MPA in Environmental Science and Policy

ENV U6220: Environmental Chemistry and Toxicology

Summer Semester 2005

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Course Description: **Environmental chemistry** is the study of the processes that affect the fate and transport of specific compounds that act as contaminants on local- to global-scale levels. In general, the compounds under consideration tend to be anthropogenic contaminants (those compounds, both organic and inorganic, released into the environments from human activities). The behavior of contaminants is influenced by physical, chemical, and biological processes naturally occurring within various ecosystems. This course describes these processes and the extent to which they affect different classes of contaminants.

However, environmental chemistry does not limit itself to the study of processes that affect synthetic or human-produced compounds (their reaction rate, speciation, degradation, sorption, etc.). In the context of this course, we consider the term "environmental chemistry" in a broader geochemical context. Indeed, we recognize that in some areas of the world, the speed and scale of environmental perturbations seem to be of such a magnitude that they have led to regional and global geochemical disruptions with subsequent releases of naturally occurring surface/subsurface materials that can generate a certain amount of toxic burden within an ecosystem.

The environmental chemistry section of the course is divided into three subsections of the global environment: Water, Soils and Sediment, and Atmosphere. Within each subsection, we will first describe the system in terms of physical processes and chemical constituents. Using case studies of selected contaminants potentially found in each system, we will then explore the fate (i.e. reactions) and transport modes that may affect the potential availability of these contaminants (or how environmental quality criteria are adversely affected) and lead to toxicological effects at the ecosystem level.

Environmental toxicology is the study of the effects of different contaminants on the health of all organisms within an ecosystem, with a particular focus on human health. While toxicologists study a wide variety of toxicants, from naturally occurring poisons (venoms) to synthetic chemicals, this course will emphasize anthropogenic toxicants, in the context of how (and whether) exposure to such toxicants should be controlled: risk assessment. Toxicological and epidemiological principles are used primarily to provide (uncertain) quantitative estimates of the harm associated with a given level of exposure: dose-response. Using a dose-response relationship necessitates quantifying exposure, an uncertain endeavor that relies on understanding human physiology and behavior. The quantitative estimates of harm from anthropogenic activity that risk assessment gives are just the starting point for the challenge of risk management: "What do we do now?" The resulting decisions are influenced by both economic factors (e.g., cost-benefit analysis) and psychological factors (e.g., risk perception).

In both the environmental chemistry and environmental toxicology sections, we have decided to use an "environmental principles" approach rather than describe all the possible alterations for each particular set of anthropogenic contaminants. Using the knowledge gained from this course, each student will be able to estimate the environmental and toxicological fates and effects of groups of compounds given its chemical nature and the system within which the compound is released. Most importantly, this course uses an approach of "authentic inquiry" in its pedagogical approach, namely that students are exposed to authentic methods of scientific inquiry rather than a suite of algorithmic solutions to specific environmental issues. The main goal of this course is to foster an understanding of how environmental scientists think and solve environmental issues and most importantly to develop an expertise in assessing the validity of scientific research and its conclusions.

Course Outline: The approach of the course will follow a general sequence of themes that will 1) define general chemistry concepts, 2) introduce the notion of chemical reactions and transport modes in different environments, and 3) define chemical mobility (and thus potential bioavailability) and reactivity based on the nature of chemicals and the media in which they occur (i.e. water, solids, air). The Environmental toxicology segment will follow the basic outline of risk assessment: hazard identification, exposure assessment, dose-response evaluation, and risk characterization, followed by risk management: how to use the numbers from risk assessment.

Daily Activities: ***Lecture sessions*** will include discussion and explanation of reading and/or web material, and how to apply critical thinking to environmental geochemistry and toxicology questions. The schedule below is a preliminary outline of the semester. Reading assignments will be provided and should be completed before the stated lecture date. Additional reading or reference material may be suggested during the course of the lecture. ***Laboratory sessions*** will involve both hands-on and minds-on exercises that will require either individual or small group work/reporting.

Evaluations:

1. Lab exercises will involve hands-on/minds-on exercises with reports due at a subsequent lab meeting.
2. A final paper in Chemistry will be base on a group project (~5 members per team) analyzing historical water quality data for the NY/NJ Harbor System and linking this work to past environmental regulations/management.
3. A final paper in Toxicology will also be done in small groups, analyzing risk assessment data and putting it into a form suitable for communicating to a lay audience.

The Final Projects will be due on Thursday August 18, 12PM. No Delays.

Policy on Late Submissions of Labs and Papers:
Ten percent (10%) of the grade will be deducted per day if the lab reports and group papers are submitted past the due date. Materials that are submitted more than one week late will not be accepted.

