   

**Project EDDIE: NUTRIENT LOADING**

**Student Handout**

This module was initially developed by Castendyk, D.N., T. Meixner, and C.A. Gibson. 6 June 2015. Project EDDIE: Nutrient Loading. Project EDDIE Module 7, Version 1. <http://cemast.illinoisstate.edu/data-for-students/modules/nutrient-loading.shtml>. Module development was supported by NSF DEB 1245707.

Learning Objectives:

* Analyze and interpret data to deepen knowledge and increase understanding of hydrogeological concepts and nitrogen cycling in aquatic systems in the context of increased nutrient availability.
* Explore advantages and disadvantages of different ways to investigate, sample, and quantify nutrients in aquatic systems.
* Develop skills for critical data analysis, graphing, and statistics.

Why this matters: Estimating nutrient loads is a critical concept for students studying water quality in a variety of environmental settings. Many of you will be asked to assess the impacts of a proposed anthropogenic activities on human water resources and/or ecosystems as part of your future careers. In this module, you will explore factors contributing to nitrogen loads that are transmitted down streams. Nitrogen is a key water quality contaminant contributing to surface water quality issues in fresh, salt, and estuarine environments. You will utilize real-time nitrate data from the US Geological Survey to calculate nitrate loads for several locations and investigate the interplay of concentration and discharge that contributes to the calculated loads.

Outline:

1. Activity A: Introduction to Nutrient Loading; Pre-readings and PowerPoint in class
2. Activity B: Explore impaired streams and real-time nitrate concentrations
3. Activity C: Collect, plot, and explain the water quality data
4. Activity D: Compare rural vs. urban land use impacts
5. Activity E: Investigating biotic controls

Potential required pre-class readings:

* Wines, M. (2014). Behind Toledo’s Water Crisis - a Long-Troubled Lake Erie, *New York Times*, August 4: 4 pages. <http://www.nytimes.com/2014/08/05/us/lifting-ban-toledo-says-its-water-is-safe-to-drink-again.html?_r=0>
* Zimmer, C. (2014). Cyanobacteria are far from just Toledo’s problem. *New York Times*, August 7: 3 pages. <http://www.nytimes.com/2014/08/07/science/cyanobacteria-are-far-from-just-toledos-problem.html>
* Shipley-Hiles, S. (2012). Dead zone pollutant grows despite decades of work. *Scientific American*, July 9: 6 pages. <http://www.scientificamerican.com/article/dead-zone-pollutant-grows-despite-decades-work/>

**Activity A:** Introduction to Water Quality

1. Please read the assigned material before coming to class, and be prepared to discuss readings with others.
   * Write down any questions you may have about the different study cases, and highlight terms you are unfamiliar with. Think about the following questions as you read, writing down your responses:
2. What are nutrients and where do they come from?
3. Are nutrients always “good”?
4. How does a cyanobacteria bloom affect an ecosystem (plants, animals, water quality, human impacts)?
5. How might a residential/ tourist area be affected by a cyanobacteria bloom?
6. How would you manage water quality impacts if you were in charge of a municipal area, and what challenges might you anticipate?
7. View the PowerPoint instruction provided by your instructor. This PowerPoint introduces you to topics related to the impact of a common contaminant, nitrate, on two different water uses: (1) human drinking water quality with respect to Blue Baby Syndrome; and (2) ecosystem health with respect to eutrophication**.**

**Activity B:** Explore impaired streams and real-time nitrate concentrations

For the second part of this module, we will be further exploring impaired water bodies near us and federal guidelines for safety using publicly available EPA water quality data.

1. **Explore impaired streams near you**

Open Google and perform a search on “303 d list *your state’s name*.” Each state will have a different set of links to follow to get to this list. Ultimately, you will find a list of rivers with the most impaired water quality within your state, for which regulatory action is required. For each river, the contaminants responsible for causing contamination should be listed.

1. What is the name of the nearest river to your school, or home town, which appears on this list?
2. What are the three most common contaminants listed for rivers in your state?
3. How often are the contaminants nitrogen, ammonia, nitrate, or nutrients cited as the cause of impairment?
4. **Explore federal regulatory guidelines**

The US Environmental Protection Agency lists water quality regulations for both Human Drinking Water <http://water.epa.gov/drink/contaminants/index.cfm>.

