Lesson Title	Ions in the environment
Length of Lesson	2 days
Created By	Chris Ruhs
Subject	Chemistry
Grade Level	10-12th Grade
State Standards	Chemistry I 6(a,c,d); 11(a,c)
DOK Level	DOK 3
DOK Application	Analyze, explain, support with evidence, and create. Students will use conceptual understandings to draw models including explanations; students will use conceptual understandings to design experiments for useful data collection.
National Standards	9-12: A (Inquiry); B (Physical Science); C (Life Science); D (Earth and Space Science)
Graduate Research Element	Biogeochemists are much concerned with the compounds found in natural environments including a handful of specific ions that tend to play a large role in most ecosystems on Earth. For my research in particular, I am interested in knowing the percentages of moisture (H_2O), organic/inorganic carbon, and nitrogen in my soil samples.

Student Learning Goal:
MS 9-12th Grade:

Chemistry I: 6 (a) Write chemical formulas of ionic compounds using monatomic and polyatomic ions. (c) Write names of compounds and their formulas. (d) Given the formula of a compound, identify oxidation states of the elements. *We will discuss ions important in the environment, their formulas and their names using a fill-in hand-out with the opportunity to identify formulas, names, and oxidation states.*
11 (a) Describe solutions in terms of solute and solvent; electrolyte or non-electrolyte; soluble or insoluble; unsaturated, saturated or supersaturated; miscible or immiscible. (c) Explore the factors that affect solubility. *Students will understand that ions are transported in the environment by water because water is polar and able to dissolve those ions as well as other polar molecules.*

National Science Education Standards of Content 9-12:
A: Inquiry: Identify questions and concepts that guide scientific investigation. *Students will be asked to work in groups to design experiments to collect data that would prove eutrophication. How can we show that the process of eutrophication actually proceeds as described in this lesson plan?*
B: Physical Science: Structure and properties of matter; chemical reactions; motion and forces. *Students will use their knowledge of ions, solubility, rain, gravity, river systems,*

geography, and biological utilization of chemicals to understand the concepts involved in eutrophication.

C. Life Science: The cell; the interdependence of organsisms. *Students will understand that the cell requires specific chemicals to produce phospholipids, DNA, RNA, amino acids, and proteins. Students will also understand that organisms depend on each other and influence each other in an ecosystem—an unbalance in one organism disturbs the balance of others.*

D. Earth and Space Science: Geochemical cycles. *Students will understand how different cycles interact in the environment.*

Materials Needed (supplies, hand-outs, resources):
Power-point, instruments for show and tell, hand-outs to fill in, any videos or images useful from the internet.

Lesson Performance Task/Assessment:
Formative:
Discussion on the environment with a hand-out to fill in blanks:

The environment acts as a series of "reservoirs" or "sinks" into which all chemicals will partition depending on the nature of the chemicals. For instance, organic compounds tend do partition into the air if the compound is volatile and into the "liposphere," a term used to denote the fatty or waxy layers that cover every living organism on earth. Alternatively, polar and ionic compounds tend to dissolve in water, because water is polar, or bind to soils because the minerals in soils tend to be slightly negatively charged (which means they tend to bind cations). We want to focus primarily on ions in this lesson plan. There are a handful of ions that are very important in the environment: H^+, Na^+, Ca^{2+}, Al^{3+}, NH^{4+}, Cl^-, OH^-, NO_3^-, SO_4^{2-}, and PO_4^{3-}.

Introduction to biogeochemical cycling:

Students will be given a hand out depicting the five main biogeochemical cycles. These cycles interact in the complex way to produce non-linear and unexpected outcomes in the environment. The five main biogeochemical cycles are:

1. Carbon cycle
2. Oxygen cycle
3. Water cycle
4. Nitrogen cycle
5. Phosphorus cycle

There are other important cycles, including the sulfur and mercury cycles, but are outside the scope of this lesson plan.

Basic model of eutrophication

One complex outcome is called eutrophication. Here is how eutrophication works: Firstly, plants need phosphorus to make phospholipids (which protect the plant's cells and organelles) and DNA & RNA (which are used to synthesize proteins); plants need nitrogen to form many of the amino acids which are used by RNA to synthesize the needed proteins. Plants also need carbon, but carbon is readily available on earth through carbon dioxide CO_2, which has been in abundance as of late. So, to get plants to grow quickly and robustly, farmers will use fertilizers rich in nitrogen and phosphorus in the form of NO_3^+, NH_4^+, and PO_4^{3-}.

Secondly, rain and outwash bring these soluble ions into river systems by dissolving them and transporting them. In the United States, this happens frequently in the Mississippi River, since it runs through much of the major agricultural land in our country where fertilizers are being used heavily. The Mississippi River empties into the Gulf of Mexico.

