# DEPARTMENT OF ENVIRONMENTAL SCIENCES AND ENGINEERING (GRAD)

The Department of Environmental Sciences and Engineering in the Gillings School of Global Public Health focuses on the interface between people and the environment. Uniquely situated in a school of public health, the department combines the physical sciences, health sciences, engineering, and policy to develop solutions to current and emerging environmental challenges. Our mission is promoting human and ecological health for all by identifying, understanding, and solving pressing environmental challenges. This multidisciplinary approach provides unique academic and research opportunities for students.

**WE WORK TO**

- Understand environmental transport and transformation of chemicals and infectious agents
- Elucidate mechanisms by which chemicals and infectious agents influence human health
- Mitigate the impacts of climate change on air, water, and health; and
- Protect vulnerable populations from toxic exposures.

Our faculty bring expertise in the physical and life sciences, engineering, and policy. We work both locally and globally, in occupational and environmental settings, on issues relevant to air quality, water, health, energy, and resource management. We aim to create a healthy and sustainable future for all.

The wide scope of departmental research is reflected in the three interdisciplinary fields of study, faculty's areas of research, and affiliated labs and research institutes. The three interdisciplinary fields of study are: Air Quality and Atmospheric Processes, Human Exposure and Health Effects, and Sustainable Water Resources.

**Air Quality and Atmospheric Processes**
Atmospheric processes have a major influence on air quality, as well as on long#term global processes. Over the past 30 years, major research contributions of our faculty and students include the generation of an experimental database used to develop and test photochemical mechanisms that contribute to air pollution; development of methods to measure and monitor airborne contaminants; work to understand air quality and health implications of energy policies, and the development and application of occupational exposure models.

**Human Exposure and Health Effects**
Our faculty study the range of processes that ultimately lead to environmentally related diseases, from characterizing and quantifying human exposure to understanding the cellular, molecular and biochemical underpinnings of these diseases. Major research activities include: developing methods to measure and monitor chemical or microbial contaminants; and elucidating the genetic and epigenetic factors that lead to differences in disease outcomes among individuals or populations.

**Sustainable Water Resources**
Population growth and economic development continue to place increasing stress on global water resources, stresses that stem primarily from rising consumptive demands for limited supplies and increasing contamination of natural waters. Our faculty seek solutions to these challenges using a variety of computational, experimental, and field approaches. Our research results improve engineering applications and provide substantive guidance to policymakers.

Our **research strengths** include:

- Characterizing exposures to contaminants in air, water, soil, and workplaces
- Developing engineering and policy solutions to reduce environmental risks
- Using molecular approaches to understand disease mechanisms caused by toxic substances in the environment
- Overcoming environmental health challenges in developing countries

Learn more (https://sph.unc.edu/envr/department-research/)

## ESE Course Competencies Mapped

Each degree in our department is mapped to five degree-specific competencies that are taught and assessed in specific courses or other learning opportunities. Learn more (https://sph.unc.edu/ese-course-competencies/)

## Resources for Current ESE Students

Current Environmental Sciences and Engineering (ESE) students can find department resources here (https://sph.unc.edu/envr/current-student-resources/).

# Master of Science in Environmental Sciences and Engineering (M.S.)

The master of science (M.S.) in the Department of Environmental Sciences and Engineering prepares students who are interested in advanced education or careers in research, practice or management in the field of environmental sciences and engineering. Students perform research leading to a thesis and potentially publishable work.

## Course Requirements

| Code | Title | Hours |
|---|---|---|
| SPHG 600 | Introduction to Public Health [1] | 3 |
| ENVR 400 | Seminar Series | 1 |
| ENVR 601 | Epidemiology for Environmental Scientists | 3 |
| Additional formal coursework (400 level or higher). Can include credits from Research skill course(s), if applicable (not including ENVR 400, 991, 993). | | 9 |
| "Depth of knowledge in a discipline" approved by student and thesis Faculty Mentor (400 level or above) | | 9 |
| **Research** | | |
| ENVR 991 | Research in Environmental Sciences and Engineering | 3 |
| **Thesis/Substitute or Dissertation** | | |
| ENVR 993 | Master's Research and Thesis | 3 |
| **Minimum Hours** [2] | | **31** |

[1] Students with a prior public health degree are not required to take SPHG 600; exemptions are available for those with non-public health degrees from accredited SPHs. Students should discuss with their Academic Coordinator.

[2] A minimum of 24 credits of graduate-level course work, which includes at least 15 credit hours of ENVR courses at the 400 level or above (to

be determined by the student and faculty mentor) and excludes ENVR 400, 991, and 993.

## Milestones

- Master's Committee
- Thesis/Substitute Defense (Master's Comprehensive Exam)
- Master's Thesis Approved
- Residence Credit
- Exit Survey
- Master's Competency Review (mastery of one research skill)

# Master of Science in Environmental Engineering (M.S.E.E.), Professional & Research Options

The master of science in environmental engineering (M.S.E.E.) in the Department of Environmental Sciences and Engineering is a program that gives students a Professional option (one year) or a Research option (two year) degree that provides students the vital skills and training needed to solve 21st century environmental engineering and public health challenges.

## Course Requirements

| Code | Title | Hours |
|---|---|---|
| SPHG 600 | Introduction to Public Health [1] | 3 |
| ENVR 400 | Seminar Series | 1 |
| ENVR 601 | Epidemiology for Environmental Scientists | 3 |
| or EPID 600 | Principles of Epidemiology for Public Health | |
| Additional formal coursework (400 level or higher). Can include credits from Research skill course(s), if applicable (not including ENVR 400, 991, 992). | | 9 |
| **Electives** | | |
| 12 or more credits at 400 level or higher. See approved list of Engineering Elective Options below. [2] | | 12 |
| **Thesis/Substitute or Dissertation** | | |
| ENVR 992 | Master's Technical Report [3] | 3 |
| **Minimum Hours** [4] | | **31** |

[1] Students with a prior public health degree are not required to take SPHG 600; exemptions are available for those with non-public health degrees from accredited SPHs. Students should discuss with their Academic Coordinator.

[2] An undergraduate or graduate course in Statistics, and one in Biological Sciences must be taken if such courses have not been taken in the past e.g., in another institution. These can count toward graduation credits if they are 400 level or above.

[3] Students completing the Professional option must specifically register for ENVR 992 **section 003** (ENVR 992.003) and associated Oral Comprehensive Exam and Technical Report. Students completing the Research option must specifically register under **their faculty mentor's** section of ENVR 992.

[4] A minimum of 24 credits of graduate-level course work, which includes at least 15 credit hours of ENVR courses at the 400 level or above (to be determined by the student and faculty mentor) and excludes ENVR 400, ENVR 991, and ENVR 993.

**Engineering Elective Course Options**

| Code | Title | Hours |
|---|---|---|
| ENVR 416 | Aerosol Physics and Chemistry | 4 |
| ENVR 451 | Introduction to Environmental Modeling | 3 |
| ENVR 453 | Groundwater Hydrology | 3 |
| ENVR 468 | Temporal GIS and Space/Time Geostatistics for the Environment and Public Health | 3 |
| ENVR 500 | Environmental Processes, Exposure, and Risk Assessment | 3 |
| ENVR 525 | Water, Sanitation, Hygiene, and Global Health | 3 |
| ENVR 582 | Sanitation for Development | 3 |
| ENVR 656 | Physical/Chemical Processes for Water Treatment | 3 |
| ENVR 666 | Numerical Methods | 3 |
| ENVR 671 | Environmental Physics I | 3 |
| ENVR 672 | Environmental Physics II | 3 |
| ENVR 675 | Air Pollution, Chemistry, and Physics | 3 |
| ENVR 755 | Analysis of Water Resource Systems | 3 |
| ENVR 759 | Multiphase Transport Phenomena | 3 |
| ENVR 760 | Uncertainty Quantification for Environmental Systems | 3 |
| ENVR 765 | Space Time Exposure Mapping and Risk Assessment | 3 |

## Milestones

- Master's Committee
- Master's Oral Exam / Approved Exam Substitute
- Thesis / Substitute Defense
- Residence Credit
- Exit Survey

# Public Health, Master's Program (M.P.H.) — Environment, Climate, and Health Concentration

Prospective students in the Environment, Climate and Health Concentration (https://sph.unc.edu/resource-pages/master-of-public-health/environment-climate-and-health-concentration/) understand that the health of the planet and the health of its people are inextricably linked. They aim to contribute innovative solutions to complex environment, climate, and health challenges: health challenges related to energy policy changes, safe drinking water, protection from infection where we work and play, economically feasible actions with co-benefits for public health and conservation of resources. If you wish to work towards creating a healthy environment as a public health professional, this Gillings MPH concentration is designed for you. The Environment, Climate and Health Concentration, housed in the Gillings School of Global Public Health and Department of Environmental Sciences and Engineering, will equip you with skills and know-how to identify and mitigate the adverse impacts of climate and environmental change on human health. Through a highly tailored curriculum and real-world experience, our students develop broadly applicable skills to address a range of exposure risks and sources. We welcome those interested in both local and global challenges.

