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Water Quality Course Outline

This curriculum packet was prepared for a sophomore or junior level, undergraduate course on surface water quality. Suggested prerequisites include a basic math course and a basic chemistry course. The lessons were put together for 50 minute class periods. The structure of the curriculum allows flexibility on the course level through adjustment of the depth to which the concepts are covered. The PowerPoint slides focus on graphics, images, and figures while the majority of the concepts are relayed by the instructor with support of the lecture notes. The instructor can determine how much time to spend on each slide and whether to focus on the details of the science or on interacting with students to relate concepts to local examples.

Introduction Section
(Lessons 1-7)

The introduction section provides background on basic water properties, the watershed concept, ground-water/surface water interaction, and water law. This framework of basic physical processes and water policy sets the stage for the study of the physical, chemical, and biological parameters covered in the following sections.

Assignment 1

The suggested assignment for this section requires students to:

- Delineate a watershed
- Discuss potential pollution risks
- Answer some basic questions about a stream
- Perform calculations on water storage after getting information from a SNOTEL snow monitoring site

Lesson 1. Class Overview and Pre-Test

The lesson

This class period is an opportunity to go over the syllabus, layout what will be covered, and get an idea of the students' background in surface water quality. By giving a pre-test you can establish the extent of student's existing knowledge. This is also an opportunity to document knowledge increase when questions are repeated on tests later. Depending on your student knowledge level, consider adding or removing questions so that the test has some questions no students know and some questions every student will know.

Student Preparation

Not Applicable – First class

Additional Information Resources

None

Class Topics

1. Overview what will be covered in the course
2. Why are people taking the class and what do they want to learn
3. Pre-test, assessment of existing level of knowledge and courses taken

Review Questions

Not Applicable – First class

Lesson 2. Water Properties and Basics

The lesson

The purpose of this lecture is to review the basics about water and to underline how critical water is to all life on earth. While the majority of the earth's surface is covered with water, very little is fresh water available for human use. The amount of available water is further decreased by human activities that pollute water sources making them unusable, as well as global climatic changes that are impacting water resource availability. The structure of the water molecule results in hydrogen bond formation which gives water a variety of unique characteristics, making life on earth possible. The content of this lecture begins with molecular structure and explores the physical phases of water and the hydrologic cycle. The fact that the solid phase of water is less dense than the liquid phase is very unique and is the reason that ice floats. If ice didn't float, then many lakes would freeze solid and aquatic life as we know it would not be possible.

Student Preparation

Read:

- Chapter 2: The Structure and Properties of Water, Applied Principles of Hydrology, Third Edition, John C. Manning

Additional Information Resources

- Lecture Notes

Class Topics

1. Earth water supply
2. Pollution, drought, and climate change further limit available water
3. Importance of water
4. Hydrogen bonding and properties of water
5. Components of the water cycle important to water quality

Review Questions

1. What percentage of the earth's water is fresh?
2. What factors are at work to further reduce the amount of water on earth available for human use?
3. What are some different specific aspects of life on earth directly influenced by water?
4. Polarity in water molecules results in _____ bonding between molecules.
5. Name a few properties of water affected/controlled by hydrogen bonding.
6. Related to the unique properties of water, what is special about the relationship between water and ice?
7. Name some key components of the hydrologic cycle which are commonly talked about in the context of water quality?

Lesson 3. Watersheds and Source Water Protection

The lesson

This lecture discusses the movement of water across the planet and the watershed concept which is critical to understanding the connection of landuse to water quality. This lecture should provide students with a basic understanding of how to read topographic maps and outline watersheds by identifying ridge lines. Hydrologic Unit Codes (HUCs) are introduced as a tool for breaking up the landscape in a hydrologically meaningful way and these lines are compared to political lines. Some basic metrics for characterizing watersheds are introduced along with the river continuum concept highlighting how waterbodies naturally change moving downstream. Finally, the importance of the watershed concept and the connectivity of water quality moving downstream are highlighted in the context of drinking water and source water protection.

Student Preparation

- Read:
  - Vannote, R. L., G. W. Minshall, K. W. Cummins, J. R. Sedell, C. E. Cushing, The River Continuum Concept, 1980. Canadian Journal of Fisheries and Aquatic Science, Volume 37.

Additional Information Resources

- Lecture Notes
- River Continuum Website: http://www.cotf.edu/ete/modules/waterq/wqcontinuum.html

Class Topics

1. Delineating a watershed
2. Watershed boundaries as tools to look at the landscape
3. Determining stream order and drainage density
4. Watershed concepts applied to drinking source water protection

Review Questions

1. What is the definition of a watershed?
2. What is a HUC?
3. What are the major Montana watersheds?
4. What is stream order?
5. Why is stream order a useful concept for understanding water quality?
6. What is drainage density?
7. What are some characteristics of a stream that you would expect to change moving down stream?
8. What is the source water protection concept?

Lesson 4. Ground-Water/Surface Water Interaction

The lesson

While this course is focused on surface water, it is impossible to separate ground-water and surface water. Exchange of surface water with ground-water is common to most streams making clear separation of the two resources impossible. In the face of climate change and drought in many areas, the influence that wells have on surface water resources is getting more attention. Both quantity and quality of surface water are heavily influenced by ground water and many stream processes are influenced by hyporheic flow which is an intermediate between surface water and deep ground water. This lecture explores some fundamental concepts surrounding the ground/surface water interaction and overviews some chemical reactions that occur in ground water and influence surface water quality. Understanding the connections between surface and ground-water is critical to understanding surface water quality, management, and policy issues.

Student Preparation

- Read:
  - Ground Water and Surface Water: A Single Resource, U.S. Geological Survey Circular 1139; (pages: 1-17, 22-25, 54-67)
    - http://pubs.usgs.gov/circ/circ1139/

Additional Information Resources

- Lecture Notes
- The entire USGS circular referenced for student reading is good background information.

