CIEE Global Institute - Yucatan

Course name:	Environmental Chemistry
Course number:	(GI) CHEM 1003 MEME
Programs offering course:	Yucatan Open Campus Block: STEM and Society
Open Campus Track:	STEM and Society
Language of instruction:	English
U.S. Semester Credits:	3
Contact Hours:	45
Term:	Fall 2019

Course Description

Students use fundamental principles of chemistry to gain an understanding of the source, fate, and reactivity of compounds in natural and human-impacted environments. Emphasis will be placed on the environmental implications of the chemistry of the atmosphere, hydrosphere, and lithosphere. Students will explore the chemistry of environmental issues like climate change, air pollution, stratospheric ozone depletion, pollution, water treatment, and use of insecticides and herbicides. While there is no formal laboratory, students will explore applications with instructor and hands on demonstrations.

Learning Objectives

Upon completion of this course, students will:

- Use SI units, significant figures, the scientific method and basic chemical principles to approach chemical environmental processes and challenges
- Identify and describe major environmental issues at home, abroad and on local to global scales
- Employ chemistry to explain major biogeochemical processes and how humans change them
- Summarize the chemistry of major human-caused environmental changes to air, soil, water (freshwater and ocean) and their impacts on humans and nonhuman biodiversity
- Explore the chemistry of important tropospheric processes, including greehhouse gases, ozone depletion, photochemical smog and acid precipitation
- Understand the basic chemistry of the greenhouse effect, the sources and sinks of the family of greenhouse gases, and their implications for climate change
- Describe the nature, reactivity, and environmental fates of toxic organic chemicals, and the chemistry of natural waters and of their pollution and purification
- Research an important environmental chemistry problem and prepare a formal presentation on that issue

- Critically review news articles from the media on environmental chemistry issues and evaluate the accuracy of the science presented
- Become an enlightened and engaged stakeholder in matters related to environmental chemistry, at home and abroad

Course Prerequisites

None

Methods of Instruction

This course is taught through the use of lectures (CIEE instructors and guest speakers), discussions, laboratory demonstrations, interviews, readings, and an internet based research project. There are co-curricular visits to local research centers. CIEE-led lectures, readings, laboratory demonstratons and guided research with discussions supply foundational information, concepts, and terminology, and help students make necessary connections. Guest lectures and interviews with researchers, engineers, farmers, and environmental professionals offer unusual opportunities to learn about “on-the-ground” application of chemical principles applied to environmental problems.

Assessment and Final Grade

Participation	20%
Independent research project written and oral report	10%
Weekly Exams	20%
Problem Sets	20%
Essays on Speakers/Site Visits	10%
Final Exam	20%
TOTAL	100%

Course Requirements

Participation (20%)

Participation is valued as meaningful contribution in the digital and tangible classroom, utilizing the resources and materials presented to students as part of the course. Meaningful contribution requires students to be prepared in advance of each class session and to have regular attendance. Students must clearly demonstrate they have engaged with the materials as directed, for example, through classroom discussions, online discussion boards, peer-to- peer feedback (after presentations), interaction with guest speakers, and attentiveness on co-curricular and outside-of-classroom activities.

Attendance and class participation

Attendance is noted for each lecture, discussion session, and activity. As the 4-week session proceeds, students earn points for thoughtful commentary, questions, and participation in discussions and for attendance.

Independent research project written and oral report
Students will undertake an internet-based project to investigate the chemistry of a key environmental problem, linked to their own lives, the lives of local people and globally. Evaluation will be based on (1) quality of data collection and analysis; (2) an individual written report (formated for an environmental chemistry, peer-review journal); (3) an oral presentation (Powerpoint) for an audience of scientist peers. The final paper will be 1000-1500 words.

Weekly Exams At the end of each week, students will complete a limited exam covering content from that week. There will be five in total. Exams will include True/False, multiple choise, fill in the blank, problem solving, and short and long answer formats.