**UNC undergrads apply to the M.P.H.– Environment, Climate and Health concentration using a separate process:**

- Current UNC seniors wishing to apply for an M.P.H. with an Environment, Climate and Health Concentration should submit a formal application to the program using this Graduate School link (http://go.unc.edu/UNCSeniorApplyMPHEHS/).
- Current UNC juniors should use this pre-admission application link (http://go.unc.edu/UNCJuniorApplyMPHEHS/).
- Details about ESE's Accelerated bachelor's-to-master's programs can be found here: https://sph.unc.edu/envr/bachelors-to-masters-programs/

## Course Requirements

Requirements for the M.P.H. degree in the Environment, Climate and Health concentration.

| Code | Title | Hours |
|---|---|---|
| **M.P.H. Integrated Core** | | |
| SPHG 711 | Data Analysis for Public Health | 2 |
| SPHG 712 | Methods and Measures for Public Health Practice | 2 |
| SPHG 713 | Systems Approaches to Understanding Public Health Issues | 2 |
| SPHG 701 | Leading from the Inside-Out | 2 |
| SPHG 721 | Public Health Solutions: Systems, Policy and Advocacy | 2 |
| SPHG 722 | Developing, Implementing, and Evaluating Public Health Solutions (MPH Comprehensive Exam administered in class) | 4 |
| **M.P.H. Practicum** | | |
| SPHG 703 | MPH Pre-Practicum Assignments | 0.5 |
| SPHG 707 | MPH Post-Practicum Assignments | 0.5 |
| **M.P.H. Concentration** | | |
| ENVR 430 | Health Effects of Environmental Agents | 3 |
| ENVR 500 | Environmental Processes, Exposure, and Risk Assessment | 3 |
| ENVR 580 | Policy Design for Environment, Climate, and Health | 3 |
| ENVR 775 | Global Climate Change: Interdisciplinary Perspectives | 1 |
| Graduate-level ENVR Discipline Depth Course | | 2 |
| Graduate-level ENVR Discipline Depth Course | | 3 |
| **M.P.H. Electives** | | |
| Electives (Graduate-level courses, 400+ level at Gillings, 500+ level at UNC) | | 9 |
| **M.P.H. Culminating Experience** | | |
| ENVR 992 | Master's Technical Report | 3 |
| **Minimum Hours** | | **42** |

## Admissions

Please visit Applying to the Gillings School (https://sph.unc.edu/students/how-to-apply/) first for details and information. Application to the residential M.P.H. is a 2-step process. Please apply separately to (1) SOPHAS and (2) UNC–Chapel Hill (via the Graduate School application link that will be sent after completing the SOPHAS application). Visit the Graduate School Web site (https://gradschool.sites.unc.edu/master-of-public-health/) for more details. If you are interested in the online M.P.H., please visit the MPH@UNC (https://onlinemph.unc.edu/) website and fill out an inquiry form.

## Milestones

- Master's Committee
- Master's Written Examination/Approved Substitute (Comprehensive Exam)
- Thesis Substitute (Culminating Experience)
- Residence Credit
- Exit Survey
- Master's Professional Work Experience (Practicum)

# Environmental Sciences and Engineering, Doctoral Program (Ph.D.)

The Ph.D., a terminal degree, is intended for incoming students with a strong background in the sciences or engineering and prepares them for careers in basic and applied research, education, or management in the field of environmental sciences and engineering. Applicants should have a strong background in the sciences, math or engineering with interest and aptitude for original and significant research; focused written statement should convey a motivation for research; strong academic record; strong letters of recommendation.

## Course Requirements

| Code | Title | Hours |
|---|---|---|
| **Public Health Foundational Courses** | | |
| SPHG 600 | Introduction to Public Health [1] | 3 |
| **Core Courses** | | |
| ENVR 400 | Seminar Series (Two semesters for 2 credits) | 2 |
| EPID 600 | Principles of Epidemiology for Public Health | 3 |
| or ENVR 601 | Epidemiology for Environmental Scientists | |
| ENVR 703 | Proposal Writing for Environmental Research [2] | 3 |
| ENVR 704 | Critical Analysis of Environmental Research (Must be taken twice, preferably during the first and second years.) | 2 |
| ENVR 991 | Research in Environmental Sciences and Engineering [3] | 6 |
| **Electives** | | |
| 15 credits for "depth of knowledge in a discipline" (approved by candidate and committee). | | 15 |
| **Thesis/Substitute or Dissertation** | | |
| ENVR 994 | Doctoral Research and Dissertation (Two semesters for 6 credits) | 6 |
| **Minimum Hours** | | **40** |

1. Students with a prior public health degree may be exempt from SPHG 600; this means a student may be excused from taking SPHG 600, but still needs to fulfill the associated 3 credit hour requirement. Exemptions are available for those with non-public health degrees from accredited SPHs. Students should discuss with their Academic Coordinator.
2. To be taken when student is ready to write dissertation proposal.
3. Students should register for ENVR 991 each semester they are doing research and may register for 1-9 total credit hours per semester.

## Milestones

The following list of milestones (non-course degree requirements) must be completed; view this list of standard milestone definitions (https://

catalog.unc.edu/graduate/degree-programs/#milestonestext) for more information.

- Doctoral Committee
- Doctoral Oral Comprehensive Exam
- Doctoral Written Exam
- Prospectus Oral Exam
- Advanced to Candidacy
- Dissertation Defense
- Doctoral Dissertation Approved/Format Accepted
- Residence Credit
- Exit Survey
- Doctoral Competency Review (Research Skills: PhD Competency 4)
- Doctoral Research Presentation (Research Presentation to ESE Audience PhD Competency 5)

# Environmental Sciences and Engineering (ENVR)

## Advanced Undergraduate and Graduate-level Courses

**ENVR 400. Seminar Series. 1 Credits.**
Presents relevant research to the Department of Environmental Sciences and Engineering. Topics and presenters are selected from among the departmental graduate students, faculty, and relevant external speakers. Student presenters learn how to present their research to a lay audience while students taking the class for credit learn how to critique a presentation as well as forge professional collaborations across disciplines. Permission of the instructor for undergraduate students.

**Rules & Requirements**
**Repeat Rules:** May be repeated for credit. 6 total credits. 6 total completions.
**Grading Status:** Letter grade.

**ENVR 403. Environmental Chemistry Processes. 3 Credits.**
Required preparation, a background in chemistry and mathematics, including ordinary differential equations. Chemical processes occurring in natural and engineered systems: chemical cycles; transport and transformation processes of chemicals in air, water, and multimedia environments; chemical dynamics; thermodynamics; structure/activity relationships.

**Rules & Requirements**
**Requisites:** Pre- or corequisite, CHEM 261.
**Grading Status:** Letter grade.
**Same as:** ENEC 403, CHEM 403.

**ENVR 404. Life Cycle Assessment: Energy and the Environment. 3 Credits.**
A systems approach to dealing with environmental pollution problems is highlighted and Life Cycle Assessment (LCA) is introduced as an assessment tool. Topics include basic environmental interactions; biogeochemical cycles and environmental impacts (global, regional, and local); and application of LCA to waste management and energy conversion systems; are addressed.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 411. Laboratory Techniques and Field Measurements. 3 Credits.**
Students learn laboratory, field, and analytical skills. Provides a solid introduction to experimental research in environmental sciences and engineering. Students are provided with applications in limnology, aquatic chemistry, and industrial hygiene.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 412. Ecological Microbiology. 3 Credits.**
Required preparation, one course in general microbiology. A description of microbial populations and communities, the environmental processes they influence, and how they can be controlled to the benefit of humankind.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 413. Limnology. 3 Credits.**
Required preparation, introductory biology, chemistry, and physics. Basic aspects of freshwater ecosystem function. Emphasis on trophic-level interactions and integration of physical, chemical, and biological principles for a holistic view of lake ecosystem dynamics.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 416. Aerosol Physics and Chemistry. 4 Credits.**
Permission of the instructor for nonmajors. Physical and chemical principles underlying behavior of particles suspended in air. Topics include rectilinear and curvilinear motion of the particles in a force field, diffusion, evaporation, and condensation, electrical and optical properties, and particle coagulation. Three lecture hours a week and two laboratory sessions.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 417. Oceanography. 3 Credits.**
Required preparation, major in a natural science or two courses in natural sciences. Studies origin of ocean basins, seawater chemistry and dynamics, biological communities, sedimentary record, and oceanographic history. Term paper. Students lacking science background should see EMES 103. Students may not receive credit for both EMES 103 and EMES 401. Course previously offered as GEOL 403/MASC 401.