Class Topics

1. Ground-water and surface water as one resource
2. Gaining versus loosing stream reaches
3. Ground-water well pumping, cone of depression, interception of water headed to surface water, legal implications
4. Hyporheic flow
5. Determining ground-water flow direction
6. Chemical reactions in ground-water influencing water quality
7. Introduction to how movement of water on the landscape for agriculture influences surface water quality and quantity

Review Questions

1. Are ground and surface water easily separated in natural systems?
2. What is the fundamental principle of the Doctrine of Prior Appropriation?
3. What is a gaining stream? A losing stream?
4. What is a cone of depression?
5. What is Hyporheic flow? Why is it important?
6. Name a few types of chemical reactions that occur in ground-water and affect water quality.
7. Why are irrigation practices important when considering water quality and quantity in a watershed?
8. What is a common water quality problem associated with agricultural field drainage?

Lesson 5. Irrigation and Surface Water

The lesson

In Montana in 2000, irrigation accounted for 94% of water us in the state with 98.6% coming from surface water. Quality and quantity of water are intimately connected, so examination of irrigation as the primary water user in the state is a necessary part of studying water quality. In addition to quantity issues, there are also direct quality issues associated with the return flow of irrigation water to natural stream channels and the contaminants that are often in that water. This lecture examines the fundamentals of irrigation including delivery and application methods in the context of efficiency. Water quality issues arising from return flow and also from artificial drainage are also covered. Stream data from irrigation efficiency work on the Beaverhead River as well as preliminary water quality data from a study on Buffalo Rapids Irrigation District are also included to put the concepts in the context of current water quality issues in Montana.

Student Preparation

- Visit the Agricultural Water Conservation Clearinghouse and select 3 frequently asked questions from the list. Summarize the answers to these questions in your own words.
    - http://agwaterconservation.colostate.edu/

Additional Information Resources

- Lecture Notes
- Agricultural Water Conservation Clearinghouse: http://agwaterconservation.colostate.edu/

Class Topics

- Irrigation as a major water user in Montana
- Diversion methods
- Mass balance look at irrigation
- Conveyance and application methods and efficiency
- Transitions in the last 3 decades in irrigation methods and drivers for the transition
- Reducing consumptive use of water in irrigation
- Water quality impacts from return flow
- Agricultural drainage and water quality implications
- Buffalo Rapids Irrigation District Project BMP implementation and evaluation Case Study

Review Questions

1. Why are we talking about irrigation in a surface water quality class?
2. What are the possible fates of water diverted for irrigation?
3. What is irrigation efficiency?
4. What transitions have occurred since the 1970's in irrigation methods in the western United States?
5. What are some of the implications to stream flows with transition from flood to sprinkler irrigation?
6. What is return flow, and how can it affect surface water quality?
7. Why are drainage systems implemented on fields and how can they effect water quality?
8. What are a few of the methods that have been implemented in Buffalo Rapids Irrigation District to address these issues?

Lesson 6. Water Law

The lesson

This lecture covers the fact that water quality is a subjective term that must be talked about in the context of a beneficial use or reference condition. The vast majority of water quality work is structured by the provisions of the Clean Water Act (CWA) and the Safe Drinking Water Act (SDWA). These two laws provide the beneficial use and quality standards that put water quality numbers in context. The major provisions of the SDWA and the CWA are covered as the primary drivers for water policy in the US. The terms "point source" and "nonpoint source" pollution are described in both a physical and a social context and the total maximum daily load (TMDL) concept is introduced as a water quality management tool. A good grasp of the legal framework surrounding water quality is critical because it is much related to funding to do water quality work and the regulatory structure that works to protect waterbodies from pollution.

Student Preparation

Read:

- The EPA Clean Water Act online module
  http://www.epa.gov/watertrain/cwa/

Additional Information Resources

- Lecture Notes
- Montana 303d – 305b Integrated Report
  - http://www.deq.state.mt.us/wqinfo/303_d/303d_information.asp
- Montana DEQ Non Point Source Plan 2007
  - http://www.deq.state.mt.us/wqinfo/nonpoint/2007NONPOINTPLAN/Final/NPSPlan.pdf

Class Topics

1. Water quality is a subjective term, only meaningful in the context of a beneficial use
2. Safe Drinking Water Act (SDWA)
3. Clean Water Act (CWA): section 404 (wetlands), 303d (impaired waters list), point source section (NPDES), 319 (nonpoint source section)
4. Total maximum daily load (TMDL) overview
5. Water quantity law: a brief overview of different types

Review Questions

1. What does the term water quality mean?
2. What are two of the main provisions of the Safe Drinking Water Act?
3. What does TMDL stand for, what does it mean?
4. What are a few different types of laws governing water quantity and use?
5. What aspect of water quality does each of the following Clean Water Act sections address?
   - NPDES permit system
   - 319
   - 303d
   - 305b
   - 404

Lesson 7. Water Quality Standards, Focus on Montana

The lesson

This lecture introduces students to water quality standards and the essential role of standards for evaluation of water quality data. The lecture looks at Montana standards as an example and reiterates the concept from the previous lecture that water quality is a subjective term and intended use must be stated to know which standards apply. Narrative standards are discussed as the conceptual goals for water quality protection which provide a basis for setting specific numeric standards which are thresholds set to protect the overarching narrative goals. Benefits and challenges of setting numeric standards are covered with a Montana example of the transition narrative to numeric standards for nutrients. Lastly, the lesson walks through some steps in determining whether a stream is impaired or not.

Student Preparation

Use the Montana Circular DEQ-7 to find the human health standard for nitrate

Additional Information Resources

- Lecture Notes
- MT Circular DEQ-7 Water Quality Standards
  - http://www.deq.state.mt.us/wqinfo/Standards/CompiledDEQ-7.pdf

Class Topics

1. Beneficial use and stream designation
2. Narrative versus numeric standards
3. Use of ecoregion classifications in setting water quality standards
4. Assessing nutrient impairment
5. Numeric water quality standards: bioconcentration, acute versus chronic, and antidegredation
6. Determining whether a stream is impaired

Review Questions

1. Water quality standards must be written with a specific _____ in mind.
2. What is the first step in determining if a stream is meeting water quality standards?
3. What water quality characteristic do classifications A to C roughly track with?
4. What water quality characteristic do classifications 1 to 3 roughly track with?
5. Montana has both numeric and _____ standards.
6. Why are ecoregions a useful tool when identifying water quality reference conditions?
7. What is an acute standard?
8. What is a chronic standard?
9. What is a bioconcentration factor?
10. Can water quality results be interpreted in the absence of water quality standards? Why?
11. In Montana, what must be present in the stream along with elevated nutrients for a waterbody to be classified as impaired by nutrients for recreation?

