GRADUATE PROGRAM AND DEGREE REQUIREMENTS

Environmental Engineering

Effective Fall 2009

Master of Engineering (M.Eng.)
Master of Science (M.S.)
Doctor of Philosophy (Ph.D.)

Department of Civil and Environmental Engineering
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THE PENNSYLVANIA STATE UNIVERSITY
Department of Civil and Environmental Engineering

Graduate Program in Environmental Engineering

Entrance Requirements

While it is strongly recommended that an applicant possess an undergraduate degree from an accredited engineering program (e.g., civil, chemical, environmental, or mechanical), non-traditional students who possess an undergraduate degree in a related scientific field (e.g., chemistry, microbiology, geology, or environmental sciences) may be considered for admission subject to the provisions outlined below. Since admission into our graduate program is highly competitive, not all qualified applicants can be admitted. To be considered for admission, applicants should have at least a 3.0 junior/senior grade-point average (GPA); a GPA of 3.5 or higher is preferred for applicants from non-engineering backgrounds.

Depending on an applicant's educational background, it may be necessary to make up undergraduate course deficiencies. Students with non-traditional (non-engineering) backgrounds can be admitted on a *provisional basis,* pending completion of all undergraduate courses deficiencies. All students must meet the minimum entrance requirements listed below in Table 1. These courses must be included in the student's plan of study, however, none will count for graduate credit. Students may take these classes on a pass/fail or audit basis. Students may petition to use other related courses to satisfy these requirements or substitute work experience (for example in wastewater and water treatment). Students are encouraged to meet with their adviser to discuss these requirements.

Table 1. Minimum Course Requirements for all Applicants.

Course Topic	Penn State Course
Advanced mathematics typical of engineering undergraduate programs (calculus through partial differential equations)	MATH 140 Calculus With Analytic Geometry MATH 141 Calculus With Analytic Geometry II MATH 251 Ordinary & Partial Differential Equations
One lecture course and one laboratory course in chemistry	CHEM 012 Chemical Principles CHEM 014 Experimental Chemistry
One year of physics	PHYS 211 General Physics: Mechanics PHYS 212 General Physics: Electricity & Magnetism
One course in fluid hydraulics or mechanics	C E 360 Fluid Mechanics
One introductory course in environmental engineering	CE 370 Introduction to Environmental Engineering, *or* CE 371 Water and Wastewater Treatment

Professional Registration

All Environmental Engineering students are encouraged to take the Fundamentals of Engineering (FE) examination in preparation for engineering-design oriented careers leading to licensing via the Professional Engineer (PE) examination. In order to take the FE examination, students must possess a baccalaureate degree from an accredited engineering program.

Non-traditional students (i.e., without an accredited engineering degree) who wish to pursue FE certification may wish to investigate the possibility of obtaining a baccalaureate degree in engineering

first. (Please note that Penn State currently enforces an enrollment control that prohibits individuals who have a baccalaureate degree in any discipline to pursue a second baccalaureate degree in engineering at Penn State.) Students without an accredited baccalaureate degree in engineering may petition to take the FE exam, based on additional class work and other professional experience. These petitions have recently been successful in DE and OH, but not in PA. Course work that may be required in order to be eligible to take the FE examination include the following: 32 credits of math and basic sciences, 32 credits of engineering sciences, 16 credits of engineering design, and 16 credits of humanities and social science courses.

Advanced Degree Programs

The program in Environmental Engineering offers three advanced degrees: Master of Engineering (M.Eng.), Master of Science (M.S.), and Doctor of Philosophy (Ph.D.). A description of the general structure of our degree programs, as well as components unique to Environmental Engineering, follows.

Master of Engineering (M.Eng.) Degree

The M.Eng. degree is intended to be a professional degree composed of a well-balanced, unified, and complete program of study leading to advanced professional practice. Students must complete 30 credits of graduate course work, present a writing portfolio as described below, and satisfy the other academic program requirements outlined in this document. While full-time students could complete the program in two semesters, part-time students take longer. Students enrolled in an M.Eng. program are not considered for department support for research or teaching assistantships.

Course Work: A minimum of 30 graduate credits (400 level and above) is required, of which 20 must be earned at Penn State. At least 15 credits must be earned in the 500 series. Students are not permitted to count audited credits toward the minimum credits required for the degree.