Problem Sets
Each week, students will complete a set of chemical problems associated each topic. These problems will include the chemical nature of environmental processes studied, how they are changing and extrapolations to what they tell us about our likely future.

Essays on Speakers/Site Visits
Students will write short 300-500 word critical essays addressing topics from invited speakers and site visits. These essays will summarize major elements of the talk or visit, fully explain the environmental chemistry behind it, and extend learning outcomes by further researching associated chemistry, environmental challenges and suggested solutions.

Class Attendance
Regular class attendance is required throughout the program, and all unexcused absences will result in a lower participation grade for any affected CIEE course. Due to the intensive schedules for Open Campus programs, unexcused absences that constitute more than 10% of the total course will result in a written warning.

Students who transfer from one CIEE class to another during the add/drop period will not be considered absent from the first session(s) of their new class, provided they were marked present for the first session(s) of their original class. Otherwise, the absence(s) from the original class carry over to the new class and count against the grade in that class.

For CIEE classes, excessively tardy (over 15 minutes late) students must be marked absent. Attendance policies also apply to any required co-curricular class excursion or event, as well as to Internship, Service Learning, or required field placement. Students who miss class for personal travel, including unforeseen delays that arise as a result of personal travel, will be marked as absent and unexcused. No make-up or re-sit opportunity will be provided.

Attendance policies also apply to any required class excursion, with the exception that some class excursions cannot accommodate any tardiness, and students risk being marked as absent if they fail to be present at the appointed time.

Unexcused absences will lead to the following penalties:

Percentage of Total Course Hours Missed	*Equivalent Number of Open Campus Semester classes*	*Minimum Penalty*
Up to 10%	1 content classes, or up to 2 language classes	Participation graded as per class requirements
10 – 20%	2 content classes, or 3-4 language classes	Participation graded as per class requirements; **written warning**
More than 20%	3 content classes, or 5 language classes	Automatic **course failure**, and possible expulsion

Weekly Schedule

NOTE: this schedule is subject to change at the discretion of the instructor to take advantage of current experiential learning opportunities.

Week 1 Chemical Origins

Session 1.1: Origins - A Chemical History of the Earth from the Big Bang to Present.

Students will explore the Big Bang, how stars and elements formed, nucleosynthesis and the birth of our solar system. They will study how the Earth has changed since its creation. They will establish an understanding of the basic elements, how they were formed and in where they persist on the planet. Students go onto study how life emerged through biochemicals, macromolecules, self-replication and molecular evolution. Students discuss and investigate how environmental chemistry informs society on decisions important to our lives.

Readings: Chapter 1: Origins, and

- Mann, A. 2018. Life after the asteroid apocalypse. PNAS 115(3): 5820-5823.
- Krishnamurthy, R., 2017. Giving rise to life: Transition from prebiotic chemistry to protobiology. *Accounts of chemical research*, *50*(3), pp.455-459.

Assigned problems from Chapter 1

Watch: Chemicals in the Environment – Dehumanizing Humanity (2017)
https://www.youtube.com/watch?v=oq2K1IvRf8M

Week 2 Foundational Chemical Concepts for Environmental Chemistry

Session 2.1: Foundations 1

Students will work through examples that demonstrate important chemical principles required to understand environmental chemistry. In this session, students will work in groups to define and calculate electromagnetic radiation, interactions between light and matter, metric prefixes, the structure of the atom, balancing nuclear reactions, half-life, solubility rules, naming ionic compounds, naming covalent compounds, photolysis and gas solubility.

Readings: Chapter 1: Origins, pp.22-29, and

Watch: 6 Chemical Reactions that Changed History (2016)
https://www.youtube.com/watch?v=jb4CMnT2-ao

Exam 1 Chemical Origins

Due: Assigned problems from Chapter 1

Session 2.2: Foundations 2

Students work through examples demonstrating important chemical principles required to understand environmental chemistry. In this session, students work in groups to define and quantify balancing chemical equations, redox reactions, thermodynamics, molar mass, stoichiometry, rate laws, Lewis structures, electromagnativity, resonance, hypervalency and formal charges, acids and bases, equilibrium calculations.