Physical Parameters Section
(Lessons 8-14)

This section covers erosion, sediment transport, channel form, riparian vegetation and temperature, as well as how these parameters vary together.

Assignment 2

The assignment for this section requires students to:

- Answer morphology questions about a stream based on a cross section
- Classify a stream using Rosgen's method
- Relate channel form to temperature fluctuations and consequences for fish
- Use data from the Yellowstone River to construct a sediment rating curve
- Use the sediment rating curve to estimate annual sediment load using daily discharge

Lesson 8. Solids and Sediment Transport

The lesson

This lecture covers the distinction between dissolved, suspended, and bedload transported solids. Higher concentrations of sediment are moved at higher flows in streams and rivers which is a key element of understanding sediment movement and channel form. The factors that contribute to higher sediment movement at high flow are laid out as the concept behind sediment rating curves to predict sediment movement in streams. Sediment rating curves are an introduction to the idea that one variable can be measured and used to estimate values of another variable. Students will have an opportunity to apply these lessons in the second class assignment to estimate sediment transport in the Yellowstone River. A second example of predicting one variable with another is introduced with turbidity. Turbidity is basically the cloudiness of a water sample and is related to suspended solids in the sample. While these types of relationships can be valuable tools in water quality monitoring, there are potential problems which are covered in this lesson as well.

Student Preparation

Read:

- Chapter 5: Erosion and Sedimentation, Water Quality, Diffuse Pollution and Watershed Management, Second Edition, Vladimir Novotny, 2003

Additional Information Resources

- Lecture Notes
- USGS Suspended-sediment database webpage – US basin sediment summary
  - http://co.water.usgs.gov/sediment/conc.frame.html
- Sigler, W. A., Master Thesis: Armored Stanchion Cattle Water Access Effects on *E. coli*, Suspended Sediment, and Nutrient Loading to Spring Creeks, Montana State University, July 2008.
- Browning, L. S., J. W. Bauder, K. E. Hershberger, and H. N. Sessoms. 2005. Irrigation return flow sourcing of sediment and flow augmentation in receiving streams: A case study. J. Soil and Water Conserv. 60(3): 134-141.

Class Topics

1. Distinction between dissolved, suspended, and bedload solids
2. Suspended sediment in major rivers of the US
3. Stoke's law of settling velocity related to particle size
4. Sediment rating curves
5. Hysteresis
6. Suspended sediment analysis
7. Turbidity and correlation to suspended sediment
8. Suspended sediment monitoring plan example

Review Questions

1. What are the three categories of transport that solids are commonly categorized by?
2. What is the primary characteristic of a solid that determines if it will be transported as suspended or bed load?
3. Stoke's Law – Settling time decreases quickly with increase in _____.
4. (T/F) The sediment load in a healthy stream will be almost zero. Why?
5. What is the name of the graph which draws a relationship between stream discharge and sediment transport?
6. What are a few possible complications with correlating sediment concentration with flow magnitude?
7. What is the common term for the discharge which occurs approximately every 1.5 years, also known as effective discharge?
8. Suspended sediment is determined by the mass of solid retained on a filter of what pore size?
9. Turbidity is a measure of what?
10. What are a few important considerations when laying out a monitoring plan to assess sediment loading to a stream?

Lesson 9. Channel Morphology & Classification

The lesson

The purpose of this lecture is to illustrate how the sediment movement concepts from the previous lecture affect channel morphology and aquatic habitat. Instream storage and transport of sediment and bedload are key components in understanding the shape and structure of a stream channel. The lecture starts with a simple look at sources of sediment and sinks for sediment and how rivers transport sediment between the two. A few equations are introduced to touch on the fundamental concepts in solid transport as it relates to channel form. Common measurements for stream characterization are described and the lecture concludes with a look at stream classification systems.

Student Preparation

- Read:
  - Applied River Morphology; Rosgen; Chapters 2 & 3
    - Chapter 2: Fundamental Principles of River Systems
    - Chapter 3: Stream Classification

Additional Information Resources

- Lecture Notes
- Applied River Morphology, Second Edition; Dave Rosgen; 1996; Wildland Hydrology
- Tools in Fluvial Geomorphology; G. Mathias Kondolf, Herve Piegay; 2003; John Wiley & Sons Ltd.
- Lewis and Clark's observations and measurements of geomorphology and hydrology, and changes with time; USGS Circular; http://pubs.er.usgs.gov/usgspubs/cir/cir1246

Class Topics

1. Sediment mass balance, sources and sinks
2. Solids transport: effective discharge, Stoke's Law, Shear Stress, and Manning's Equation
3. Identifying bankfull stage, velocity profiles, and bedload transport
4. Channel characterization: width depth ratio, entrenchment, slope, sinuosity, and bank conditions
5. Channel classification

Review Questions

1. What are some sediment sinks in river systems?
2. Stream velocity increases as _____ and _____ increase and as _____ decreases? (this was in the Manning Equation)
3. Is stream water velocity faster on the inside or outside of curves?
4. Is stream water velocity faster on the surface or on the bottom of the stream?
5. Bankfull cross section is a function of the solids supplied to the channel being reworked by velocity differences and hydraulics in the channel. _____ is often dominant in the overall solids carried by a river, but _____ is typically dominant in determining channel form.
6. What are some measurements often taken to characterize channel form?
7. One of the earliest stream classification systems put forth by Schumm separated streams into 3 regions that correlate to elevation, what are those regions?
8. The three main categories of stream classification based on plan view are?
9. (T/F) Rosgen is a chef who became famous for cooking elaborate meals on river boats.