Writing Portfolio*:* The submission of a writing portfolio is required for the M.Eng. degree. The writing portfolio should be developed with the adviser and may consist of the following types of writing samples: a semester paper, a report that documents a semester design project, an applied research paper, or professional papers. The writing sample must demonstrate in-depth knowledge of an engineering topic presented in a format typical of professional practice. The faculty adviser, with department head over-sight, shall review the portfolio to determine if the candidate has satisfied the writing skills requirement.

Students who have activated their intent to graduate must submit the approved writing portfolio to the department's Academic Programs Office, 218 Sackett Bldg, by the published *Master's Paper Draft Review Deadline.* The Academic Programs Office will certify receipt of the writing portfolio to Graduate Enrollment Services.

Master of Science (M.S.) Degree

The M.S. degree program is strongly oriented toward research. Students must complete 30 graduate credits, prepare a thesis, and satisfy the other academic program requirements outlined in this document. Typically, an M.S. degree takes one and a half years in residence to complete, assuming a summer is spent on thesis-related research. Often times a student will defend late in a semester following the completion of research and the thesis. For example, a student entering in a fall semester might defend in December of the following year, or January of the spring semester. In both cases, these dates are beyond the University’s allowed completion date, so the student will officially be recognized at graduation ceremony in May. Students entering in the spring semester typically finish their studies during the summer of the following year and may attend graduation ceremonies in the summer or fall (December). Most employers will consider a student “graduated” when they have fulfilled all requirements (course and thesis) for the M.S. program, and thus the Universities official date of graduation generally does not affect employment status.

Course Work: A minimum of 30 graduate credits (400 level and above) is required, of which 20 must be earned at Penn State. At least 18 credits at the 500 and 600 level, combined, must be included in the program. A minimum of 12 credits of course work (400 and 500 level), as contrasted with research, must be completed in the *major* (courses prefixed CE). At least six credits must be devoted to the thesis (CE 600 or CE 610). Course work taken outside of the major area of emphasis can be used to satisfy the requirement of having 6 credits in a minor or general studies (i.e., outside of the major program of study). A formal minor program must meet the approval of the departments or committees responsible for both the major and minor fields.

M.S. Advisory Committee: The M.S. advisory committee shall consist of at least three members including the candidate's adviser and thesis supervisor, which are normally the same individual. One of the committee members may be from outside of the Department of Civil and Environmental Engineering. The student's adviser shall chair the advisory committee.

Thesis: The candidate's research topic must be approved by the advisory committee. The thesis is prepared under the supervision of the thesis adviser and advisory committee. An oral defense, which is open to the public, is required. The thesis must be submitted in accordance with the guidelines and deadlines established by the Graduate School. The Academic Programs Office must have a copy of the signature page submitted to the Thesis Office to keep in your file.

Doctor of Philosophy (Ph.D.) Degree

A student must first complete an M.S. degree before entering the Ph.D. program. A minimum of 21 credits of graduate course work (400 level and above) is required beyond the M.S. degree, or 15 credits beyond the M.S. in Environmental Engineering from Penn State. Students may petition to reduce the number of required credits based on professional experience or on unusual prior course work (such as two undergraduate degrees). Prior to completion of the Ph.D. program, the candidate must spend at least two consecutive semesters as a registered full-time student. While completion of the Ph.D. program ordinarily takes four years past the M.S. degree, the duration of the program varies from three to five years depending on the student's background and professional interests. Ph.D. candidates must successfully satisfy the following requirements indicated below.

Candidacy and English Examinations: Official status as a doctoral student is granted when the candidacy examination has been passed. The examinations are administered by the department and must be scheduled during the second semester after entering the program. Ph.D. candidates are required to demonstrate high-level competence in the core requirement topics. Ph.D. candidates are also required to demonstrate competence in the use of the English language, including reading, writing, listening, and speaking, to satisfy the language and communications skills requirements established by the department. Deficiencies are identified at the time of the candidacy examination, and students are directed into remedial work as appropriate.

Comprehensive Examinations: The Comprehensive Examinations (written and oral) should be scheduled during the first semester following completion of course work, excluding research credits. These examinations are administered by the (entire) doctoral committee and serve as an oral and written defense of the proposed dissertation research.

Final Oral Examination (Dissertation Defense): The final oral examination is normally not held until at least three months have elapsed after the Comprehensive Examination was passed. This oral examination is based mainly on the dissertation. A favorable vote of at least two-thirds of the doctoral committee is required for passing.

PLEASE NOTE: All exams must be scheduled in the department's Academic Programs Office.