**Rules & Requirements**
**Grading Status:** Letter grade.
**Same as:** EMES 401, BIOL 350.

**ENVR 419. Chemical Equilibria in Natural Waters. 3 Credits.**
Principles and applications of chemical equilibria to natural waters. Acid-base, solubility, complex formation, and redox reactions are discussed. This course uses a problem-solving approach to illustrate chemical speciation and environmental implications. Three lecture hours per week.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 421. Environmental Health Microbiology. 3 Credits.**
Required preparation: introductory course in microbiology or permission of the instructor. This course covers microbes of public health importance in water, wastewater, and other environmental matrices, including detection, quantification, transport, and survival in environmental media; control measures to reduce exposures; quantitative microbial risk assessment; and the epidemiology of infectious diseases transmitted via the environment.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 423. Industrial Toxicology. 3 Credits.**
Toxicological assessment of and a case presentation of related exposure is given. A conceptual approach is utilized to design appropriate programs to prevent worker ill health due to toxicant exposure.

**Rules & Requirements**
**Requisites:** Prerequisite, ENVR 430, or permission of the instructor.
**Grading Status:** Letter grade.

**ENVR 425. Introduction to Health Physics: Radiation and Radiation Protection. 3 Credits.**
This course concentrates on fundamentals of radiation and protection, including types of radiation, radioactive decay, interaction with matter, biological effects, detection and measurement, protection methods/techniques, external and internal dose, etc. Lectures include hazards in categories of environmental radiation, nuclear energy, medical applications, industrial uses, etc.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 430. Health Effects of Environmental Agents. 3 Credits.**
Required preparation, basic biology, chemistry through organic, calculus. Permission of the instructor for students lacking this preparation. Interactions of environmental agents (chemicals, infectious organisms, radiation) with biological systems including humans, with attention to routes of entry, distribution, metabolism, elimination, and mechanisms of adverse effects. Three lecture hours per week.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 431. Techniques in Environmental Health Sciences. 2 Credits.**
Required preparation, basic biology, chemistry through organic, math through calculus; permission of the instructor for students lacking this preparation. A practical introduction to the measurement of biological end-points, emphasizing adverse effects of environmental agents, using laboratory and field techniques. Two laboratory hours per week.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 432. Occupational Safety and Ergonomics. 3 Credits.**
Fundamentals of occupational safety and ergonomics with emphasis on legislation and organization of industrial safety and ergonomic programs, including hazard recognition, analysis, control, and motivational factors pertaining to industrial accident and cumulative trauma disorder prevention.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 433. Health Hazards of Industrial Operation. 3 Credits.**
An introduction to occupational hygiene and the health hazards associated with industrial operations. Fundamental scientific principles are used to provide the foundation for assessing and controlling the exposures found in the work environment. Topics with broad application include: noise, heat stress, and ventilation. Specific industrial operations examined include: welding, electroplating, and spray painting, among others. The concept of Total Worker Health is explored with a focus on the role of labor unions. No prerequisites.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 451. Introduction to Environmental Modeling. 3 Credits.**
Focuses on how to model environmental transport and chemistry of pollutants. Covers mole balances, rate laws, chemical kinetics, and reactor design. Principles are applied to any environmental system where chemical transformations must be described. Three lecture hours per week.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 452. Fluid Dynamics. 3 Credits.**
The physical properties of fluids, kinematics, governing equations, viscous incompressible flow, vorticity dynamics, boundary layers, irrotational incompressible flow. Course previously offered as GEOL 560/MASC 560.

**Rules & Requirements**
**Requisites:** Prerequisite, PHYS 401; permission of the instructor for students lacking the prerequisite.
**Grading Status:** Letter grade.
**Same as:** EMES 560, PHYS 660.

**ENVR 453. Groundwater Hydrology. 3 Credits.**
Required preparation, math through differential equations and some familiarity with fluid mechanics. Conservation principles for mass, momentum, and energy developed and applied to groundwater systems. Scope includes the movement of water, gas, and organic liquid phases, the transport and reaction of contaminants. Three lecture hours per week.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 468. Temporal GIS and Space/Time Geostatistics for the Environment and Public Health. 3 Credits.**
Reviews geographical information systems (GIS). Covers geostatistics theory for the interpolation of environmental and health monitoring data across space and time. Uses publicly available water and air quality monitoring data to create maps used for environmental assessment, regulatory compliance analysis, exposure science, and risk analysis.

**Rules & Requirements**
**Requisites:** Prerequisite, MATH 232; permission of the instructor for students lacking the prerequisite.
**Grading Status:** Letter grade.
**Same as:** ENEC 468.

**ENVR 470. Environmental Risk Assessment. 3 Credits.**
Required preparation, one course in probability and statistics. Use of mathematical models and computer simulation tools to estimate the human health impacts of exposure to environmental pollutants. Three lecture hours per week.

**Rules & Requirements**
**Grading Status:** Letter grade.
**Same as:** ENEC 470.

**ENVR 472. Quantitative Risk Assessment in Environmental Health Microbiology. 3 Credits.**
Recommended preparation, microbiology, epidemiology, and infectious diseases. Survey of alternative approaches, frameworks, and decision-making tools for quantitative risk assessment of microbial pathogens that infect humans and cause disease by the exposure routes of water, food, air, and other vehicles.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 500. Environmental Processes, Exposure, and Risk Assessment. 3 Credits.**
Environmental chemical and biological transport and transformation, exposure to environmental contaminants, and environmental risk assessment.

**Rules & Requirements**
**Requisites:** Prerequisite, CHEM 261.
**Grading Status:** Letter grade.

**ENVR 505. Chemical Oceanography. 4 Credits.**
Graduate students only; undergraduates must have permission of the instructor. Overview of chemical processes in the ocean. Topics include physical chemistry of seawater, major element cycles, hydrothermal vents, geochemical tracers, air-sea gas exchange, particle transport, sedimentary processes, and marine organic geochemistry. Three lecture and two recitation hours per week. Course previously offered as GEOL 505/MASC 505.

**Rules & Requirements**
**Grading Status:** Letter grade.
**Same as:** EMES 505.

**ENVR 514. Measurement of NOx, O3, and Volatile Organic Compounds. 3 Credits.**
This course is intended to develop a student's ability to operate the primary instruments for measuring these important pollutants, collect and process samples where necessary, record data, and process instrument data into final air concentration data.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 520. Biological Oceanography. 4 Credits.**
For undergraduate (juniors and seniors) and graduate students. Marine ecosystem processes pertaining to the structure, function, and ecological interactions of biological communities; management of biological resources; taxonomy and natural history of pelagic and benthic marine organisms. Three lecture and recitation hours per week. One mandatory weekend field trip. Course previously offered as MASC 504.

**Rules & Requirements**
**Grading Status:** Letter grade.
**Same as:** EMES 507, BIOL 657.

**ENVR 522. Environmental Change and Human Health. 3 Credits.**
The course will provide students with a multidisciplinary perspective of environmental changes to encompass both human health and ecological health.

**Rules & Requirements**
**Requisites:** Prerequisite, ENEC 201 or 202.
**Grading Status:** Letter grade.
**Same as:** ENEC 522.

**ENVR 525. Water, Sanitation, Hygiene, and Global Health. 3 Credits.**
Builds on an understanding of infectious and toxic hazards, disease causation, and environmental transmission. Deals with hazard and disease classification; safety, risk, and vulnerability; interventions and their health impact; approaches in different settings; distal factors (e.g., water scarcity, climate change); and approaches to studying unsafe water, sanitation, and hygiene. Previously offered as ENVR 682.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 540. Introduction to Risk Management and Insurance. 3 Credits.**
Introduces the motivations, objectives, and principles of financial risk management through the lens of insurance, reinsurance and financial institutions. Students will become familiar with key concepts that shape these industries so they can effectively communicate using industry vocabulary, metrics, and tools. Standards governing financial risk management are introduced as are the different types of risks that financial institutions, insurers and reinsurers analyze when conducting business. Students will make use of software and tools to characterize and price risk in various activities, carry out basic quantitative risk assessments, and learn what drives success and failure in financial risk management.

**Rules & Requirements**
**Requisites:** Pre- or corequisite, Two or more of the following classes (or permission of the instructor): MATH 231, MATH 232, STOR 151, STOR 155, BIOS 511, BIOS 512, BIOS 600, ECON 400, BIOL/ENEC 562.
**Grading Status:** Letter grade.
**Same as:** DATA 540, ENEC 540.

**ENVR 541. Natural Hazards and Financial Risk. 3 Credits.**
Society's growing exposure to the financial risks associated with natural hazards (e.g., flood, drought, extreme temperatures) has made it increasingly important to both accurately quantify these risks and develop innovative strategies for managing them. This course provides exposure to the fundamentals of financial risk management with application to natural hazards an emphasis on developing coupled models that consider natural variability, engineered/managed structures and financial/economic factors. Students will learn to (i) model the financial risk posed by extreme events; (ii) understand the merits of various risk management tools; and (iii) develop effective strategies for managing natural hazard-based financial risk.