Lesson 10.
Erosion and Best Management Practices (BMPs)

The lesson

This lecture builds on the sediment transport discussion from the previous two lessons by covering the delivery of sediment to streams through erosion. An overview of the different types of erosion is provided and then the RUSLE soil loss model is introduced. Looking at the different variables used by RUSLE to predict soil erosion provides a structured way to think about the factors involved in erosion on the landscape. The lesson then overviews a variety of common BMPs used to reduce erosion. By discussing the important driving factors behind erosion and looking at BMPs that have been developed to address them, this lesson should help to calibrate students' eyes to problems and potential solutions in their environment.

Student Preparation

- Refer to the Water Quality chapter reading for Solids and Sediment Transport in Lesson 8.

Additional Information Resources

- Lecture Notes
- Water Quality, Second Edition, Diffuse Pollution and Watershed Management; Vladimir Novotny; 2003 Chapter 10: Abatement of Agricultural Diffuse Pollution.

Class Topics

1. Types of erosion: rainsplash, sheetwash, rilling, gullies, piping, bank erosion, bottom scour
2. Erosion and sediment sources in the landscape
3. RUSLE soil loss equation, overview of the factors included in the model
4. Best management practices (BMPs) overview
    - Cropping systems, silt fences, urban runoff, filter strips, riparian fencing and rotational grazing, slope stabilization, seeding and planting etc.

Review Questions

1. What is a primary concern with rainsplash erosion?
2. What do the following components of RUSLE soil loss equation deal with?
    a. R, K, L, S, C, P
3. What are each of the following land uses and BMPs physically doing to cause or reduce soil erosion?
    a. Cutting roads into forest hillsides
    b. Applying coconut fiber fabric to road cuts
    c. Tilling on the contour
    d. Alternating swaths of highly erodible and erosion resistant crops
    e. Clearing land for a new construction site
    f. Installing silt fences
    g. Installing permeable pavers in city environments
    h. Diverting rain gutter downspouts into flower beds rather than onto driveways
    i. Planting willows along stream banks
    j. Installing riparian fencing and rotational grazing plans for livestock
    k. Hydro seeding/mulching reclaimed mine tailing slopes
4. When you armor a stream bank to stop erosion, what are you doing to the critical shear stress level for that bank?
5. What are some of the common themes that BMPs strive to accomplish?

Lesson 11.
Grand Canyon Controlled Flood – Article Discussion

The lesson

This lesson looks at the controlled flood research on the Colorado River through the Grand Canyon National Park to illustrate the importance of natural river flows for river function. The presentation is adapted from a presentation by Dr. Duncan Patten who was the senior environmental researcher for the controlled floods released from Glen Canyon Dam in 1996. The presentation provides the visuals to help support a class discussion about an article by Dr. Patten about the flood. This lesson examines the tradeoffs that our society must weigh as we strive for energy independence while trying to protect our incredible ecosystems.
One option for this lesson is to designate students into groups who have an interest in flow management from the dam (power producers, fishermen, boaters, and ecologists). As students read the article, they can think from that perspective and bring their concerns to a class discussion about the way the dam should be managed.

Student Preparation

- Read:
  - Duncan T. Patten, David A. Harpman, Mary I. Voita, and Timothy J. Randle, A managed flood on the Colorado River: Background, Objectives, Design, and Implementation; Ecological Applications, June 2001.
- Think about the implications of different flow management or controlled flood plans from the perspective of a designated stakeholder group.

Additional Information Resources

- Lecture Notes
- Current Grand Canyon Research is available at the Grand Canyon Monitoring and Research Center:
  - http://www.gcmrc.gov/

Class Topics

1. Overview of the Colorado River system below Glen Canyon Dam and through the Grand Canyon
2. Stakeholders in the operation of the dam and their interests: recreation, power production, endangered species, and water supply
3. Dam effects on the hydrograph of the river through the Grand Canyon
4. Effects upstream from Glen Canyon Dam: fisheries, siltation, cultural resources.
5. Effects downstream from Glen Canyon Dam: sediment transport, water temperature, riparian vegetation
6. Focus on dam effects to sediment transport and channel morphology changes

Review Questions

1. Name 3 different stakeholder groups interested in flow management out of Glen Canyon Dam?
2. How do the interests of these groups conflict?
3. Describe the changes in the hydrograph of the Colorado River through the Grand Canyon as a result of the construction of Glen Canyon Dam.
4. What effect has the dam had on sediment dynamics in the river?

Lesson 12. Temperature

The lesson

This lecture discusses the importance of temperature in aquatic ecosystems and examines the factors that control temperature in a stream. There are a variety of factors on the landscape and within the stream system itself that contribute to the average temperature of a stream as well as the fluctuations in temperature on a daily and annual basis. This lecture follows a structure for thinking about stream temperature laid out in a paper by Geoffrey Poole which is an assigned reading for the class. In the face of climate change and diminishing instream flow, understanding the factors that control temperature is critical for management of water to protect fish and other aquatic species.

Student Preparation

- Read:
  - An Ecological Perspective on In-Stream Temperature: Natural Heat Dynamics and Mechanisms of Human-Caused Thermal Degradation. Geoffrey C. Poole. Cara H. Berman. Environmental Management. 2001.
  - Evaluating Laboratory-Derived Thermal Criteria in the Field: An Example Involving Bonneville Cutthroat Trout. Amy J. Shrank, Frank J. Rahel, Helene C. Hohnstone. Transactions of the American Fisheries Society. 2003

Additional Information Resources

- Lecture Notes

Class Topics

1. Temperature affects dissolved oxygen, rate of photosynthesis, and the rate of metabolism and chemical reactions which all affect aquatic life
2. Temperature can affect aquatic species in a number of sub-lethal ways without directly killing them
3. Landscape and in-steam controls on temperature
4. Monitoring temperature and expected fluctuations on a daily and seasonal scale

Review Questions

1. If the water doesn't get hot enough to kill the fish, why do we care about temperature fluctuations?
2. What are some of the external drivers that influence stream temperature?
3. What are some of the fluvial structures that influence stream temperature?
4. Describe the effect that hyporheic flow has on the temperature patterns in a stream.
5. If you were designing a monitoring plan to characterize the temperature of the East Gallatin River, what tools would you use and what types of considerations would be important?