1. What is the Maximum Contaminant Level (MCL) for nitrate (reported as nitrate-nitrogen) in mg/L?
2. What are the potential health impacts of consuming water with concentrations above this limit?
3. What are the common sources of nitrate in water?
4. **Explore variability in nitrate concentrations over time**

The objective of this activity is to understand that dissolved concentrations of constituents in stream water are not constant over time. We call this variability. Some variability is natural and some variability is anthropogenic.

1. Open the U.S. Geological Survey’s “Water Quality Watch” web page:[http://waterwatch.usgs.gov/wqwatch/](http://www.google.com/url?q=http%3A%2F%2Fwaterwatch.usgs.gov%2Fwqwatch%2F&sa=D&sntz=1&usg=AFQjCNFbkjKPMnYHIs9p8mPdSnXpbc8XDw)
2. What parameters are available for you to access in Real Time? Click on the downward arrow beside the “Measurements” tab to find out, select each parameter to see how much data is available, and record your notes here:
3. Select “Nitrate” from the list of variables. This map shows concentrations of nitrate measured autonomously with an ion-selective electrode (ISE) at select U.S. stream gages.
   1. Why do you think there so few nitrate sites compared to other parameters?
   2. Name one state that has a higher density of nitrate data compared to the rest of the nation.
   3. To what major U.S. river does surface water from this state flow?
   4. Where does this river enter the ocean?
   5. What are some common land use practices in this state? What is the possible relationship between this land use and water quality?

d. Click the “Animate” button. You are now watching a movie of daily nitrate concentrations measured at stream gages around the United States since the start of the month.

* 1. In general, how much does nitrate concentration vary over time? Circle one:

Not much

Somewhat variable

Lots of variability

Extreme variability from one day to the next

* 1. Which states show the most variability in nitrate concentrations since the start of the month and which states show the least?
  2. For one of the state with the most variability, what natural process(es) might cause nitrate to fluctuate over time? Explain the natural timing of this process and how it affects concentrations.
  3. For the same state, what anthropogenic process(es) might cause nitrate to fluctuate over time? Explain the natural timing of this process and how it affects concentrations.

**Activity C:** Collect, plot, and explain the water quality data

During this portion of the module, you will search for and work with local water quality data, and generate plots that will allow you to further analyze the data, answering questions as you go.

1. **Assessment of acute, local, water quality impacts**

Watershed managers need to know how often a risk presents itself in a watershed in order for action to be taken. For financially strapped government’s, priority is given to problems that have the highest probability of occurring and which are associated with the most severe impacts. “Blue-baby syndrome” is a condition that leads to infant mortality. It is caused by the ingestion of nitrate in drinking water which subsequently bonds to oxygen sites on hemoglobin in the blood of the infant. This impairs the circulation of oxygen in the bloodstream and causes the baby to turn blue. Obviously, society would like to avoid this outcome.

Let’s assume that the Cedar River, Iowa, is being considered for use as a drinking water supply by the municipality of Palo, Iowa (note, this is probably not happening in reality). Is this river water safe for human consumption? To answer this question, we will first explore the variability of nitrate within this river.