Readings: Chapter 1: Origins, pp.29-49

Watch: Stoichiometry – Crash Course Chemistry (2013)
https://www.youtube.com/watch?v=UL1jmJaUkaQ

Due: Assigned problems from Chapter 1, Essay 1: Environmental Chemistry and Society

Week 3 The Atmosphere

Session 3.1: Overview of the Atmosphere and Its Chemistry

Students begin with an overview of the chemical nature of the atmosphere. They explore the atmospheric layers: Exosphere, Thermosphere, Mesosphere and Troposphere. Students investigate the troposphere in terms of planetary energy budget and the chemistry of the greenhouse effect. They use the internal combustion engine as a model of tropospheric chemistry.

Readings: Chapter 3: The Atmosphere, pp. 95-117

Due: Assigned problems from Chapter 1

Weekly Exam 2

Session 3.2: Site Visit to Museum of Natural History or Natural Landscape Shaped by Environmental Chemistry

Students will visit the local natural history museum and/or a natural landscape shaped by environmental chemistry (caves, cenotes, etc.). They explore museum exhibits, the landscape and complete a worksheet on related key themes in environmental chemistry. Students will then have an invited speaker who will share what environmental chemistry research is being done locally and how environmental chemistry improves environmental and human health.

Readings: What is an Environmental Chemist? 2019. Environmental Science dot org
https://www.environmentalscience.org/career/environmental-chemist

Assigned problems from Chapter 3

Session 3.3: Human-Caused Atmospheric Changes and Their Chemistry

Students learn the basic chemistry of greenhouse gases, smog and ozone. They consider the hydroxyl radical and its related reactions, including carbon monoxide, alkanes, alkenes, terpenes, N and S compounds and nighttime reactions. They investigate the chemistry of acid deposition and ozone depletion. Students then examine the origin of greenhouse gases and how they are measured. Finally, students link greenhouse gas accumulation to global climate change.

Readings: Chapter 3, pp. 118-157, and

- Aguilar, M.D. and de Fuentes, A.G., 2013. Climate Change and Water Access Vulnerability in the Human Settlement Systems of Mexico: The Merida Metropolitan Area, Yucatan 4(1): 14-41. http://www.inegi.org.mx/rde/RDE_08/Doctos/RDE_08_Art2.pdf
- Kennett, D.J., Breitenbach, S.F., Aquino, V.V., Asmerom, Y., Awe, J., Baldini, J.U., Bartlein, P., Culleton, B.J., Ebert, C., Jazwa, C. and Macri, M.J., 2012. Development and disintegration of Maya political systems in response to climate change. *Science*, *338*(6108), pp.788-791.

Due: Essay 2: Environmental Chemistry and Society – Local Research and Application

Week 4 The Lithosphere

Session 4.1: Overview of the Lithosphere and Its Chemistry

Students begin with an overview of the chemical nature of the lithosphere. Students examine soil formation from physical weathering, chemical weathering, how minerals interact with different components of the lithosphere as well as the atmosphere and hydrosphere. They analyze organic matter decays and how it adds to soil structure and fertility. This involves study of respiration and redox chemistry. They also explore below ground carbon storage and whether soils are a net source or sink for carbon.

Readings: Chapter 3: The Lithosphere, pp. 165-175, and

- Schlindwein, V. and Schmid, F., 2016. Mid-ocean-ridge seismicity reveals extreme types of ocean lithosphere. *Nature*, *535*(7611), p.276.

Watch: Scotese, C. 2015. 240 million years ago to 250 million years in the future. https://www.youtube.com/watch?v=uLahVJNnoZ4

Due: Assigned problems from Chapter 3

Weekly Exam 3

Session 4.2: Environmental Chemistry and Agriculture

Students will visit a local farm or related soil research lab. They explore local soil chemistry, including physical and chemical weathering, organic matter and decay, measures of soil fertility and any problems with soil depletion or contamination. They speak with an agricultural engineer on how soils have been traditionally used by farmers and the impact those practices have on the local soils. Students will then work in groups to investigate soils in other parts of the world and how agricultural practices might differ with geography and related soil chemistry. Finally, students discuss how soil chemistry impacts local culture.