Lesson 13. Riparian Areas and Vegetation

The lesson

The purpose of this lecture is to illustrate the function and importance of riparian areas and the critical role they play in protecting water quality and ecosystem integrity. Riparian areas are the transitional areas between aquatic and terrestrial environments. The benefits these areas provide are very large relative to the small portion of the landscape they make up. Habitat, flood control, and filtration of runoff are only a few of the critical aspects of riparian areas covered in this lesson. Intact and functioning riparian areas play a critical role in protecting water quality and aquatic ecosystem health.

Student Preparation

- Read:
  - Part of Chapter 3 – Human Alteration of Riparian Areas (Pages 99-127): Riparian Areas, Functions and Strategies for Management. National Research Council. National Academy Press. 2002.

Additional Information Resources

- Lecture Notes
- Chapters 2 and 3 of the Riparian Areas referenced for students
  - Structure and Functioning of Riparian Areas Across the United States
  - Human Alterations of Riparian Areas

Class Topics

1. Riparian area definitions
2. Function and importance of riparian vegetation: bank stabilization, bank building, runoff filtration, large woody debris, temperature control, habitat
3. Floodplain function and protection
4. Characterizing riparian areas, stubble height, Greenline Method, Proper Functioning Condition

Review Questions

1. There are a lot of different definitions for riparian areas, what are some common themes in the definitions?
2. Name some important functions and services that riparian areas/vegetation provide.
3. What is the function of a floodplain during flooding?
4. What are some characteristics of vegetation that influence effectiveness as bank stabilizers?
5. Why is it important to manage human activities in floodplains?
6. What does the term dynamic equilibrium mean in the context of riparian systems?
7. What are a few methods for assessing riparian vegetation and/or riparian health?

Lesson 14. Test over Introduction and Physical Sections

Student Preparation

- Review notes and review questions from the end of each lecture

Additional Information Resources

- Possible test questions are included in the curriculum materials

Chemical Parameters Section
(Lessons 15-26)

This section will give students an introduction to the spectrum of chemical parameters in water. Students will be exposed to the factors that control parameter concentrations in-stream, sources on the landscape, and why we care about these parameters. Topics cover the spectrum from general dissolved solids, nutrients and pH to metals, and pharmaceuticals.

Assignment 3 – Salinity, Electrical Conductivity, Ion Balance, and Nutrients

This assignment requires students to:

- Work with data provided for the Powder River to plot electrical conductivity against total dissolved solids and establish a relationship
- Use the relationship to estimate annual dissolved solid load in the River
- Calculate an ion balance on a water sample to check the accuracy of the lab results
- Answer conceptual questions about using the river water for irrigation
- Answer questions about carbonic acid using a Log C pH diagram

Lesson 15 & 16. Total Dissolved Solids (TDS), Electrical Conductivity (EC), and Hardness

The lesson

This lesson introduces the chemical parameters section with a discussion of dissolved solids in general. The lesson walks through the solids typically dissolved in water throughout the hydrologic cycle, starting with rain water chemistry and moving through rivers to the ocean. Calculation of ion balance is presented as a convenient method for checking laboratory results for accuracy, based on the principle that water has a net neutral charge. It is very common to estimate total dissolved solids (TDS) by measuring electrical conductivity (EC). The underlying principle is that H20 itself does not conduct electricity but the ions in it do, so as the salt in the water increases, it conducts electricity more easily. This fact makes it possible to measure EC continuously in a river in order to better capture fluctuations in salt concentrations on a daily, seasonal, or annual basis. Water hardness is covered as a parameter that is interesting to homeowners because it makes it more difficult to create lather from soap and hence makes water "hard" to work with. This lesson should be spread over at least 2 days.

Student Preparation

- Read:
  - Chapter 3: Dissolved Solids, Water Quality, An Introduction, Claude E. Boyd, Kluwer Academic Publishers, 2000
  - Chapter 4: Aqueous Reactions and Solution Stoichiometry, Chemistry, the Central Science, Prentice Hall, Englewood Cliffs, New Jersey.

Additional Information Resources

- Lecture Notes

Class Topics

1. What is a dissolved solid, analytically and in principle
2. Typical TDS values and some guidelines to put numbers in context
3. Review of aquatic chemical reaction notation and the process of dissolution
4. Overview of TDS levels and constituents in rain water, rivers, internally drained basins, and the ocean
5. TDS in relation to discharge
6. Net neutral charge of water, ion balance calculations as a method for checking lab results (Example worked out on the board)
7. Correlation between TDS and EC
8. Monitoring for TDS and EC.
9. Hardness

Review Questions

1. What is the analytical definition of total dissolved solids?
2. What is salinity?
3. Why is the term salinity not strictly equivalent to the analytical definition of TDS?
4. What do these TDS values represent?
   a. 500 mg/L b. 120 mg/L c. 35,000 mg/L
5. What should the left side of this dissolution reaction look like?
   _____ → $Na^+(aq) + Cl^-(aq)$
6. _____ makes water the most universal solvent.
7. (T/F) Total dissolved solids in rain water is always zero. Why?
8. What is the dominant chemical constituent (pair) transported by world rivers?
9. Is chemical composition more consistent through time in small rivers or large rivers?
10. How does the chemistry differ between lakes with and without outlets?
11. TDS tends to go _____ when stream discharge goes up.
12. Water has a net neutral charge. How does this allow for double checking analytical results from a laboratory?
13. If we want to know about TDS why might we talk about EC?
14. What is meant by the term "hard" water?

Lesson 17. Salinity and Sodicity Issues with Water

The lesson

Salinity and sodicity are the two parameters most commonly discussed related to irrigation water quality. Crop stress from soil salinization and soil damage from high sodium irrigation water are both discussed. The interaction of salinity and sodicity is covered along with insights on how negative effects from salinity and sodicity can be addressed. When humans drink water that is too salty, they can get diarrhea or become dehydrated. In the same way, the survival and productivity of plants is compromised when salt in irrigation water is too high. Salt management is a concern for irrigators around the world and as many populations struggle to feed themselves, an understanding these concepts is critical to maintaining the world's food supply.