1. Open the U.S. Geological Survey’s “Water Quality Watch” web page:<http://waterwatch.usgs.gov/wqwatch/>
2. Under the “State” menu, select “Iowa” and allow the map to refresh.
3. Under the measurement menu, select “Nitrate.”
4. Move your mouse over the available triangles until you find “Cedar River at Blairs Ferry Rd, at Palo, IA.” This triangle is equidistant from the top (North) and the bottom (South) of the map, and about an inch to the left of the right (East) boundary of the state.
5. Once you find it, click once on the triangle, and the click again on the eight-digit hydrologic unit code (HUC) number “05464420” which identifies this site.
6. Now you are in the official USGS data site for the Cedar River at Blairs Ferry Rd, Palo, IA. Scroll down and explore the plots of the available data. We would like to see whether nitrate concentrations change over the course of the agricultural season.
7. Scroll back up to the box labelled “Available Parameters.”
8. Uncheck “gage height” and “water temperatures.”
9. Change the starting date to April 1, 2014 and the end date to September 1, 2014. Enter these dates in YEAR-MO-DY format (i.e. 2014-04-01, and 2014-09-01, respectively). The top graph shows discharge in ft3/sec whereas the bottom graph shows nitrate-nitrogen (NO3-N) concentration in mg/L.
10. When was the concentration of NO3-N the highest, and when was it the lowest?
11. What land use activities might have occurred when nitrate concentrations were the highest?
12. How did changes to stream discharge affect nitrate concentrations?
13. What might have caused this variability?
    1. Now, we will explore a fundamental question asked by watershed managers, “What is the likelihood (or probability) that the water in Cedar River will be unfit for human consumption?” The following exercise will help us find the answer.
14. Under the heading “Output Format,” select the “Tab-separated” circle and click “GO.”
15. Copy and paste the 15-minute nitrate concentration data into an Excel worksheet.
16. Delete all unnecessary column headers and columns so that you only have a single row of concentration data.
17. Using the sort tool in Excel, sort this column from the highest to lowest concentration. To do this, click on the “Data” tab at the top of the page, highlight the entire column of data, click on the “Sort” button in the middle of the top of the page, order the data from largest to smallest, and click “Okay.”
18. Add a new column to the right of the concentration data called “Rank” (R). In this column, the highest concentration value has a rank equal to 1, the next highest concentration has a rank of 2, and so forth for the entire dataset. There should be 13,897 data points in this dataset. This means the total number (n) of this dataset is 13,897.
19. Add a third column to the right called Probability (p). This will be the likelihood that a concentration of a given Rank (R) will occur within the dataset. Calculate the probability by dividing the rank by the total number (n) plus one. Type this equation in a new column and fill it down for the entire dataset.

**p=R/(n+1)**

1. Finally, calculate a fourth column showing the Percent Probability (%), by multiplying the probability number by 100. This is the probability that a given concentration occurred during any 15 second period between April and September, 2014.
2. **Make a plot** showing NO3-N concentration on the y-axis vs. % probability on the x-axis.
3. Draw a horizon line at 10 mg/L showing the U.S. EPA National Drinking Water Regulation.
4. Based on this graph, what is the probability that nitrate concentrations in the Cedar River will meet or exceed EPA Drinking Water Regulation resulting in acute impacts to human health?
5. Judging from your assessment, should watershed managers develop this river into a drinking water resource?
6. The EPA can impose serious economic fines on a state that consistently fails to meet guidelines. Given your understanding of nitrate variability in the Cedar River, would it be fair to Iowa for the EPA to impose fines based on the % probability you calculated? Why or why not?

**Activity D:** Compare rural vs. urban land use impacts

Run-off from cities and farms are a major source of pollution to streams. A pipe delivering wastewater effluent from a sewage treatment plant is considered a **point source** of pollution, whereas storm-water runoff from city streets or agricultural fields are considered **non-point sources** of pollution. These non-point sources are episodic in nature and dispersed in origin. However, the effects of non-point source pollution are profound and pervasive; non-point sources are the dominant source of nutrients (i.e. nitrate and phosphate) to most US streams, rivers, and lakes (see the 303(d) list for your state). Managing pollution requires understanding of how different sources of the pollutant influence the delivery of nutrients to receiving waters.

In this activity, we will compare nitrate concentration from a single storm event in a rural setting to an urban setting. Our rural setting is Indian Creek at Fairbury, IL (USGS site no:05554300, drainage area 67 mi2). For simplicity, we will call this site **Rural Illinois Stream**. Our urban setting is a different Indian Creek at Leawood, KS (USGS site No. 06893390, drainage area 64 mi2). For simplicity, we will call this site **Urban Kansas Stream**. Note, these are different streams. We will use USGS data from May 30 to June 6, 2015 for both systems.

1. **Exploring land use**

Before we begin, let’s explore these two sites, one rural and one urban.

1. For the **Rural Illinois Stream**, go to Google Maps (maps.google.com) and type in Fairbury, IL into the search bar. Click on satellite view (bottom left corner) to view both Fairbury, IL and the surrounding landscape. What is the predominant form of land-use in this area of the country?
2. Move your cursor immediately below the search bar over the words Fairbury IL 61739, a small pop-up menu will appear. At the bottom of this menu select “Quick Facts”. What is the population of Fairbury, IL?
3. The USGS gauging station is located at 40°43’22.0” N, 88°31'48" W. Type those coordinates into the search bar. A flag will appear at the USGS gauging station. Note the location and land-use surrounding the gauging station. What are the likely sources of nutrients for this stream?
4. For the **Urban Kansas Stream**, do the same thing for Leewood, KS. Click on satellite view and map view (bottom left corner) to view both Leewood, KS and the surrounding landscape. What is the predominant form of land-use in this area of the country?
5. Move your cursor immediately below the search bar over the words Leewood KS, a small pop-up menu will appear. At the bottom of this menu select “Quick Facts”. What is the population of Leewood KS?