**Rules & Requirements**
**Requisites:** Pre- or corequisite, At least 2 of the following courses in mathematics or statistics (or permission of instructor): MATH 231, MATH 232, STOR 151, STOR 155, BIOS 511, BIOS 512, BIOS 600, ECON 400, BIOL/ENEC 562; some programming experience (COMP 110, COMP 116, or BIOS 511) helpful, but not required.
**Grading Status:** Letter grade.
**Same as:** DATA 541, ENEC 541.

**ENVR 542. Insurance: Balancing Risk and Return. 1.5 Credits.**
Students will develop a quantitative understanding of concepts underlying actuarial science, including discounted cash flows, net present value and the uncertainties related to liabilities/claims, inflation and interest/discount rates. Asset/premium investment strategies will also be covered, with an introduction to the properties of different asset classes, consideration of uncertainty, and methods by which assets can be assembled into portfolios that balance profitability with the risk. The course will develop students' analytical skills and awareness of the benefits and challenges of quantitative risk analysis, and they will analyze situations in which risk management failed and describe the underlying causes of failure.

**Rules & Requirements**
**Requisites:** Pre- or corequisite, At least 2 of the following courses in mathematics or statistics (or permission of instructor): MATH 231, MATH 232, STOR 151, STOR 155, BIOS 511, BIOS 512, BIOS 600, ECON 400, BIOL/ENEC 562; some programming experience (COMP 110, COMP 116, or BIOS 511) is helpful, but not required.
**Grading Status:** Letter grade.
**Same as:** DATA 542, ENEC 542.

**ENVR 543. Risk, Data Science and AI. 3 Credits.**
Students are introduced to advanced techniques in data sciences, machine learning, and artificial intelligence and their application to the management of financial risks. Students will learn to discover, process, and visualize natural hazard and financial data, and will be taught to quantify various financial risks (e.g., natural hazards) and design management strategies to mitigate negative outcomes. Students will learn basic programming methods and apply data analysis and machine learning techniques to model the complex systems that give rise to risk. Structured case studies and in-class assignments will help students build expertise to be used in longer group projects.

**Rules & Requirements**
**Requisites:** Pre- or corequisite, At least 2 of the following courses in mathematics or statistics (or permission of instructor): MATH 231, MATH 232, STOR 151, STOR 155, BIOS 511, BIOS 512, BIOS 600, ECON 400, BIOL/ENEC 562; some programming experience (COMP 110, COMP 116, or BIOS 511) is helpful, but not required.
**Grading Status:** Letter grade.
**Same as:** DATA 543, ENEC 543.

**ENVR 548. Sustainable Energy Systems. 3 Credits.**
This course will provide an introduction to urgent topics related to energy, sustainability, and the environment. The course material will focus on new technologies, policies, and plans in cities and different governing bodies in the energy system with a focus on developing tools to analyze energy for its sustainability, impact on people, the environment, and the economy.

**Rules & Requirements**
**Grading Status:** Letter grade.
**Same as:** PLAN 548, ENEC 548.

**ENVR 570. Uncertainty, Decisions, and the Environment. 3 Credits.**
Required preparation, one course in probability and statistics. Use of quantitative tools for balancing conflicting priorities (such as costs versus human health protection) and evaluating uncertainties when making environmental decisions.

**Rules & Requirements**
**Grading Status:** Letter grade.
**Same as:** ENEC 570.

**ENVR 575. Global Climate Change: Science, Impacts, Solutions. 3 Credits.**
This class addresses the importance of climate change in its entirety. The first half of the course addresses climate science, followed by climate change impacts, energy and mitigation technologies, economics, and international politics. Improving communication and quantitative skills is emphasized through homework, in-class presentations, and a research paper.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 580. Policy Design for Environment, Climate, and Health. 3 Credits.**
Students will be introduced to the types of policy instruments that can be used to solve environmental health problems. The course provides a framework for understanding the tasks involved, the main institutions responsible, and an in-depth description of the policy instruments used to tackle environmental health problems.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 582. Sanitation for Development. 3 Credits.**
Over a million children die yearly from diarrhea, in part because 2.0 billion humans do not have access to a basic toilet. This course presents the problems and context of inadequate sanitation in the developing world, and, more importantly, the types of solutions and approaches available to reduce these problems.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 593. Undergraduate Practicum in Environmental Health Sciences. 3 Credits.**
A practical experience in a setting relevant to environmental health.

**Rules & Requirements**
**Repeat Rules:** May be repeated for credit. 6 total credits. 2 total completions.
**Grading Status:** Letter grade.

**ENVR 600. Environmental Health. 3 Credits.**
This course examines the relationship between environmental quality, human health and welfare, with particular attention to contamination in human environment; physical, biological, and social factors; trade-offs regarding prevention and remediation measures. Three lecture hours per week.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 601. Epidemiology for Environmental Scientists. 3 Credits.**
An introduction to relevant epidemiologic concepts that inform environmental science research. Learning objectives include discussing basic epidemiologic concepts and measures of disease occurrence in populations, explaining epidemiological study designs for studying associations between risk factors or exposures in populations, evaluating epidemiologic evidence, and comprehending basic ethical principles.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 610. Global Perspectives on Environmental Health Inequalities. 3 Credits.**
Students will learn about how social, economic, and political factors impact environmental health outcomes and will be introduced to theories and methods for incorporating social determinants frameworks into environmental health research, as well as the role of environmental justice movements.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 630. Systems Biology in Environmental Health. 3 Credits.**
Required preparation, one year of biology. Environmental systems biology examines how environmental stressors influence the components of a biological system, and how the interactions between these components result in changes in the function and behavior of that system.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 635. Energy Modeling for Environment and Public Health. 3 Credits.**
Recommended preparation, MATH 231. This course will equip students with an overview of contemporary issues in energy modeling and energy systems analysis, with a focus on environmental and public health impacts of energy systems. Students will gain exposure to a variety of research methodologies, analytical tools, and applications of energy modeling applied to environmental and public health related problems such as climate change, air pollution, and water footprints of energy systems.

**Rules & Requirements**
**Grading Status:** Letter grade.
**Same as:** ENEC 635, PLAN 635.

**ENVR 640. Environmental Exposure Assessment. 3 Credits.**
Permission of the instructor for nonmajors. The course material introduces the general concepts of assessing environmental exposures to chemicals in human populations. This includes the design of ecologic and personal monitoring studies, the techniques and equipment used for sampling and analysis, and interpretation of data.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 650. Principles of Chemical Carcinogenesis. 3 Credits.**
Required preparation, organic chemistry. Bioactivation of carcinogens, interaction of activated metabolites with DNA, and their effects on DNA structure, replication, repair, and the control of these processes during development of chemically induced carcinogenesis.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 656. Physical/Chemical Processes for Water Treatment. 3 Credits.**
Principles of disinfection, oxidation, coagulation, precipitation, sedimentation, filtration, adsorption, ion exchange, and membrane processes; applications to water and wastewater treatment. Three lecture hours per week. Previously offered as ENVR 756.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 661. Scientific Computation I. 3 Credits.**
Requires some programming experience and basic numerical analysis. Error in computation, solutions of nonlinear equations, interpolation, approximation of functions, Fourier methods, numerical integration and differentiation, introduction to numerical solution of ODEs, Gaussian elimination.

**Rules & Requirements**
**Grading Status:** Letter grade.
**Same as:** MATH 661.

**ENVR 662. Scientific Computation II. 3 Credits.**
Theory and practical issues arising in linear algebra problems derived from physical applications, e.g., discretization of ODEs and PDEs. Linear systems, linear least squares, eigenvalue problems, singular value decomposition.

**Rules & Requirements**
**Requisites:** Prerequisite, MATH 661.
**Grading Status:** Letter grade.
**Same as:** MATH 662, COMP 662.

**ENVR 666. Numerical Methods. 3 Credits.**
Numerical methods for solving problems arising in sciences and engineering. Solution of linear equations using direct and iterative approaches, solution of nonlinear systems of algebraic equations, solution of ordinary differential equations including single and multistep methods, and methods for stiff systems of ODEs and collocation methods for linear and nonlinear PDEs.

**Rules & Requirements**
**Requisites:** Prerequisites, COMP 116 and MATH 383.
**Grading Status:** Letter grade.

**ENVR 668. Methods of Applied Mathematics I. 3 Credits.**
Requires an undergraduate course in differential equations. Contour integration, asymptotic expansions, steepest descent/stationary phase methods, special functions arising in physical applications, elliptic and theta functions, elementary bifurcation theory.