Student Preparation

- Read:
  - The first two chapters of Agricultural Salinity and Drainage, Blaine R. Hanson, University of California Irrigation Program, University of California, Davis, 1999.
    - 1 - Crops, Water, and Salinity – pages 1-33
    - 2 - Water, Soils, and Salinity – pages 36-55
  - Frequently Asked Questions about Saline and/or Sodic Water and Soils
    - http://waterquality.montana.edu/docs/methane/saline-sodic_faq.shtml

Additional Information Resources

- Lecture Notes
- Ludwick, Albert E., et al. Western Fertilizer Handbook Ninth Edition. Danville, IL: Interstate Publishers, Inc. 2002.
- Additional webpages at http://waterquality.montana.edu/docs/methane.shtml
  - Basics of Salinity and Sodicity Effects on Soil Physical Properties (2003)
  - Diagnosing Salinity Problems
  - Salinity, Sodicity, and Flooding Tolerance of Selected Plant Species of the Northern Cheyenne Reservation (2001)

Class Topics

1. Explanation of terms: salinity and sodicity
2. Problems from high salinity: plants experience drought and toxicity = reduced crop yields
3. Osmotic stress, concept and effect
4. All irrigation water contains salt and requires salt management
5. High sodium concentration resulting in soil structure damage: soil dispersion
6. Quantifying sodium: Sodium adsorption ratio (SAR) & Exchangeable sodium percentage (ESP)
7. Relationship of SAR to hydraulic conductivity of soil, Hansen Diagram and implications for irrigators
8. Preview of correlation with coal bed methane topic

Review Questions

1. What is saline water?
2. What is sodic water?
3. What are two mechanisms that can cause the concentration of salt in the soil root zone to increase?
4. Why is salinity in irrigation water a concern?
5. Why is sodicity in irrigation water a concern?
6. How is salinity reported?
7. How is sodicity reported?
8. Summarize the relationship between EC and SAR in irrigation water and the risk for reduced hydraulic conductivity. (Ayers and Westcot or Hanson Figure)
9. What soil texture is at highest risk from sodic irrigation water and why?

Lesson 18.
Coal Bed Methane (CBM) – Powder River Basin

The lesson

This lesson applies the salinity and sodicity concepts from the previous lesson to the issues associated with CBM product water in Eastern Montana and Wyoming. Background is given on coal and methane formation to explain the connection between methane extraction and water quality. With the increasing importance of domestic energy independence, extraction of methane within the US has gained a lot of momentum. In order to get coal bed methane out of the ground, water must be pumped from the coal seams to free the methane. In most CBM development, the water is of very poor quality, and it is typically pumped back into the ground for disposal. In the Powder River Basin, much larger amounts of water must be pumped from the coal seams to remove the gas but the quality of the water is much better than in other basins. Product water in the Powder River Basin does however typically have high levels of sodium that can cause damage to soils if not managed properly. The issues associated with CBM development and product water management are outlined in this lesson from a water quality perspective as well as in a broader context.

Student Preparation

- Watch: Prairies and Pipelines, Issues in Coal Bed Methane Development
- Read: Frequently asked questions about coal bed methane (CBM)
    - http://waterquality.montana.edu/docs/methane/cbmfaq.shtml

Additional Information Resources

- Coal Bed Methane Primer, New Source of Natural Gas – Environmental Implications, Background and development in the Rock Mountain West, February 2004, ALL Consulting
    - http://www.all-llc.com/publicdownloads/CBMPRIMERFINAL.pdf

Class Topics

1. What is CBM: formation process, storage in cracks, held in place by water
2. CBM extraction process and infrastructure on the surface
3. CBM development numbers, wells, roads, power, gas lines
4. Chemistry of CBM product water
5. MSU research findings about CBM product water
6. Water quality and broader considerations with CBM development

Review Questions

1. What is coal bed methane?
2. Why does water quality come into play when talking about getting gas out of the ground?
3. How is the Powder River Basin different from other coal basins with respect to extracting CBM?
4. What are the two primary water quality parameters of concern in the Powder River Basin?
5. What are a few of the methods for using or disposing of CBM product water?
6. What are a few of the concerns associated with disposal of CBM product water?
7. What are a few non water related concerns that arise with the extraction of CBM?

Lesson 19. Nutrients - Nitrogen

The lesson

This lesson explores the reasons that nitrogen pollution to aquatic systems gets so much attention in water management. Nitrogen makes up the largest component of our atmosphere at 78 percent and the cycling of this nutrient around the planet is critical to life. Along with carbon and oxygen, nitrogen makes up a dominant proportion of living material. As a result of plant demand for nitrogen, fertilizer is added to fields to increase yields, but not all of the nitrogen is absorbed into the plants and some ends up in waterways. Nutrients that are taken up by plants are often consumed by humans and animals which are largely released in feces. Human waste is typically dealt with by treating the waste water and then releasing it back into surface or ground water. Traditionally treatment was not designed to remove nutrients. Improvements to treatment have been made in some cases but nutrients from human waste are an important source of aquatic pollution. Nutrients in animal waste also poses problems when this waste is deposited adjacent to streams or when manure is concentrated due to confinement of animals in feeding areas. Understanding the cycling of nitrogen on the planet is an important part of managing aquatic pollution.