Readings: Sohng, J., Singhakumara, B.M.P. and Ashton, M.S., 2017. Effects on soil chemistry of tropical deforestation for agriculture and subsequent reforestation with special reference to changes in carbon and nitrogen. *Forest ecology and management*, *389*, pp.331-340.

Assigned problems from Chapter 4

Session 4.3: Human-Caused Lithospheric Changes and Their Chemistry

Students investigate human disturbance to the lithosphere, including metals and complexation, and phytoremediation efforts to correct problems. Soil acid deposition is then considered with buffering: limestone, cation exchange, aluminum and biotic systems. Aluminum toxicity and pH will also be studied.

Readings: Chapter 4: The Lithosphere, pp. 176-186, and

- Estrada-Medina, H., Bautista, F., Jiménez-Osornio, J.J.M., González-Iturbe, J.A. and Aguilar Cordero, W.D.J., 2013. Maya and WRB soil classification in Yucatan, Mexico: differences and similarities. *ISRN Soil Science*, *2013*.

- Beach, T., Dunning, N., Luzzadder-Beach, S., Cook, D.E. and Lohse, J., 2006. Impacts of the ancient Maya on soils and soil erosion in the central Maya Lowlands. *Catena*, *65*(2), pp.166-178.

Due: Essay 3: Environmental Chemistry and Society – Agriculture, Soils and Culture

Week 5 The Hydrosphere

Session 5.1: Overview of the Hydrosphere and Its Chemistry

Students begin with an overview of the chemical nature of the hydrosphere. They explore the unique chemistry of water and apply it to freshwater stratification, thermohaline circulation and salinity. Students investigate water as a solvent, including temperature and salinity effects. Students then analyze water in the context of the carbon, nitrogen, phosphorus and sulfur cycles, with special attention to how these cycles are changing with human global impact. Groups of students will investigate a major biogeochemical cycle and how it is changing through human impact. In the next session, students share and discuss their findings.

Readings: Chapter 5: The Hydrosphere, pp. 95-117, and

- Steffen, W., Richardson, K., Rockström, J., Cornell, S.E., Fetzer, I., Bennett, E.M., Biggs, R., Carpenter, S.R., De Vries, W., de Wit, C.A. and Folke, C., 2015. Planetary boundaries: Guiding human development on a changing planet. *Science*, *347*(6223), p.1259855.

Due: Assigned problems from Chapter 4

Weekly Exam 4

Session 5.2: The Environmental Chemistry of Changing Biogeochemical Cycles

Students present the environmental chemistry of major biogeochemical cycles and how they are impacted by humans. Students consider global thresholds of change, how close we are to surpassing those changes and what the effects will be on the local, regional and global human society. Students then discuss possible solutions or changes suggested by environmental chemistry for how best to avoid or ameliorate negative impacts. Students will write a brief proposal for their own independent research of 250 words.

Readings: Dris, R., Gasperi, J., Rocher, V., Saad, M., Renault, N. and Tassin, B., 2015. Microplastic contamination in an urban area: a case study in Greater Paris. *Environmental Chemistry*, *12*(5), pp.592-599.

Due: Assigned problems from Chapter 5

Session 5.3: Human-Caused Hydrospheric Changes and Their Chemistry

Students investigate human disturbance to the hydrosphere. They focus on water quality and its importance. To do so, they explore potentiometric pH measurements, Total Dissolved Solids (TDS), Salinity, Total Organic Carbon (TOC) and Biological Oxygen Demand (BOD), how these are measured, calculated and used. They consider the importance of dissolved oxygen in understanding water quality, how it is measured and its impact on aquatic life. They then explore the role of nitrates, nitrites, phosphates and sulfates in water quality and how humans impact their concentrations in the hydrosphere.