Grades will be based on the following:
- 60% on labs and assignments (50% for Chemistry and 50% for Toxicology)
- 40% on final papers/projects (50% for Chemistry and 50% for Toxicology)

Attendance Policy:
Attendance of lectures is strongly encouraged since complementary material, in addition to required readings, will be presented in lectures and included in examinations/discussions.

Course Outline
Environmental Chemistry Section

1) Class 1: June 02, Introduction – General Lecture - Chemistry Review
Objectives: (Louchouarn Lead)
- Introduction of course: goals and objectives, etc.
- Special Lecture "Double Standards in Public Policy: Acknowledging the burden on science in decision-making"
- Basic concepts of general chemistry: Review of chemical reactions and mass balance concepts, sorption, dissolution, etc

Read: Library Folder #1
Williams Sections 1.1-1.10

Lab 1: Math review #1

2) Class 2: June 9, Chemistry Review Continued: Mass Balance – Solutions – Acids and Bases
Objectives: (Louchouarn Lead)
- Solutions
- Sorption and rate constants
- Acid/Bases

Read: Library Folder #2
Williams Sections 1.10, 7.4-7.8

Lab 2: Sediment and Contaminant Dispersion in a River-Estuary System

3) Class 3: June 16, Global Acidification
Objectives: (Louchouarn Lead)
- Solution equilibrium (distribution of species in water): pH
- Climate change and the legacy of acid rain

Read: Library Folder: Acids & Bases
Williams Sections 7.9-7.11
Spiro & Stigliani Sections: 11.2, 12.2, 12.4

Lab 3: Scientific Inquiry: pH & Alkalinity

4) Class 4: June 23, Atmospheric Pollution: Urban impact of combustion/incineration

Objectives: (Louchouarn Lead)

- VOCs and O_3 production
- Combustion sources of particulate matter and their toxic burden

Read: Spiro & Stigliani: Chap. 9; Girard: Chap. 4.

Lab 4: Historical Reconstruction of Atmospheric Pollution in an Urban System

5) Class 5: June 30, Oxygen, Life, and the Cycling of Toxic Metals

Objectives: (Louchouarn Lead)

- NOM: Power of ecosystems and the redox scale
- Inorganic contaminants: The "global" players

Read: Spiro & Stigliani: Sections13.1-13.2, 17.5
Girard: Chap. 14

Lab 5: Contaminant Modeling in a Reservoir (applications to management strategies)

6) Class 6: July 07, Nutrients, wastes, and anthropogenic impact on aquatic ecosystems

Objectives: (Louchouarn Lead)

- Nutrient dynamics and aquatic eutrophication
- Coastal hypoxia: a case study of science-policy interaction

Read: Spiro & Stigliani: Sections13.3

Lab 6: Preparation of Final Project - Water Quality Trends in NY/NJ Harbor

Environmental Toxicology Section

7) Class 1: July14, Overview Of Human Health Risk Assessment; Hazard Identification

Objectives: (Ennever Lead)

- Goals and process of risk assessment and risk management
- Uncertainties: sources and implications
- The first step: Hazard identification
- Implications of flaws in hazard identification

Read: Packet #1

Lab 1: Quantitative Analysis of the Implications of Uncertainty in Hazard Identification

8) Class 2: Regulatory Toxicology and Dose-Response Assessment

Objectives: (Ennever Lead)

- Disparate approaches for carcinogens and noncarcinogens
- Extrapolation of carcinogenic effect: Science and belief
- Quantification of noncarcinogenic effect: Safety in numbers
- Uncertainties and their implications

Read: Packet #2; *"Risk and Decision Making"* pp. i-ii (Preface); 1-10

Lab 2: Availability, Scope, and Interpretation of Regulatory Toxicology Databases

9) Class 3: July 28, Basic Exposure Assessment Methods and Design
Objectives: (Ennever Lead)

- Numerical estimates of chemical concentrations in environmental samples
- Physiology and activity determinants of intake of air, water and soil
- Uncertainties resulting from assumptions and modeling

Read: Packet #3; *"Risk and Decision Making"* pp.12-52

Lab 3: Exposure Assessment: Prospects for Improvement

10) Class 4: August 4, Risk Characterization and Risk Management
Objectives: (Ennever Lead)

- Getting numbers from exposure and dose-response
- "Now what?": using the numbers
- Rules of thumb, cost-benefit analysis

Read: Packet #4; *"Risk and Decision Making"* pp.53-74; Appendix C

Lab 4: Risk Characterization: Completing the Process

11) Class 5: August 11, Risk Perception and Communication
Objectives: (Ennever Lead)

- The psychology of risk perception
- Effective and ineffective risk communication strategies
- Environmental chemistry and toxicology in environmental decision making

Read: Packet #5; "Risk and Decision Making" pp. 75-107

Lab 5: Communications about Risk among Stakeholders