Student Preparation

- Read:
  - Chapter 1 – Nitrogen, Agriculture, Hydrology and Water Quality

Additional Information Resources

- Lecture Notes
- Flux and Sources of Nutrients in the Mississippi-Atchafalaya River Basin, Topic 3 Report, May 1999.
  http://oceanservice.noaa.gov/products/hypox_t3final.pdf
- Frontline Video: Poisoned Waters - http://www.pbs.org/wgbh/pages/frontline/poisonedwaters/

Class Topics

1. Reasons for concern about nutrients: human and aquatic health
2. Nitrates and Methemoglobinemia (blue baby syndrome)
3. Ammonia toxicity to aquatic organisms
4. Eutrophication, limiting nutrient concept, phosphorus versus nitrogen limitation
5. The nitrogen cycle
6. Nitrogen movement in aquatic systems and nutrient spiraling
7. Seasonal and diurnal fluctuations of in-stream nitrogen concentration

Review Questions

1. Why are standards set for ammonia nitrogen?
2. Why are standards set for nitrate?
3. Why are standards set for total nitrogen?
4. What is the Redfield Ratio and Limiting Nutrient concept?
5. What are the 3 primary analytical groups of nitrogen and what species make them up?
6. What are the 5 main fluxes between species in the nitrogen cycle?
7. What are some sources of nitrogen on the landscape that contribute to water quality issues?
8. What are some dynamics within aquatic systems that affect total nitrogen concentration the speciation of nitrogen?

Lesson 20. Phosphorus, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), and Nutrient Flux to the Gulf of Mexico

The lesson

This lecture looks at phosphorus, which unlike nitrogen, does not have any direct human health issues, but is a major cause of eutrophication in freshwater systems. The phosphorus cycle is much less dynamic than the nitrogen cycle because the majority of phosphorus is strongly tied up in solids. However, the amount of phosphorus required by living organisms is much lower than the concentration of nitrogen required. This means that even though most phosphorus is in the solid phase and is unavailable to plants, a small amount of soluble phosphorus reaching a water body can cause large amounts of plant growth. Excessive amounts of aquatic plant growth means more oxygen is required to break down the plants when they die. This phenomenon known as eutrophication has resulted in large anoxic areas in the Gulf of Mexico which has negatively impacted aquatic ecosystems and fishermen that depend on them.

Student Preparation

- Read:
  - Chapter 2 – Phosphorus, Agriculture, Hydrology and Water Quality
  - Chapter 2 – Photosynthesis, Aquatic Pollution, An Introductory Text, Third Edition

Additional Information Resources

- Lecture Notes
- Gulf of Mexico Hypoxia Task Force Reports

Class Topics

1. Review nutrient concepts from nitrogen lesson
2. Phosphorus species and cycle overview
3. Explanation of the dominance of solid phases of phosphorus
4. Factors effecting DO solubility
5. Dissolved oxygen standards and measurement
6. Fluctuations in DO concentration
7. BOD and Chemical Oxygen Demand (COD)
8. Flux of nutrients to the Gulf of Mexico and eutrophication

Review Questions

1. Why are water quality standards set for phosphorus?
2. Does nutrient spiraling occur with phosphorus?
3. What are the two most common categories of P analysis in water samples?
4. Where is the majority of phosphorus found in an aquatic system?
5. Why is sulfuric acid often added to nutrient samples in the field?
6. What are a few typical nutrient analysis methods?
7. What is meant by the Gulf of Mexico Dead Zone?
8. What landuse has been identified as the primary contributor of nutrients to the Mississippi and the dead zone?

Lesson 21 & 22. pH and Alkalinity

The lesson

This lesson exposes students to the fundamentals of pH and the exchange of hydrogen ions in aquatic environments. Understanding the basics of pH is critical because most chemical reactions in water are influenced by pH. This lecture demystifies the "p" and the "H" in pH. The lecture revisits some basic chemical formula notation from introductory chemistry and introduces log concentration / pH diagrams as useful tools to see how acids behave across the pH scale. Alkalinity is the ability of a solution to neutralize acid and titration is a common method for measuring alkalinity in solution. Alkalinity and buffer capacity of a solution are related and covered as a critical aspect of maintaining pH with ranges that are suitable for life processes to take place.

Student Preparation

- Read:
  - Aquatic Environmental Chemistry, Alan G. Howard – Chapter 3 – The acidity of water

Additional Information Resources

- Lecture Notes
- Chemistry, the central science, Brown, LeMay, Bursten
  - Chapter 16 – Acid/Base Equilibria
  - Chapter 17 – Additional Aspects of Aqueous Equilibria

Class Topics

1. Dissociation of water and the hydronium ion, formation of H_30^+ and OH^-
2. The pH scale, log scale
3. pH notation, an explanation of the "p"
4. Chemical equilibrium formulas for dissociation of water
5. Log Concentration / pH Diagram for water
6. Rain water and pH
7. Acidity and the points of the pH scale where acids give up their H^+ ions (pK values)
   a. Ammonia, phosphoric acid, and carbonic acid examples
8. Buffering capacity of acids, information you can get from a Log Concentration/pH Diagram
9. Acid rain in the US, landscape buffering capacity, pH effect on fish

Review Questions

1. Describe the following units of measure.
   - Mass Concentration
   - Molarity [M]
   - Normality
2. What is the concept of ion activity?
3. What does the "p" stand for in pH?
4. What is an equilibrium constant (K)?
5. What is pH and what is the meaning of a pH value of: 0, 7, 14?
6. What is alkalinity?
7. What is the significance of the pK value for an acid?
8. What information can be determined about an acid using a log C pH diagram?

Lesson 23. Oxidation and Reduction: Redox

The lesson

This lecture covers the basic concepts of redox chemistry as it relates to water quality. Similar to acid/base chemistry, a basic understanding of oxidation and reduction (redox) of elements is critical to understanding chemical reactions in water. With acidity, pH is a measure of the concentration of hydrogen ions in solution. Similarly, with redox we can think of pE as the concentration of electrons available in a solution. The pH (acidity) and pE (redox) conditions of aquatic systems will determine which form different elements will be found in. This is very important because different forms (or species) of elements can have different toxicity and mobility levels in the environment. The lecture is concluded with coverage of acid mine drainage which is the result of pyrite minerals being oxidized to release hydrogen ions which produce highly acidic water quality conditions and the classic orange deposits associated with mine runoff where pyrite is present.