**Rules & Requirements**
**Grading Status:** Letter grade.
**Same as:** MATH 668.

**ENVR 669. Methods of Applied Mathematics II. 3 Credits.**
Perturbation methods for ODEs and PDEs, WKBJ method, averaging and modulation theory for linear and nonlinear wave equations, long-time asymptotics of Fourier integral representations of PDEs, Green's functions, dynamical systems tools.

**Rules & Requirements**
**Requisites:** Prerequisite, MATH 668.
**Grading Status:** Letter grade.
**Same as:** MATH 669.

**ENVR 671. Environmental Physics I. 3 Credits.**
A first graduate-level course in physical principles relevant to environmental systems. Topics include dimensional analysis, tensor calculus, conservation of mass and momentum. Applications are considered from natural and engineered systems and across all relevant media. Focus is on the development of mechanistic representation of environmental systems.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 672. Environmental Physics II. 3 Credits.**
Second part of a graduate-level sequence in physical principles relevant to environmental systems. Topics include turbulence, conservation of energy, multiscale methods, and thermodynamics. Applications are considered from natural and engineered systems and across all relevant media. Focus is on development of mechanistic representation of environmental systems.

**Rules & Requirements**
**Requisites:** Prerequisite, ENVR 671.
**Grading Status:** Letter grade.

**ENVR 673. Hydraulics for Environmental Engineering. 3 Credits.**
Permission of the instructor for undergraduates. This course teaches practical basics of how to solve environmental engineering problems in the hydraulics of pipes, pumps, networks, and open channels. The course is a mix of classroom lectures, problem-solving sessions, and laboratory sessions.

**Rules & Requirements**
**Requisites:** Prerequisites, MATH 231 and PHYS 114.
**Grading Status:** Letter grade.

**ENVR 675. Air Pollution, Chemistry, and Physics. 3 Credits.**
This class is designed for graduate students planning for research in air pollution, emphasizing chemical kinetics and engineering approaches to problem solving in addition to atmospheric structure, meteorology, and modeling. We address problems of stratospheric and tropospheric ozone, particulate matter, and acid rain. We emphasize quantitative problem solving in homework.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 683. Water-Health Research I. 2 Credits.**
Permission of the instructor for undergraduates and nonmajors. Introduces students to methods for research conception, design, planning, and implementation in fields related to water and its impacts on health. Students study approaches and tools that may be applied in water-related research and are coached in developing their own research design.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 684. Water-Health Research II. 2 Credits.**
Permission of the instructor for undergraduates and nonmajors. Familiarizes students with the principles of scientific communication with an emphasis on scientific writing and oral presentations. Using their own water and health research, students learn how to communicate effectively in informal settings and how to prepare for interviews with the media.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 685. Water and Sanitation Planning and Policy in Less Developed Countries. 3 Credits.**
Permission of the instructor. Seminar on policy and planning approaches for providing improved community water and sanitation services in developed countries. Topics include the choice of appropriate technology and level of service, pricing, metering, and connection charges; cost recovery and targeting subsidies to the poor; water venting; community participation in the management and operation of water systems; and rent-seeking behavior in the provision of water supplies.

**Rules & Requirements**
**Grading Status:** Letter grade.
**Same as:** PLAN 685.

**ENVR 687. Writing for Journal Publication on Water and Sanitation Hygiene, Health, and Development. 2 Credits.**
This course familiarizes students with scientific paper writing and coaches students towards journal manuscript submission. Students should have a data set of results. Sessions begin with student presentations and discussion, followed by a brief preparatory lecture on the next assignment. Substantive preparation is required between sessions.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 691H. Honors Research. 3 Credits.**
Permission of the instructor. Directed readings or laboratory study of a selected topic. A written report is required in the form of an honors thesis (ENVR 692H).

**Rules & Requirements**
**IDEAs in Action Gen Ed:** RESEARCH.
**Repeat Rules:** May be repeated for credit. 6 total credits. 2 total completions.
**Grading Status:** Letter grade.

**ENVR 692H. Honors Thesis. 3 Credits.**
Students complete honors research projects.

**Rules & Requirements**
**IDEAs in Action Gen Ed:** RESEARCH.
**Grading Status:** Letter grade.

**ENVR 695. Undergraduate Research. 1-3 Credits.**
Directed readings or laboratory study. Written reports are required. May be taken more than once for credit. Three to nine hours per week.

**Rules & Requirements**
**IDEAs in Action Gen Ed:** RESEARCH.
**Repeat Rules:** May be repeated for credit. 6 total credits. 2 total completions.
**Grading Status:** Letter grade.

**ENVR 698. Senior Capstone Course. 3 Credits.**
This capstone course covers a range of issues in public health ethics, particularly focused on environmental health. Students will work on a team-based project over the course of the semester. The projects will be focused on topics that have ethical relevance and will integrate students' knowledge in environmental health.

**Rules & Requirements**
**Grading Status:** Letter grade.

## Graduate-level Courses

**ENVR 701. Ecology of Aquatic Plants and Wetland Ecosystems. 3 Credits.**
Adaptations of aquatic plants and microorganisms of land-water interface regions of lakes and rivers, their nutrition, growth, population dynamics, competition, herbivory, productivity, physiological control measures. Wetlands functions, values to humans. Three lecture hours per week.

**Rules & Requirements**
**Requisites:** Prerequisites, BIOL 101, CHEM 101, 102; permission of the instructor for students lacking the prerequisites.
**Grading Status:** Letter grade.

**ENVR 703. Proposal Writing for Environmental Research. 3 Credits.**
This course is intended for PhD students to become familiar with the methods for writing a research proposal, grant application or response to a request for proposal/application (RFP/RFA). The course will provide orientation in conception, planning and implementation of writing a grant.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 704. Critical Analysis of Environmental Research. 1 Credits.**
This 1 credit course is intended for PhD students. Students will learn how to conduct formal peer reviews for environmental health, science and engineering journals. In so doing, they will develop skills needed to critically evaluate environmental research.

**Rules & Requirements**
**Repeat Rules:** May be repeated for credit. 2 total credits. 2 total completions.
**Grading Status:** Letter grade.

**ENVR 705. One Health: Philosophy to Practical Integration. 1-3 Credits.**
This course explores the intersection of human, animal, and environmental health and facilitates the understanding of health as an inexorably linked system requiring multidisciplinary collaborative efforts. The One Health concept demonstrates the importance of a holistic approach to disease prevention and the maintenance of human, animal, and environmental health.

**Rules & Requirements**
**Grading Status:** Letter grade.
**Same as:** PUBH 705.

**ENVR 707. Advanced Toxicology. 3 Credits.**
Cellular and physiological basis of toxicity of environmental chemicals, with emphasis on inhalation toxicology, developmental toxicology, immunotoxicology, radiation toxicology, renal toxicology, and neurotoxicology. Three lecture hours per week.

**Rules & Requirements**
**Requisites:** Prerequisite, PHCO 702; permission of the instructor for students lacking the prerequisite.
**Grading Status:** Letter grade.
**Same as:** TOXC 707, PHCO 707.

**ENVR 710. Environmental Process Biotechnology. 3 Credits.**
Required preparation, a previous or concurrent course in microbiology. Theory and practice of biological processes used to remove contaminants from environmental media, including water, wastewater, soil, and air.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 722. Toxicology Seminar III. 1 Credits.**
Presentations by outside invited speakers, local faculty, advanced graduate students, and postdoctoral trainees. Topics will cover all areas of research in toxicology. One hour per week.

**Rules & Requirements**
**Grading Status:** Letter grade.
**Same as:** TOXC 722.

**ENVR 724. Current Topics in Environmental Analytical Chemistry. 1 Credits.**
Students will select, critically review, and discuss current research papers for content, relevance, innovation, and clarity. Papers can be from any aspect of the environmental sciences. Two lecture hours per week, every other week.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 725. Environmental Physical-Organic Chemistry. 3 Credits.**
The physical chemistry of the partitioning, exchange, and chemical transformation of organic contaminants in the water, air, and soil environments.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 726. Instrumental Methods for the Chemical Analysis of Environmental Samples. 3 Credits.**
Required preparation, basic or general chemistry. Emphasis on acquiring laboratory skills and hands-on experience with instrumentation including chromatography and mass spectrometry; sample handling and preparation; quality assurance and control. Three lecture hours or one lecture hour and four laboratory hours per week.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 730. Computational Toxicology and Exposure Science. 3 Credits.**
This course provides an introduction to the field of computational toxicology and exposure science. Students will be equipped to understand databases and tools that can more efficiently evaluate chemical-biological and chemical-disease relationships. Students will be expected to use excel and R/Rstudio, and run script that is provided by the instructor as a gentle 'welcome' to the coding environment. The course is designed for students in public health, toxicology, exposure science, epidemiology, and related disciplines.