Readings: Chapter 5: The Hydrosphere, pp. 118-224, and

- Chuang, P.C., Young, M.B., Dale, A.W., Miller, L.G., Herrera-Silveira, J.A. and Paytan, A., 2017. Methane fluxes from tropical coastal lagoons surrounded by mangroves, Yucatán, Mexico. *Journal of Geophysical Research: Biogeosciences*, *122*(5), pp.1156-1174.

Watch: McGrath, T. 2017. How Pollution is Changing the Ocean's Chemistry https://www.youtube.com/watch?v=KJPpJhQxaLw TedTalk

Assigned problems from Chapter 5

Due: Essay 4: Environmental Chemistry and Society – Water, Society and Culture

Week 6 The Biosphere

Session 6.1: Overview of the Biosphere and Its Chemistry 1: Prokaryotes through Plants

Students begin with an overview of the chemical nature of the biosphere. They explore how living organisms take chemicals from the environment and reconfigure them. Students investigate the importance of bacteria in biogeochemical cycles, including nitrogen fixation. They also explore fungi, including mycorryhzal fungi and their importance in phosphorus capture for plants. Finally, students see the importance of plant chemistry, from photosynthesis to secondary compounds they use to protect themselves from pathogens and herbivores.

Readings: Meinwald, J. and Eisner, T., 2008. Chemical ecology in retrospect and prospect. *Proceedings of the National Academy of Sciences*, *105*(12), pp.4539-4540, and Van Alstyne, K.L., Nelson, T.A. and Ridgway, R.L., 2015. Environmental chemistry and chemical ecology of "green tide" seaweed blooms. *Integrative and comparative biology*, *55*(3), pp.518-532.

Due: Assigned problems from Chapter 5

Weekly Exam 5

Session 6.2: Overview of the Biosphere and Its Chemistry 2: Animals

Students continue their overview of the chemical nature of the biosphere. They explore how living animals take chemicals from the environment and reconfigure them. Students investigate the importance of chemistry in the daily lives of animals, from diet to mating. They describe plant-animal chemically-mediated interactions, including chemical defenses in both plants and animals, aposematism, mimicry and the chemistry of mate choice. They see how chemistry is used as a signal between plants, plants and animals and between animals. Using online resources, students investigate chemical-mediated ecology and behavior of a local biological system, explaining the chemistry in detail.

Readings:
Dyer, L.A., Philbin, C.S., Ochsenrider, K.M., Richards, L.A., Massad, T.J., Smilanich, A.M., Forister, M.L., Parchman, T.L., Galland, L.M., Hurtado, P.J. and Espeset, A.E., 2018. Modern approaches to study plant–insect interactions in chemical ecology. *Nature Reviews Chemistry*, and Pickett, J.A., Birkett, M.A., Dewhirst, S.Y., Logan, J.G., Omolo, M.O., Torto, B., Pelletier, J., Syed, Z. and Leal, W.S., 2010. Chemical ecology of animal and human pathogen vectors in a changing global climate. *Journal of chemical ecology*, *36*(1), pp.113-121.

Due: Essay on

Session 6.3: Independent Research Project Presentations

Students present the results of their independent research projects in a 10 minute PowerPoint presentation to the rest of the group. Students will ask questions and discuss each presentation. Students will consider each of their peer's research topic, the research supporting it and thoughts on next steps.

Final Exam

Due: Essay 5: Environmental Chemistry and Society – Chemicals in the Biosphere and their Impact on Society

Course Materials

Textbook
Overway, K.S., 2017. *Environmental Chemistry: An Analytical Approach*. John Wiley & Sons.

Readings

Aguilar, M.D. and de Fuentes, A.G., 2013. Climate Change and Water Access Vulnerability in the Human Settlement Systems of Mexico: The Merida Metropolitan Area, Yucatan 4(1): 14-41.

