senior requirement  ENVE 416 or ENVE 490

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)

Assistant Professors  Drew Gentner (Chemical & Environmental Engineering), Desiree Plata (Chemical & Environmental Engineering)

Courses

ENVE 101b / ENAS 101b / EVST 105b / MENG 101b, Energy, Engines, and Environment  Staff
Energy sustainability and global warming; thermodynamic fundamentals; engines (combustion technologies, fossil-fuel pollution, carbon capture and sequestration). Wind, solar, biomass, and other renewable energy sources. Designed for freshmen and sophomores in science and engineering and for non-science majors. Prerequisite: A score of 4 or 5 on Advanced Placement examinations in mathematics and/or science.  SC

* ENVE 120a / CENG 120a / ENAS 120a, Introduction to Environmental Engineering  Jordan Peccia
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 210a / CENG 210a, Principles of Chemical Engineering and Process Modeling  André Taylor
Analysis of the transport and reactions of chemical species as applied to problems in chemical, biochemical, and environmental systems. Emphasis on the interpretation of laboratory experiments, mathematical modeling, and dimensional analysis. Prerequisite: MATH 120 or permission of instructor.  QR, SC RP

ENVE 215a, Environmental Engineering Practice  Desiree Plata
Focus on the technical tools of environmental engineering and science, with emphasis on data acquisition and integration, experimental project design and problem solving, and science and engineering communication. Students emerge competent in the skills needed for environmental exploration and communication and armed with the tools of discovery. Prerequisite: ENVE 120.

ENVE 315b / CENG 315b, Transport Phenomena  Amir Haji Akbari Balou
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.  QB, SC RP

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 410b, Environmental Technology in the Developing World  Jaehong Kim
Focus on the practical application of environmental engineering fundamentals to solve real-world environmental and human health problems in underdeveloped regions of the world and provide students with international, hands-on learning experience. Utilization of problem-based learning practices to define and solve problems related to water and wastewater treatment, water and air quality monitoring and control, subsurface remediation, and hygienic infrastructure such as latrines. Students may design and build small-scale systems, install and operate the systems in the field site, monitor and analyze system performance, and/or perform engineering simulations.

ENVE 416b / CENG 416b, Chemical Engineering Process Design  Eric Altman
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 438b, Water Chemistry Desiree Plata
The quantitative treatment of chemical processes, primarily those involving inorganic chemicals, in aquatic systems such as lakes, oceans, rivers, estuaries, groundwaters, and wastewaters. Review of chemical thermodynamics, followed by discussions of acid-base, precipitation-dissolution, coordination, and reduction-oxidation reactions. Emphasis on equilibrium calculations as a tool for understanding variables that govern chemical composition of aquatic systems and the fate of inorganic pollutants. ENVE 120 and working knowledge of algebra. QR, SC

ENVE 442a, Modeling and Analysis of Carbon Footprints Edgar Hertwich
Carbon footprints of nations, products, households, and enterprises. Assessment of carbon footprints using input-output models and life cycle assessment. Analysis and interpretation of carbon footprint results. Students learn modeling with MatLab and common databases used in the field. Prerequisites: ENAS 151 or MATH 120; PHYS 170

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 Jordan Peccia
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.