**Rules & Requirements**
**Requisites:** Prerequisites, Basic knowledge of environmental science, chemistry, and biology is required, familiarity with excel and basic data software, and students are required to be willing to run R/Rstudio and other example coding packages, with script largely already provided for.
**Grading Status:** Letter grade.

**ENVR 732. Health Effects of Outdoor and Indoor Air Pollution. 3 Credits.**
Required preparation, knowledge of basic human physiology and biochemistry helpful. Assessing health effects of air pollutants on normal and diseased human populations, including children. Physiology, cellular and molecular biology, immunology, genetics, dosimetry will be integrated. Three lecture hours per week.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 742. Theory and Practice of Evaluating Human Health Risks of Chemicals. 2 Credits.**
ENVR/TOXC 707 and ENVR 470 are highly recommended. This course will provide students who already have good knowledge of the basic principles of toxicology and environmental health with real-life examples of how the information is integrated for the purpose of judging what chemical exposures may pose risk to human health.

**Rules & Requirements**
**Requisites:** Prerequisites, ENVR/TOXC/BIOC 442 or ENVR 430.
**Grading Status:** Letter grade.

**ENVR 749. Biochemical Toxicology. 3 Credits.**
Required preparation, one course in biochemistry. Biochemical actions of toxicants and assessment of cellular damage by biochemical measurements. Three lecture hours per week.

**Rules & Requirements**
**Requisites:** Prerequisite, CHEM 430; permission of the instructor for students lacking the prerequisites.
**Grading Status:** Letter grade.
**Same as:** BIOC 749, TOXC 749.

**ENVR 753. Programming for Environmental Applications. 1 Credits.**
A one-credit course designed to give new graduate students the tools to apply the Python programming language to their own research and work. The course covers introductory material including the variable types and data structures and progresses to more advanced capabilities, such as regression analysis and optimization. The course is heavily focused on bi-/weekly assignments meant to reinforce the lectures and highlights basic applications in environmental science. Companion course to ENVR 755.

**Rules & Requirements**
**Requisites:** Corequisite, ENVR 755.
**Grading Status:** Letter grade.

**ENVR 754. Air Pollution Control. 3 Credits.**
Engineering control of air pollution control systems and discussion of air pollution regulation and standards. Spring. (Odd-numbered years.)

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 755. Analysis of Water Resource Systems. 3 Credits.**
Permission of the instructor for nonmajors. Use of mathematical models to design and evaluate regional water supply and treatment systems. Engineering and economic methods are incorporated into quantitative analyses of regional scenarios. Social and political aspects also discussed. Three lecture hours per week.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 757. Water and Wastewater Treatment Plant Design. 3 Credits.**
The application of the theory of water and wastewater treatment to the design of municipal facilities. The course includes the principles of design and modern design practices. Design and analysis of design of specific works for water and wastewater treatment.

**Rules & Requirements**
**Requisites:** Prerequisites, ENVR 710 and 756.
**Grading Status:** Letter grade.

**ENVR 758. Environmental Engineering Project. 3 Credits.**
Permission of the instructor. Ad hoc project designed for a student team in addressing a current problem in environmental engineering. Projects may include laboratory or pilot-scale studies, collection and analysis of data from full-scale systems, or comprehensive analysis of relevant problems in environmental engineering practice. Three lecture hours per week.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 759. Multiphase Transport Phenomena. 3 Credits.**
Continuum mechanical approach to formulating mass, momentum, energy, and entropy equations to describe multiphase transport phenomena. Three lecture hours per week.

**Rules & Requirements**
**Requisites:** Prerequisite, ENVR 453.
**Grading Status:** Letter grade.

**ENVR 760. Uncertainty Quantification for Environmental Systems. 3 Credits.**
Quantitative assessment of how uncertainty in mechanistic models (subsurface, ocean, atmosphere, global climate), parameters, and auxiliary conditions of a model is manifest in uncertainty in model predictions. Topics include: model formulations, statistical tools, Monte Carlo methods, moment methods, estimation methods, statistical simulation methods, reduced order models, and data assimilation approaches.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 761. Numerical ODE/PDE, I. 3 Credits.**
Single, multistep methods for ODEs: stability regions, the root condition; stiff systems, backward difference formulas; two-point BVPs; stability theory; finite difference methods for linear advection diffusion equations.

**Rules & Requirements**
**Requisites:** Prerequisites, MATH 661 and 662.
**Grading Status:** Letter grade.
**Same as:** MATH 761, MASC 781.

**ENVR 762. Numerical ODE/PDE, II. 3 Credits.**
Elliptic equation methods (finite differences, elements, integral equations); hyperbolic conservation law methods (Lax-Fiedrich, characteristics, entropy condition, shock tracking/capturing); spectral, pseudo-spectral methods; particle methods, fast summation, fast multipole/vortex methods.

**Rules & Requirements**
**Requisites:** Prerequisite, MATH 761.
**Grading Status:** Letter grade.
**Same as:** MATH 762, EMES 782.

**ENVR 763. Mathematical Modeling I. 3 Credits.**
Nondimensionalization and identification of leading order physical effects with respect to relevant scales and phenomena; derivation of classical models of fluid mechanics (lubrication, slender filament, thin films, Stokes flow); derivation of weakly nonlinear envelope equations. Fall.

**Rules & Requirements**
**Requisites:** Prerequisites, MATH 661, 662, 668, and 669.
**Grading Status:** Letter grade.
**Same as:** MATH 768, MASC 783.

**ENVR 764. Mathematical Modeling II. 3 Credits.**
Current models in science and technology: topics ranging from material science applications (e.g., flow of polymers and LCPs); geophysical applications (e.g., ocean circulation, quasi-geostrophic models, atmospheric vortices).

**Rules & Requirements**
**Requisites:** Prerequisites, MATH 661, 662, 668, and 669.
**Grading Status:** Letter grade.
**Same as:** MATH 769, EMES 784.

**ENVR 765. Space Time Exposure Mapping and Risk Assessment. 3 Credits.**
Theory and MATLAB numerical implementation of linear geostatistics (simple/ordinary/universal kriging) and modern geostatistics (Bayesian Maximum Entropy) to map environmental and health processes varying across space and time. Applications in exposure assessment, environmental epidemiology, medical geography, and risk assessment.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 766. Stochastic Environmental Health Modeling. 3 Credits.**
Required preparation, statistics. A holistic/stochastic perspective, spatiotemporal random field modeling of environmental exposure and biological variabilities. Uncertainty in environmental exposure. Biomarkers and population damage indicators for epidemiological analysis. Cell-based stochastic differential equations. Three lecture hours per week.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 767. Modeling for Environmental Risk Analysis. 3 Credits.**
Mathematical methods for development of advanced models in environmental risk assessment, including exposure assessment and exposure-response assessment, are developed and applied. Three lecture hours per week.

**Rules & Requirements**
**Requisites:** Prerequisite, ENVR 470.
**Grading Status:** Letter grade.

**ENVR 768. Microenvironmental Air Flow Modeling. 3 Credits.**
Required preparation, fluid mechanics. Permission of the instructor. Applications of finite element and vortex methods for modeling air flows of significance in industrial hygiene applications. Three lecture hours per week.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 769. Quantitative Methods for Exposure Science. 3 Credits.**
SAS regression and statistics, two ENVR courses (e.g. 430, 470, 707, 740, 770, 890), or permission of the instructor. Mathematical approaches for assessing environmental and/or occupational exposures to chemicals in human populations using stochastic (group) statistics, regression analysis and modeling, and pharmacokinetic modeling; focus on human biomarker data.

**Rules & Requirements**
**Requisites:** Prerequisite, BIOS 511.
**Grading Status:** Letter grade.

**ENVR 770. Biological Monitoring. 3 Credits.**
This course provides both practical and theoretical information on biological monitoring of chemical exposures and how to evaluate and interpret exposure data. Three lecture hours per week and a term paper (three credit hours).

**Rules & Requirements**
**Requisites:** Prerequisite, ENVR 430.
**Grading Status:** Letter grade.

**ENVR 771. Exposure Analysis. 3 Credits.**
This course is intended for students interested in research involving exposure to environmental contaminants. The course focuses on the integration of engineering principles, with statistical tools to enhance inference. Statistical models based on the Johnson system of distributions are explored for the analysis data including exposure-biomarker relationships.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 773. Modeling Atmospheric Chemistry. 3 Credits.**
Air pollution is formed through thousands of chemical reactions. Computer models are used to simulate this complex chemistry and used to make policy. Current computational restraints force a simplified representation of atmospheric chemistry in these models, and the focus of this course is the implications of this on predictions.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 775. Global Climate Change: Interdisciplinary Perspectives. 1 Credits.**
This class addresses the complexity and importance of global climate change from several disciplines. A top expert will lecture each week, addressing these themes: the science of human influences on climate; impacts and adaptation; global energy and technology; communication; and economics and international solutions.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 777. Air Quality and Atmospheric Sciences Seminar. 1 Credits.**
This course gives students practice organizing a scientific presentation and speaking in front of an audience and promoting interdisciplinary interaction. Students will research topics and organize presentations for faculty and other students. The topics may be any aspect of air quality and atmospheric sciences.