Program Requirements

Graduate students in the Environmental Engineering program must meet with an adviser immediately after arriving on campus to begin their graduate studies. All graduate students, particularly M.S. degree candidates, should prepare a proposed plan of study which can be obtained in the Academic Programs Office. It is recommended that the study plan include information on the scheduling sequence in order to avoid potential scheduling conflicts during subsequent semesters. A Ph.D. candidate's course plan is considered to be more flexible since many students change course selections during the first year in order to align their research interests with the courses being offered.

The Environmental Engineering program is built upon a core of scientific and engineering knowledge, with specific courses (or their equivalent) required by all graduate students in the program. All students enrolled in the program must satisfy the continuous registration and the Core Course Requirements outlined in this document. In addition, all graduate students (M.Eng., M.S., and Ph.D) are encouraged to attend the weekly Environmental Engineering seminars that cover environmental engineering research and professional topics. These seminars also provide a good opportunity for students to practice and improve their technical presentation skills.

Continuous Registration

Graduate students must maintain continuous registration by scheduling at least one credit *each semester* from the date of admission until all degree requirements have been satisfied. Degree requirements have been satisfied when the student has completed the required course work and the student's writing portfolio, thesis, or dissertation has been approved by the department. Students accessing the resources of the University (i.e., faculty, facilities, etc.) during the summer must also register for the Summer Session. Students who fail to maintain continuous registration will be dropped from the program.

Core Course Requirements

Students select a program of study that satisfies the Core Course Requirements (Table 3) as well as an individually chosen area of specialization. Programs of study that satisfy the course requirements for each degree are developed in consultation with the adviser.

Table 2. Core Course Requirements. Students must demonstrate competence in each of the following four core areas: Biology, Chemistry, Chemical Transport, and Process Engineering (3 credits in each core area) from these suggested courses.

BIOLOGY	**CHEMISTRY**
CE 497x Environmental Microbiology Topics (2 cr.) *and* CE 479 Environmental Microbiology Laboratory (1 cr.) *or* CE 579 Environmental Pollution Microbiology (3 cr.)	CE 570 Environmental Aquatic Chemistry (3 cr.) *or* CE 573 Environmental Organic Chemistry (3 cr.)
PROCESS ENGINEERING	**CHEMICAL TRANSPORT**
CE 571 Physical-Chemical Treatment Processes (3 cr.) *or* CE 572 Biological Treatment Processes (3 cr.)	CE 576 Physical-Chemical Treatment Processes (3 cr.) *or* CE 580 Hydrodynamic Mixing Processes (3 cr.)

Research Requirements

Participation in independent research is required for the M.S. and Ph.D. degrees. The Environmental Engineering faculty undertake research requiring expertise in engineering, chemistry, microbiology, and computer modeling. Recently completed or ongoing investigations range from strictly fundamental concepts in water and wastewater treatment to mission-oriented research. Research areas include:

•activated carbon regeneration •adsorption, coagulation, and flocculation •bioenergy production •biological production of hydrogen •biogeochemistry of acid mine drainage •bioremediation of acid mine drainage •bioremediation of metals and radionuclides •bioremediation of organic contaminants •desalination •fluid mechanics and substrate transport in biofilms and microbial aggregates •microbial fuel cells •removal of trace contaminants using activated carbon •sorption and bioavailability of organic contaminants in soils and sediments •transport of colloids in porous media •use of ozone in water and wastewater treatment •waste minimization and pollution prevention

Students are encouraged to take courses outside of the environmental engineering specialty. Courses in geohydrology, geochemistry, agronomy, chemical engineering, chemistry, biotechnology, mineral processing, and materials science are of particular interest.

Table 3. Courses applicable to the core curriculum and areas of specialization.

C E	462	Open Channel Hydraulics
C E	465W	Water Resources Capstone Design
C E	472W	Environmental Engineering Capstone Design
C E	475	Water Quality Chemistry
C E	476	Solid and Hazardous Wastes
C E	479	Environmental Microbiology Laboratory
C E	497x	Environmental Microbiology Topics
C E	497y	Applied Field Methods in Environmental Engineering
C E	555	Groundwater Hydrology: Analysis & Modeling
C E	561	Fundamentals of Surface Hydrology
C E	562	Scaling Issues in Surface Hydrology
C E	566	Uncertainty & Reliability in Water Resources Engineering
C E	567	River Engineering
C E	570	Environmental Aquatic Chemistry
C E	571	Physical-Chemical Treatment Processes
C E	572	Biological Treatment Processes
C E	573	Environmental Organic Chemistry
C E	575	Industrial Waste Management
C E	576	Environmental Transport Processes
C E	578	Groundwater Remediation
C E	579	Environmental Pollution Microbiology
C E	580	Surface Water Quality Modeling
C E	591	Environmental Engineering Seminar
C E	592	Environmental Engineering Literature Topics
BIOL	415	Ecotoxicology
BIOL	435	Ecology of Lakes & Streams
B M B	400	Molecular Biology of the Gene
B M B	401	General Biochemistry
B M B	402	General Biochemistry
CH E	401	Chemical Process Engineering