Thirdly, there are organisms like algae living in the Gulf of Mexico which can utilize the nitrogen and phosphorus being dumped there. When this added "food" is dumped there (eutrophication means "adequate food" or "well nourished") algae begin to grow rapidly, since all of the required nutrients have just become readily available. These algae reproduce rapidly and quickly use up the available nutrients. At some critical point in this process the available food is completely consumed, leaving the large algal population to starve. The dead algal biomass sinks to the bottom and decays, using up all the oxygen in the water column. Now you have a water system void of oxygen, which causes fish to die, adding more decaying biomass to the area. This process leads to hypoxia and anoxia, but usually rebounds after enough oxygen is allowed to re-enter the system.

This entire process is called eutrophication. Notice that the water, nitrogen, and phosphorus cycles interacted through dissolving and transport to cause an unbalance in the biological part of the carbon cycle at a locale (algal bloom in the Gulf), which in turn caused an unbalance in the oxygen cycle (by using up the all available oxygen through organic decay), which finally caused fish kills, affecting the fishing industry and making the area unsafe. An overbalance in one cycle can affect and be affected by all the others.

Who likes football? Have you ever heard of Alabama Crimson Tide? Why are they called the Alabama Crimson Tide? What is a crimson tide, anyway? A crimson tide refers to an explosion in the growth of red algae in the ocean. This happens once in a while along the coast of Alabama, when eutrophication is taking place.

The science of biogeochemistry

So how do we know all of this stuff?

*Put students in groups and have them design a set of experiments that would allow us to collect the data necessary to prove that eutrophication works the way described above.

Scientists were curious as to why these huge algal blooms occurred in the Gulf of Mexico. Using chemical analysis, they were able to determine that an increase in nitrogen and phosphorus levels in the water systems were somehow related to algal blooms, which lead to fish kills, hypoxia, and anoxia. Scientists back-tracked this over-abundance of nutrients to the Mississippi River and then to the streams and creeks which collected runoff from fertilized farmland. The entire chain reaction made sense, was testable, and explains the phenomenon. Scientists today continue to study, measure, monitor, and model the oxygen levels in the Gulf waters and in the soils underneath the water. There are other places around the world where this occurs.

This would be a good place to show electronic probes, mass spectrometry, elemental analysis, and other tools used by scientists.

Summative:
Draw a picture of eutrophication including farmland, fertilizer, streams, rivers, Gulf, algae, and fish kills. Draw arrows showing flow, and indicate which cycle is involved at each location. Give explanations where appropriate.

Student-lead, teacher-guided summary discussion and test questions.

Lesson Relevance to Performance Task and Students:
This lesson plan is designed to give relevant, significant, and personal context to chemistry and ions. Chemistry is not something that only scientists should be interested in, but affects us, especially in the environment. For the topic of ions in the environment (which often involves water systems), eutrophication is a natural discussion topic; it lends itself to integrating many different subject areas into one holistic understanding, as well as impacting the student with something of local importance.

Anticipatory Set/Capture Interest:
"Can anyone tell me how football is related to ions?"

Guided Practice:
*Student inquiry on how to prove eutrophication. Open discussion.

Independent Practice:
Drawing eutrophication.

Remediation and/or Enrichment:
Remediation:
Individual IEP

Enrichment:

Grow algae in the classroom, and add fertilizer to it to see what happens over time.

Check(s) for Understanding:
What is eutrophication?
Why are nitrogen and phosphorus so important?
What is a crimson tide?
What are the five main biogeochemical cycles?

Closure:
A student-lead, teacher-guided summary discussion will bring closure to the lesson plan.

Possible Alternate Subject Integrations:
Biology: expand the discussion on nitrogen and phosphorus for its biochemical significance. Talk about how cells use phosphorus as phospholipids for protection; talk about how DNA uses and phosphorus "backbone"; talk about how DNA is used to make mRNA, tRNA, and rRNA, which collaborate to make proteins; talk about how nitrogen is often necessary to form the amino acids which make up these proteins. YouTube has a wealth of videos showing this process. A firm grasp of these basic cellular functions will enable students to understand how over-fertilization affects the ecosystem, and more generally, how an environmental unbalance affects the biosphere.

Earth Science: this lesson plan can act as part of the discussion on water systems, and the water cycle as a whole.

Teacher Notes:
Simple Google searches for any of the topics covered here will produce more information, imagery, and video than you could possibly use. This is a complex topic that integrates the major scientific disciplines, and students may have many questions, because this topic is useful, interesting, and affects us personally: do some background reading if you're unfamiliar, and bring extra materials for further reading.

Day 1: Power-point, hand-outs, videos, pictures, and discussion.
Day 2: Drawing eutrophication and designing experiments to prove eutrophication.