Beach, T., Dunning, N., Luzzadder-Beach, S., Cook, D.E. and Lohse, J., 2006. Impacts of the ancient Maya on soils and soil erosion in the central Maya Lowlands. *Catena*, *65*(2), pp.166-178.

Chuang, P.C., Young, M.B., Dale, A.W., Miller, L.G., Herrera-Silveira, J.A. and Paytan, A., 2017. Methane fluxes from tropical coastal lagoons surrounded by mangroves, Yucatán, Mexico. *Journal of Geophysical Research: Biogeosciences*, *122*(5), pp.1156-1174.

Dris, R., Gasperi, J., Rocher, V., Saad, M., Renault, N. and Tassin, B., 2015. Microplastic contamination in an urban area: a case study in Greater Paris. *Environmental Chemistry*, *12*(5), pp.592-599

Dyer, L.A., Philbin, C.S., Ochsenrider, K.M., Richards, L.A., Massad, T.J., Smilanich, A.M., Forister, M.L., Parchman, T.L., Galland, L.M., Hurtado, P.J. and Espeset, A.E., 2018. Modern approaches to study plant–insect interactions in chemical ecology. *Nature Reviews Chemistry*

Estrada-Medina, H., Bautista, F., Jiménez-Osornio, J.J.M., González-Iturbe, J.A. and Aguilar Cordero, W.D.J., 2013. Maya and WRB soil classification in Yucatan, Mexico: differences and similarities. *ISRN Soil Science*, *2013.*

Kennett, D.J., Breitenbach, S.F., Aquino, V.V., Asmerom, Y., Awe, J., Baldini, J.U., Bartlein, P., Culleton, B.J., Ebert, C., Jazwa, C. and Macri, M.J., 2012. Development and disintegration of Maya political systems in response to climate change. *Science*, *338*(6108), pp.788-791.

Krishnamurthy, R., 2017. Giving rise to life: Transition from prebiotic chemistry to protobiology. *Accounts of chemical research*, *50*(3), pp.455-459.

Mann, A. 2018. Life after the asteroid apocalypse. PNAS 115(3): 5820-5823.

Meinwald, J. and Eisner, T., 2008. Chemical ecology in retrospect and prospect. *Proceedings of the National Academy of Sciences*, *105*(12), pp.4539-4540

Schlindwein, V. and Schmid, F., 2016. Mid-ocean-ridge seismicity reveals extreme types of ocean lithosphere. *Nature*, *535*(7611), p.276

Sohng, J., Singhakumara, B.M.P. and Ashton, M.S., 2017. Effects on soil chemistry of tropical deforestation for agriculture and subsequent reforestation with special reference to changes in carbon and nitrogen. *Forest ecology and management*, *389*, pp.331-340

Steffen, W., Richardson, K., Rockström, J., Cornell, S.E., Fetzer, I., Bennett, E.M., Biggs, R., Carpenter, S.R., De Vries, W., de Wit, C.A. and Folke, C., 2015. Planetary boundaries: Guiding human development on a changing planet. *Science*, *347*(6223), p.1259855

Van Alstyne, K.L., Nelson, T.A. and Ridgway, R.L., 2015. Environmental chemistry and chemical ecology of "green tide" seaweed blooms. *Integrative and comparative biology*, *55*(3), pp.518-532.

Online Resources

FAO. Climate Smart Agriculture (2017) http://www.fao.org/climate-smart-agriculture/overview/en/

Natural Resources Defense Council. (2015). http://www.nrdc.org/energy/renewables/geothermal.asp
Nature latest research and reviews in Environmental Chemistry https://www.nature.com/subjects/environmental-chemistry
United States Department of Energy. (2015). Geothermal Energy. http://energy.gov/eere/geothermal/geothermal-energy-us-department-energy
United Nations Framework Convention on Climate Change. (2014). *The Mechanisms under the Kyoto Protocol: Emissions Trading, the Clean Development Mechanism and Joint Implementation.* http://unfccc.int/kyoto_protocol/mechanisms/items/1673.php