CH E 414	Kinetics & Industrial Chemistry
CHEM 402	Chemistry in the Environment
CHEM 425	Chromatography & Electrochemistry
CHEM 426	Chemical Spectroscopy
CHEM 448	Surface Chemistry
EGEE 597A	Fundamentals of Electrochemistry
E R M 431	Environmental Toxicology
E R M 435	Limnology
E R M 447	Stream Restoration
E R M 450	Wetland Conservation
F SC 430	Air Pollutants From Combustion Sources
GEOSC 409W	Geomicrobiology
GEOSC 412	Water Resources Geochemistry
GEOSC 413	Techniques in Environmental Geochemistry
GEOSC 452	Introduction to Hydrogeology
ME 403	Polymer Electrolyte Fuel Cells
M E 405	Indoor Air Quality Engineering
M E 470	Fundamentals of Air Pollution
ME 497C	Dynamics of Energy Systems (
METEO 454	Introduction to Micrometeorology
MICRB 401	Microbial Physiology & Structure
MICRB 413	Microbial Diversity
MN PR 426	Aqueous Processing
MNG 445	Environmental Concerns in the Mining Industry
NUC E 420	Radiological Safety
NUC E 428	Radioactive Waste Control
SOILS 412W	Soil Ecology
SOILS 419	Soil Environmental Chemistry

Research Facilities

Kappe Environmental Engineering Laboratories

The Kappe Environmental Engineering Laboratories include the newly constructed 1,800 ft^2 BioEnergy Laboratory, part of the 9,800 ft^2 Kappe Environmental Engineering Laboratories on the University Park campus supervised by a laboratory manager (Mr. David Faulds). These laboratories include general research lab areas, dedicated microscopy and dark rooms, multiple temperature control rooms, and general-use rooms for instrumentation and preparations (http://www.engr.psu.edu/ce/kappe_lab.html). Major equipment available for this project includes: single-channel (Gamry Scientific) and multi-channel potentiostats; multimeters and computers for data acquisition; two microscopes equipped for phase contrast, epifluorescence, and DIC techniques with digital image capture and analysis capabilities; anaerobic glove boxes (3) for culture work; laminar flow hood for sterile culture transfers; respirometers for gas production measurement in batch or continuous flow bioreactors; bioreactors with pH and reactor flow control; gas chromatographs (4) for gas and volatile acids measurements; ion chromatographs (2) for measuring cations and anions in water samples; UV-vis spectrophotometers (2); a Total Organic Carbon/Total Nitrogen analyzer; a potentiostat; and numerous multi-channel multimeters and data acquisition systems. Other equipment available include: atomic force microscope (AFM); particle counters (3); high pressure liquid chromatograph (1): UV spectrophotometers (2); scintillation counter; atomic absorption spectrophotometer; computer-aided titrimeter; fluorimeter; Toxicity Analyzers (2); and various centrifuges, ovens, mutimeters, data acquisition systems, balances, freezers, and typical laboratory equipment.

Other Laboratories
Other research and teaching laboratories in the department include an engineering computation laboratory, structures laboratory, materials and soils laboratory, CAD laboratory, hydraulics laboratory, transportation laboratory, and the Bernard Hankin Construction Engineering and Management Research Laboratory. Most of these facilities are conveniently located in the Sackett and Hammond Buildings. Each laboratory is equipped with the standard equipment required for each specialty area. A recently commissioned Building Enclosure Test Facility serves both the Civil and Environmental Engineering and Architectural Engineering Departments.

Academic Computing
The Center for Academic Computing (CAC) provides a broad range of service and production facilities in support of Penn State's academic and research programs.

Computer laboratories are provided by CAC in over 30 locations on the University Park Campus. Computer training seminars, workshops, and open houses are available throughout the year. Students can purchase computer systems, peripherals, and software though Penn State's Microcomputer Order Center (MOC) at educational discount prices. Students can obtain an Access Account through CAC, which enables the use of electronic mail, Internet services, CAC labs, and the generation of personal web pages.