The USGS gauging station is located at 38°56'18"N, 94°36'28"W. Type those coordinates into the search bar. A flag will appear at the USGS gauging station. Note the location and land-use surrounding the gauging station. What are the likely sources of nutrients for this stream?

1. **Exploring Nutrient Dynamics in these watersheds**

Now, let’s formulate some hypotheses:

1. Which location do you think will have a higher base flow (i.e. groundwater) nitrate concentration? Why?
2. What do you expect happens to nitrate concentrations during a rainfall event at **Rural Illinois Stream** (Indian Creek in Fairbury, IL)? In the space below, draw a graph of Concentration (y-axis) vs. Discharge (x-axis) showing how you expect nitrate concentration to change during a rain event (i.e. the rising limb of the storm hydrograph).
3. What do you expect happens to nitrate concentrations during a rainfall event at **Urban Kansas Stream** (Indian Creek in Leewood, KS)? In the space below, draw a graph of Concentration (y-axis) vs. Discharge (x-axis) showing how you expect nitrate concentration to change during a rain event (i.e. the rising limb of the storm hydrograph).
4. **Test your hypotheses**
5. Open the USGS Water Quality Watch web page<http://waterwatch.usgs.gov/wqwatch/> in a second tab.
6. View data for the State of Illinois.
7. Under “Measurement,” select “Nitrate.”
8. Indian Creek at Fairbury IL is the fourth triangle down from the northern border in the east central section of the state.
9. Click on the Indian Creek at Fairbury IL (USGS [05554300](http://waterdata.usgs.gov/nwis/uv?site_no=05554300) ) triangle and click on the eight-digit hydrologic unit code (HUC) for the stream gage.
10. Under the box titled “Available Parameters,” uncheck everything except “Discharge” and “NO3+NO2, water, in situ.” Change the output format to “Graph.” Enter the date range for May 30, 2015 (2015-05-30) to June 6, 2015 (2015-06-06). Click “GO.”
11. Print both graphs, and write “**Rural Illinois Stream Water Quality**” at the top.
12. Open the USGS Water Quality Watch web page<http://waterwatch.usgs.gov/wqwatch/>
13. View data for the State of Kansas.
14. Under “Measurement,” select “Nitrate.”
15. Indian Creek at Leewood Kansas is the triangle to the far right on the eastern state line.
16. Click on the Indian Creek at Leewood Kansas (USGS [06893390](http://waterdata.usgs.gov/nwis/uv?site_no=06893390)) triangle and click on the eight-digit hydrologic unit code (HUC) for the stream gage.
17. Under the box titled “Available Parameters,” uncheck everything except “Discharge” and “NO3+NO2.” Change the output format to “Graph.” Enter the date range for May 30, 2015 (2015-05-30) to June 6, 2015 (2015-06-06). Click “GO.”
18. Print both graphs, and write “**Urban Kansas Stream Water Quality**” at the top.
19. **Answer the following questions:**
20. What happens to nitrate concentration in the Rural Illinois Stream as discharge increases?
21. What processes most likely drive concentration changes in rural settings?
22. What happens to nitrate concentrations in the Urban Kansas Stream as discharge increases?
23. What processes most likely drive concentrations changes in urban settings?
24. Is this what you predicted in your hypothesis? What have you learned from this comparison?
25. If you were a watershed manager, how would you manage nitrate concentrations in a

rural setting strongly influenced by non-point sources of nitrate?

1. How would you manage nitrate concentrations in an urban setting strongly influence by point sources of nitrate?

**Activity E:** Biotic controls on nutrient concentration and water quality

To this point, we have been exploring nitrate as a pollutant. As we stated earlier, high concentrations of nitrate have human health effects, mainly in the form of “blue baby syndrome”. In addition, this exercise has been primarily focused on delivery of nitrogen to streams and consequences for the variability of nitrate concentrations in the water column.