**Rules & Requirements**
**Repeat Rules:** May be repeated for credit. 3 total credits. 3 total completions.
**Grading Status:** Letter grade.

**ENVR 779. Project Management and Implementation. 3 Credits.**
This course presents program/project management and implementation concepts, tools and methods applicable to global public health projects. Students will learn and practice the skills necessary to successfully plan, implement and evaluate a project including how to organize and lead successful project teams in complex environments. This course is designed to give students the skills to successfully develop, engage and support global public health projects.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 780. Urban Water Services Planning and Design. 3 Credits.**
This course helps students learn and apply principles of water supply sewerage and drainage planning and design, work collaboratively on real-world problems with insufficient data, and present technical findings in a clear and convincing way.

**Rules & Requirements**
**Requisites:** Prerequisite, ENVR 673; permission of the instructor for students lacking the prerequisite.
**Grading Status:** Letter grade.

**ENVR 781. Water Resources Planning and Policy Analysis. 3 Credits.**
Water resources planning and management. Federal and state water resources policies. Analytical skills to identify environmental problems associated with urban water resources development.

**Rules & Requirements**
**Grading Status:** Letter grade.
**Same as:** PLAN 781.

**ENVR 782. Occupational Health Nursing II: Occupational Health Programming. 3 Credits.**
Continuation of ENVR 791. Role components of occupational health nursing with emphasis on designing, implementing, and evaluating occupational health programs. Emphasis on analysis of factors influencing the delivery of health care at the worksite.

**Rules & Requirements**
**Requisites:** Prerequisite, ENVR 791; Permission of the instructor for students lacking the prerequisite.
**Grading Status:** Letter grade.

**ENVR 783. Setting Environmental Priorities. 3 Credits.**
This course is intended to develop a student's ability to estimate the relative merits of research and policy actions in several broad environmental areas, with attention to the associated uncertainty. Criteria to be included are both quantitative and qualitative, with an emphasis on public health, environmental, and economic metrics.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 784. Community-Driven Research and Environmental Justice. 3 Credits.**
In this course, students will learn from community residents who challenge public health scientists to conduct research on environmental and occupational hazards that impact their health.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 785. Public Investment Theory. 3 Credits.**
Basic theory, process, and techniques of public investment planning and decision making, involving synthesis of economic, political, and technologic aspects. Theory underlying benefit-cost analysis, adaptation to a descriptive and normative model for planning public projects and programs.

**Rules & Requirements**
**Requisites:** Prerequisite, PLAN 710.
**Grading Status:** Letter grade.
**Same as:** PLAN 785.

**ENVR 786. Environmental Quality Management. 3 Credits.**
Planning and analysis of regional environmental system with a focus on management of mass flows that affect the quality of the regional environment.

**Rules & Requirements**
**Grading Status:** Letter grade.
**Same as:** PLAN 786.

**ENVR 787. Applied Environmental Finance: How to Pay for Environmental Services. 3 Credits.**
How can governments, communities, organizations, and businesses fund environmental services? This applied course reviews the diverse tools and strategies that environmental service providers use to pay for programs. The course will focus on environmental services related to: drinking water, wastewater, storm-water, watershed protection, energy efficiency, renewable energy, sustainability, and wetlands.

**Rules & Requirements**
**Grading Status:** Letter grade.
**Same as:** PUBA 787, PLAN 787.

**ENVR 788. Managing Environmental Financial Risk. 3 Credits.**
As society's exposure to environmental risks grows, it has become increasingly important to find innovative tools for mitigating these risks. This course is designed to introduce students to the fundamentals of financial risk management within an environmental context, with an emphasis on developing coupled environmental-financial systems models.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 789. International Field Research. 2 Credits.**
Course offers theoretical foundations in cultural sensitivity, personal security, communication, organization and research along with guided practical exercises in conducting international field research. The result is the development of cross-cultural and applied research skills that prepare the student to conduct successful field research.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 791. Occupational Health Nursing I: Occupational Health Assessment. 3 Credits.**
Occupational Health Nursing I: Occupational Health Assessment.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 793. Writing Scientific Papers for WaSH Peer-Reviewed Journal Publication. 2 Credits.**
A two-credit, fall course open to graduate students with a complete data set with results to communicate to other scientists as a scientific paper or manuscript submission to peer-reviewed journals on an aspect of water and health. Undergraduate honors students admissible at discretion of the instructor.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 795. Critical issues in work, worker and workplace health. 3 Credits.**
This course prepares students to contribute as members of an interdisciplinary team to protect and promote workers' health. Students will learn that work is a social determinant of health and explore the context in which worker health protection/promotion practitioners work. Students will be able to summarize key regulations and policies that impact work and worker health.

**Rules & Requirements**
**Grading Status:** Letter grade.
**Same as:** HBEH 785.

**ENVR 797. Fundamentals of Industrial Hygiene. 3 Credits.**
Provides broad understanding of industrial hygiene. Major emphasis is recognition of hazards in the workplace, evaluation of measurement of those hazards, and application of control strategies. The course will focus on introductory level industrial hygiene concepts associated with the anticipation, recognition, evaluation, control, and confirmation of control of occupational health hazards.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 850. Systems Analysis in Environmental Planning. 3 Credits.**
Required preparation, calculus. Applications of systems analysis techniques to the management of environmental quality.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 890. Problems in Environmental Sciences and Engineering. 1-21 Credits.**
For students who wish to undertake individual or special topics study of a specific problem in environmental sciences and engineering. The subject and requirements of the project are arranged with the faculty in each individual instance. One or more hours per week. Permission of the department.

**Rules & Requirements**
**Repeat Rules:** May be repeated for credit; may be repeated in the same term for different topics.
**Grading Status:** Letter grade.

**ENVR 981. Environmental Sciences Practicum. 1-9 Credits.**
A practical experience in public health/environmental health sciences.

**Rules & Requirements**
**Repeat Rules:** May be repeated for credit.
**Grading Status:** Letter grade.

**ENVR 989. Environmental Crisis Management. 3 Credits.**
This course will focus on practical solutions to public health related disasters where students extend, critique, and apply knowledge gained in the classroom. This experience-based course will have flexibility to allow for substantive contributions from students of all backgrounds enrolled in the Gillings School of Global Public Health.

**Rules & Requirements**
**Grading Status:** Letter grade.

**ENVR 990. Environmental Engineering Brief. 1.5-3 Credits.**
Students in ENVR 990 will work in concert with their advisor to identify and define an engineering problem, describe a solution to the problem, and develop a plan for implementation. These briefs serve as a foundation for the student's master's technical report.

**Rules & Requirements**
**Repeat Rules:** May be repeated for credit. 15 total credits. 5 total completions.
**Grading Status:** Letter grade.

**ENVR 991. Research in Environmental Sciences and Engineering. 1-9 Credits.**
Consultation with the faculty and approval of subject and proposed program required. Permission of the instructor. May be repeated. Hours and credits to be arranged.

**Rules & Requirements**
**Repeat Rules:** May be repeated for credit.
**Grading Status:** Letter grade.

**ENVR 992. Master's Technical Report. 3 Credits.**
The technical report requirement for M.S.P.H., M.P.H., and M.S.E.E. candidates is satisfied by the extensive study of a problem in environmental sciences and engineering.

**Rules & Requirements**
**Repeat Rules:** May be repeated for credit.

**ENVR 993. Master's Research and Thesis. 3 Credits.**
**Rules & Requirements**
**Repeat Rules:** May be repeated for credit.

**ENVR 994. Doctoral Research and Dissertation. 3 Credits.**
**Rules & Requirements**
**Repeat Rules:** May be repeated for credit.