The Department of Civil and Environmental Engineering and the Center for Academic Computing jointly operate a PC facility. This laboratory is comprised of 25 IBM PC PC300GL computers with 32M memory, CD, sound, 15-inch monitors, and an extensive list of productivity and engineering software, including *Autocad* and *Mathematica*. The CAD laboratory has 30 work stations and two plotters. The Environmental Engineering graduate student laboratories and offices also contain many personal computers and software for data analysis, plotting, and word processing.

Research Centers and Institutes
Students studying civil or environmental engineering have access to numerous research resources and facilities on campus. Students may use the research facilities at the Applied Research Laboratory, the Center for Bioremediation and Detoxification, the Center for Geochemistry and Environmental Geochemistry, the College of Engineering's Environmental Institute, the H2E Center, Environmental Resources Research Institute, the Materials Research Laboratory, the Pennsylvania Housing Research Center, and the Pennsylvania Transportation Institute. In addition, the Agricultural Research Service (USDA) maintains the Northeast Watershed Research Center on campus.

Graduate Faculty

The Environmental Engineering program currently consists of seven faculty members from the Department of Civil and Environmental Engineering. Five additional faculty members specialize in the Hydrosystems emphasis within the Civil Engineering program. Further assistance is provided by faculty and staff from other departments in fields such as air pollution, incineration, hydrogeology, industrial engineering, geochemistry, economics, law, biochemistry, limnology and aquatic biology. Many of the participants in this program hold joint appointments through Penn State's Environmental Resources Research Institute.

Environmental Engineering Faculty

RACHEL A. BRENNAN, Ph.D. (Illinois), assistant professor. In-situ bioremediation of soil and groundwater contaminants; physical, chemical, and biological treatment of acid mine drainage; chitin as a sustainable nutrient source for hazardous waste treatment; enzymatic biocatalysis of endocrine disruptors; molecular microbial ecology within remediation systems.

WILLIAM D. BURGOS, Ph.D. (Virginia Tech), associate professor. Bioremediation of soil, sediment and groundwater; biological iron(III) reduction; biological uranium(VI) reduction; biogeochemistry of Fe(II) and Mn(II) oxidation in coal mine drainage; contaminant interactions with natural organic matter.

FRED S. CANNON, Ph.D. (Illinois), P.E., professor. Water, air, and hazardous waste treatment; activated carbon, advanced oxidation, and surface chemistry; industrial pollution prevention.

BRIAN A. DEMPSEY, Ph.D. (North Carolina), professor. Aquatic chemistry with an emphasis on solid/liquid interfacial phenomena; chemistry of iron and aluminum; investigation & treatment of mine drainage; natural organic materials; coagulation; low-pressure membrane filtration.

BRUCE E. LOGAN, Ph.D. (California, Berkeley), Kappe Professor of Environmental Engineering. Environmental and chemical transport processes; bioenergy production via biological hydrogen production and microbial fuel cells; Bioadhesion; bioremediation; particle coagulation, filtration and transport.

JACK V. MATSON, Ph.D. (Rice), P.E., professor. Innovative engineering design, air pollution, industrial pollution prevention.

JOHN M. REGAN, Ph.D. (Wisconsin), P.E., assistant professor. Biological processes with an emphasis on fermentative hydrogen production, nitrification, regrowth in drinking water distribution systems, molecular microbial ecology, and biofilm systems.

Water Resources Engineering Faculty

CHRISTOPHER J. DUFFY, Ph.D. (New Mexico Institute of Mining and Technology), P.H., professor. Stochastic and numerical modeling of groundwater flow and solute transport; modeling large-scale hydrologic systems.

MICHEAL GOOSEFF, Ph.D. (Colorado, Boulder), assistant professor. Solute transport and fate in aquatic systems; ecological engineering; hydrologic responses to climate change; water quality modeling.

DAVID F. HILL, Ph.D. (California, Berkeley), associate professor. Experimental fluid mechanics; stratified flows; wave mechanics; coastal engineering; perturbation methods.

PEGGY A. JOHNSON, Ph.D. (Maryland), professor, Department Head. Reliability and uncertainty analysis; river hydraulics; bridge scour; river restoration.

PATRICK REED, Ph.D. (Illinois), associate professor. Monitoring networks design, systems optimization using genetic algorithms, multiobjective decision support, geostatistical interpolation of nonstationary phenomena, and hydrologic modeling.

THORSTEN WAGENER, Ph.D. (Imperial College), assistant professor. Analysis and modeling of complex hydrological systems, predictions in ungauged basins, uncertainty and sensitivity analysis, environmental change, and scenario analysis.