However, nitrogen is also a critical element for all biological organisms. Therefore, in-stream nitrate concentrations have the potential to be influenced by biotic users of nitrogen. In streams and lakes, algae take up nitrogen from the water column during photosynthesis. Heterotrophic microbes, such as bacteria and fungi, can also take up nitrogen from the water column. Nitrogen can be released back into the water column by decomposition or excretion. Thus, areas or times of high biological activity can result in changes in nitrogen concentrations.

Nitrogen comes in different forms. Most nitrogen is found in the atmosphere as N2 gas, but this form of nitrogen is not readily available to most organisms. Plants can readily use nitrogen in the form of nitrate and ammonium. In this activity, we are again focusing on nitrogen in the form of nitrate (NO3-N).

As we saw in the last activity, Indian Creek in Leewood, Kansas typically has relatively high nitrate concentrations. Leewood is a suburb of Kansas City, Missouri/Kansas. Therefore, Indian Creek drains a relatively large urban area and a wastewater treatment plant is located immediately upstream of the stream gauging station/surface water quality sampling site. We will explore the variability of nitrate during a short time scale (i.e. a 24-hour period) and see if it offers insights to potential biological controls on nitrate concentrations.

1. **Exploring the nitrogen cycle**

a. List some biological activities that could influence nitrogen concentrations in streams.

b. Which of these activities might dominate a stream in mid-July? Why?

c. Write the general equations for photosynthesis and decomposition.

d. Based on these equations, **sketch** the diel (24 hour) dissolved oxygen curve in a highly productive stream.

e. Based on this figure, **sketch** the diel (24 hour) nitrate curve.

1. **Exploring Indian Creek**
2. Go to Google Maps (maps.google.com). The USGS gauging station is located at 38°56'18"N, 94°36'28"W. Type those coordinates into the search bar. A flag will appear at the USGS gauging station. Zoom into this location to explore the stream. Make sure you are using the satellite setting. Look at the physical dynamics of the stream? Is there a riparian zone present along the stream? Can you see the stream itself or is it completely shaded and covered by the riparian zone?
3. Open a new tab in your internet browser. Open the USGS Water Quality Watch web page [http://waterwatch.usgs.gov/wqwatch/. View data for the State of Kansas. Under “Measurement,” select “Nitrate.” Indian Creek at Leewood Kansas is the triangle to the far right on the eastern state line.](http://waterwatch.usgs.gov/wqwatch/)
4. [Click on the Indian Creek at Leewood Kansas (USGS](http://waterwatch.usgs.gov/wqwatch/) [06893390](http://waterdata.usgs.gov/nwis/uv?site_no=06893390)[) triangle and click on the eight digit hydrologic unit code (HUC) for the stream gage.](http://waterwatch.usgs.gov/wqwatch/)
5. Pictures of the site should scroll at the top of the page. Look at the picture dated July 25, 2012. How would you describe this channel?
6. **Testing hypotheses**
7. Go to the web page for the Indian Creek at Leawood KS (USGS 06893390) site. Go back to the box titled “Available Parameters”.
8. Change the “Available Parameters” so that Discharge, DO (dissolved oxygen), and NO3+NO2 in situ, and Photosynthetically Active Radiation (PAR) are selected.
9. Under the heading “Output Format,” select the “Tab-separated” circle. Change the date range to June 2, 2015 (2015-06-2) to June 2, 2015 (2015-06-2) and click “GO.”
10. Save this web page as a .txt file. Make sure you include the .txt at the end of the file name.
11. Open the .txt file in Excel, Excel should recognize it as a tab-separated file.
12. Make a plot showing time (x-axis) vs. discharge (y-axis) over the 24-hour period.
13. Make a plot showing time (x-axis) vs. PAR (y-axis) over the 24-hour period.
14. Make a plot showing time (x-axis) vs. dissolved oxygen (y-axis) over the 24-hour period.
15. Make a plot showing time (x-axis) vs. nitrate (y-axis) over the 24-hour period.
16. Examine and describe the graphs in your own words. When does DO peak? When does PAR peak? When does nitrate peak? What do you notice about the graphs of DO and nitrate? How much influence does discharge have on these parameters?
17. Interpret the graphs. Do these results support your hypothesis? Why or why not? Explain what biological activity could be driving the observed pattern. How would this biological activity create this pattern?
18. **Expansion questions**
    * + - 1. What conditions facilitate biological control on nitrate concentrations?
          2. Would you predict similar dynamics for an agricultural stream? A forested stream? A mountain stream? Why or why not?
          3. How might biological processes be used to improve water quality?