*Following the faculty member's name is a section number that students should use when registering for independent studies, reading, research, and thesis and dissertation courses with that particular professor.*

# Professors

**Joe Brown (137),** Water and Sanitation, Environmental Health Microbiology; Director, Water Institute (Interim); Director, Engineering Programs
**Gregory W. Characklis (98),** Water Resources Engineering, Economics and Management; Director, Institute for Risk Management and Insurance Innovations
**Orlando Coronell (10),** Physical and Chemical Processes for Water Treatment, Membrane Technology, Granular Sorbents; Associate Chair for Academics
**Rebecca C. Fry (7),** Toxicogenomics, Epigenetics, Genetics, Toxicology; Director, Institute for Environmental Health Solutions; Director, Institute for Environmental Health Solutions; Department Chair
**Avram Gold (43),** Environmental Chemistry
**Kun Lu (37),** Microbiome, Exposome, Omics Profiling (Metabolomics, Proteomics, Lipidomics), DNA Adducts, Biomarker Development, Cancer, Chronic Inflammation, Children's Health
**Richard A. Luettich Jr. (68),** Marine Sciences, Coastal Physics, Hurricane Storm Surge Modeling; Director, Institute of Marine Science
**Christopher S. Martens (92),** Marine Sciences, Biogeochemistry
**Cass T. Miller (59),** Porous Medium Systems, Environmental Physics, Environmental Modeling

**Rachel T. Noble (110),** Marine Microbial Ecology, Water Quality Microbiology, Non-Point Source (e.g., Storm water), Contamination of Receiving Waters
**Leena A. Nylander-French (95),** Skin and Inhalation Exposures to Toxicants, Exposure Modeling; Director, Occupational Safety and Health Education and Research Center
**Hans W. Paerl (65),** Aquatic Microbial Ecology, Marine and Freshwater Nutrient Cycling
**Michael C. Piehler (33),** Marine Environmental Sciences, Environmental Microbial Ecology
**Jason Surratt (30),** Atmospheric Chemistry, Secondary Organic Aerosols, Heterogeneous Chemistry, Air Pollution
**Barbara J. Turpin (32),** Atmospheric Chemistry, Air Pollution and Human Exposure; Director, Graduate Studies
**William Vizuete (6),** Atmospheric Modeling, Air Pollution, Environmental Engineering, Atmospheric Chemistry
**Paul B. Watkins,** Drug Safety Sciences, Pharmacotherapy and Experimental Therapeutics, Genomics Technologies
**J. Jason West (16),** Air Pollution, Climate Change, Atmospheric Modeling, Global Health, Environmental Policy, Environmental Engineering
**Dale Whittington (70),** Water Resources Economics, International Development

## Associate Professors

**Julia Rager (130),** Environmental Risk Assessment, Exposure Assessment, Genetics, Toxicology; Associate Chair for Strategic Initiatives
**Marc L. Serre (100),** Space/Time Statistics, Exposure Assessment, Environmental Modeling, Hydrology, Geostatistics, GIS, Environmental Epidemiology, Risk Assessment, Medical Geography

## Assistant Professors

**Noah Kittner (131),** Energy Systems Analysis, Sustainability Science, Energy and Environmental Policy, Energy in Underserved communities
**Musa Manga (5),** Environmental Engineering, Water, Sanitation, Water Resource Management

## Research Professors

**Bill Gray,** Hydrology, Porous Media Flow, Environmental Thermodynamics
**Glenn Morrison (124),** Indoor Air, Surface Chemistry, Human Exposure
**Mark D. Sobsey,** Environmental Health Microbiology, Virology, Water, Sanitation and Hygiene

## Research Associate Professor

**Zhenfa Zhang,** Synthetic Organic Chemistry

## Research Assistant Professors

**Ryan Cronk (11),** Global Water, Sanitation and Hygiene (WaSH), Environmental Risk Assessment
**Michael Fisher (136),** Global Water, Sanitation and Hygiene (WaSH)
**Megan Lott,** Environmental Microbiology, Microbes of the Built Environment and Wastewater-based Epidemiology
**Timothy Weigand (108),** Fluid Dynamics, AI/Machine Learning, Mechanistic Modelling, Computational Science

## Teaching Associate Professors

**Amanda Northcross (134),** Exposure Assessment, Air Pollution, Global Health; Director, Undergraduate Studies (B.S.P.H. and Assured Enrollment Programs)
**John Staley (135),** Occupational Health and Safety; NC OSHERC; NIOSH Center for Excellence: the Carolina Center for Healthy Work Design and Worker Well-being

## Clinical Associate Professor

**Courtney Woods (51),** Health Equity, Systems Modeling, Environmental Epidemiology, Risk Assessment, Global Health; Director, E.C.H. M.P.H. Program

## Adjunct Professors

**Sarav Arunachalam,** Air Quality Modeling, Analyses, and Health Risk; Environmental Policy
**Stephen Bennett,** Natural Hazards Risk Modeling, Climate Risks for Reinsurance Underwriting, Extreme Weather and Climate Preparation and Response
**Linda S. Birnbaum,** Xenobiotic Metabolism, Biochemical Toxicology
**Clarissa Brocklehurst,** Water Supply and Sanitation
**Daniel L. Costa,** Pulmonary Toxicology
**Felix Dodds,** Sustainable Development, Finance, Climate, Environmental Security
**Jonathan Freedman,** Toxicology, Chemical Exposure, Risk Assessment
**Shabbir H. Gheewala,** Life Cycle Assessment
**Jackie MacDonald Gibson,** Water Quality, Environmental Justice, Risk Assessment
**M. Ian Gilmour,** Immunotoxicology
**Marc Jeuland,** Sustainability, Climate Resilience, Water and Health, Environmental Health Cost-benefit Anaylsis
**Valeria Ochoa-Herrera,** Biological and Physico-Chemical Wastewater Treatment, Bioremediation, Biotechnology, Sustainability
**Stephanie Padilla,** Biomolecular and Computational Toxicology
**David Peden,** Immunotoxicology, Cardiopulmonary Toxicology, Translational and Clinical Research in Environmental Lung Disease
**Joseph Pinto,** Atmospheric Modeling
**Joachim Pleil,** Exposure Assessment
**Havala Pye,** Air Quality Modeling
**Ana Rappold,** Environmental Exposure Assessment, Climate Change, Wildfires and Air Quality
**Jacky Rosati Rowe,** Exposure Assessment
**Aaron Salzberg,** Water Supply Planning and Sanitation; Director, Water Institute
**ManishKumar Shrivastava,** Atmospheric Chemistry, Secondary Organic Aerosols, Earth Systems Modeling, Climate and Health Impacts
**James M. Samet (67),** Mechanistic Toxicology, Cardiopulmonary Toxicology, Ambient Air Pollutants
**Jill R. Stewart (26),** Water Quality Microbiology, Ecological Assessment and Prediction
**Miroslav Styblo (79),** Nutritional Biochemistry and Biochemical Toxicology
**Bill Suk,** Hazardous Substances Remediation, Environmental Toxicology, Children's Environmental Health
**Cecilia Tan,** Mechanisms of Environmental Exposure and Disease, Physiologically-based Pharmacokinetic (PBPK) Modeling
**John Tomaro,** Research Collaborator for the Water Institute

## Adjunct Associate Professors

**Bok Haeng (B.H.) Baek**, Atmospheric Chemistry and Emission Models, Emissions Trends, Air Pollution Control Response
**Karsten Baumann,** Aerosol Chemistry
**Jared Bowden,** Air Quality and Climate Modeling

**Jada Brooks,** Health Equity, Community Engaged Research, Environmental Justice
**Kristin Isaacs,** Human Exposure Modeling, Risk Assessment
**Janice Lee,** Human Health Risk Assessment, Susceptibility, Mode of Action, Systematic Review
**Liz Naess,** Ambient Air Quality Data Analysis, Science and Policy, Health Equity
**Roger Sit,** Radiation Physics
**Thomas B. Starr,** Risk Assessment
**John Wambaugh,** Computational Toxicology and Exposure

## Adjunct Assistant Professors

**Celeste Carberry,** Toxicological Mechanisms and Health Effects of Environmental Exposures
**Rich Cravener,** Healthy, Safety and Industrial Hygiene; NC OSHERC; NIOSH
**Radhika Dhingra (132),** Air Pollution, Epidemiology, Epigenetics, Health Effects
**Crystal Lee Pow Jackson,** Occupational and Environmental Epidemiology
**Jordan Kern,** Environmental modeling, Systems Analysis, Financial Risk Management
**Hannah Liberatore,** Analytical Method Development for Per- and Polyfluoroalkyl Substances (PFAS) sampling and Combustion Ion Chromatography
**Lucas Rocha Melogno,** Environmental Health Science, Policy Translation
**Javad Roostaei,** Environmental Science, Machine Learning, Data Science, AI
**Antonia Sebastian,** Environmental Hazards, Flood Risk Reduction
**Lauren Eaves Sellers,** Environmental Exposure, Prenatal Health Effects, and Epigenetics
**David Singleton,** Environmental Microbiology
**Frank J. Stillo, III,** Risk Assessment, Risk Communication of Environmental Exposures in Drinking Water
**W. Jon Wallace,** Occupational Safety and Health Education

## Professors Emeriti

**Jamie Bartram**
**Russell F. Christman**
**Douglas Crawford-Brown**
**Francis A. DiGiano**
**Michael Flynn**
**Donald L. Fox**
**Harvey E. Jeffries**
**Pete Kolsky**
**Donald T. Lauria**
**David Leith**
**David H. Moreau**
**Mark S. Shuman**
**Stephen C. Whalen**
**Donald Willhoit**

## Clinical Professor Emeritus

**Donald E. Francisco**

## Contact Information

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