Student Preparation

- Read:
  - Aquatic Environmental Chemistry, Alan G. Howard - Chapter 5 – Oxidation and Reduction

Additional Information Resources

- Lecture Notes
- Chemistry, the central science – Chapter 20 - Electrochemistry

Class Topics

1. Parallel between acid/base chemistry and redox chemistry: acid/base deals with proton exchange (pH values), redox deals with the electron exchange (pE values)
2. Redox potential can be though about in terms of the number of available electrons in a solution, high oxygen concentration is associated with oxidizing conditions (high pE) and few free electrons in solution while low oxygen means reduced conditions (low pE) and lots of free electrons in solution.
3. Oxidation state: general rules, using the periodic table to identify oxidation states
4. Redox state related to anoxic conditions in wetlands, rotten egg smell
5. Oxidation states of metals: Iron II versus Iron III, Manganese II versus Manganese IV, Arsenic and Mercury, oxidation states and importance related to toxicity and mobility
6. Stability Field Diagrams: diagrams with pH on the x axis and pE on the y axis, different species of elements are stable and predominate at different acidity and redox potentials
7. Acid mine drainage = Redox chemistry

Review Questions

1. Low pE means a low or a high concentration of free electrons?
2. Is there a low or high concentration of oxygen when pE is high?
3. What are a few of the concepts behind determining the oxidation state of an element in various compounds?
4. When water is pumped from the ground and manganese precipitates out, what is the process at work?
5. What is happening when rust is created?
6. What is a stability field diagram and what can we determine from examining it?
7. What is acid mine drainage?

Lesson 24. Clark Fork Superfund Overview

The lesson

This lesson overviews the long list of environmental issues that make up the Clark Fork series of Superfund sites. This series of four contiguous sites together make up the largest Superfund site in the country. There is a diversity of water quality issues associated with the site in addition to soil and air quality issues. The impacts to the Clark Fork Drainage as a result of mining range from acid mine drainage, to tailings deposits on floodplains, to soils contaminated during smelting of minerals, to ground water contaminated by chemicals used to preserve wood for the mines. This enormous scale environmental disaster provides opportunities to learn both about mistakes of the past as well as innovative restoration efforts of today.

Student Preparation

- None

Additional Information Resources

- Lecture Notes
- Pit Lake System Characterization and Remediation for the Berkeley Pit, Montana Tech of the University of Montana, Nov. 1999 http://www.epa.gov/hardrockmining/a4/a4147.pdf
- Historic Context of Butte, Montana DEQ website, http://www.deq.mt.gov/abandonedmines/linkdocs/techdocs/183tech.asp
- Clark Fork River Technical Assistance Committee: http://www.cfrtac.org/

Class Topics

1. The Butte area and the Berkeley Pit, Redox and pH conditions in the pit lake
2. Silver Bow Creek floodplain tailings sediment restoration area
3. Anaconda Smelter Site
4. Montana Pole controlled ground water site
5. Milltown dam removal and restoration site
6. Preliminary changes in water quality over the course of restoration

Review Questions

1. What natural process acted in the first part of the 20th century to create widespread environmental devastation in the Clark Fork Basin?
2. What is the concern at the Montana Pole Superfund Site?
3. What was the mechanism for contamination at the Anaconda Smelter Site?
4. What is the primary concern with the stretch of Silver Bow Creek from Butte to the Warm Springs Ponds?
5. Why where the Warm Springs Ponds created and how do they operate?
6. What is the concern and remediation approach being taken at the Milltown Dam Site?
7. Why has it been deemed appropriate to relocate contaminated sediment from Milltown dam to cap the tailings at the Opportunity Ponds near Anaconda?
8. What are the redox conditions in the Berkley Pit and why is it important to understand the chemical conditions in the pit?

Lesson 25. Pharmaceuticals and Personal Care Products

The lesson

This lecture introduces some of the concerns and factors associated with pharmaceuticals and personal care products (PPCPs) in surface and ground water. Chemicals are available in the United States to address everything from birth control, to insect repellent, to bacterial infections and an increasing number of studies are identifying these chemicals in our water supplies. PPCPs are often only present in water at concentrations on the order of parts per trillion. This makes studying them analytically challenging and expensive. Regulatory agencies lack sufficient knowledge and understanding about many of these chemicals to set meaningful water quality standards and while evidence of impacts to human health from PPCPs in the environment has not been documented, impacts to fish have been documented. Understanding the pathways these chemicals take to reach our water supplies and what we can do to reduce PPCPs getting into water resources is important knowledge for all citizens.

Student Preparation

- Read Article: Hirsch, R. T. Ternes, K. Haberer and K.-L. Kratz. 1999. Occurrence of antibiotics in the aquatic environment, Sci. Total Environ. 225, pp. 109–118.

Additional Information Resources

- Lecture Notes
- Kinney, Chad A., Presence and distribution of wastewater-derived pharmaceuticals in soil irrigated with reclaimed water, Environmental Toxicology and Chemistry, Vol. 25, no. 2, 2006.Hirsch, R. T. Ternes, K. Haberer and K.-L. Kratz. 1999. Occurrence of antibiotics in the aquatic environment, Sci. Total Environ. 225, pp. 109–118.
- Miller, Kathleen J., Joseph Meek, Helena Valley Ground Water: Pharmaceuticals, Personal Care Products, Endocrine Disruptors (PPCPs) and Microbial Indicators of Fecal Contamination, Montana DEQ Report
- Buerge, Ignaz J., Thomas Poiger, Markus D. Muller, and Hans-Rudolf Buser, Caffeine, an Anthropogenic Marker for Wastewater Contamination of Surface Waters. Environmental Science and Technology, 2003, 37:691-700.

Class Topics

1. Overview: what are pharmaceuticals and personal care products (PPCPs)
2. Movement of PPCPs in the environment
3. Issues and concerns with PPCPs
4. Highlights from Studies about PPCPs in water resources

Review Questions

1. What are PPCPs?
2. What are the concerns with PPCPs?
3. Describe the adverse effects on fish that have been observed due to hormones in natural waterbodies.
4. What are the primary concerns with antibiotics in the environment?
5. What are some of the factors that have limited our understanding of PPCPs in the environment?

Lesson 26. Test over Chemical Section

Student Preparation

- Review notes and review questions from the end of each lecture.

Additional Information Resources

- Possible test questions are included in the curriculum materials

Biological Parameters Section
(Lessons 27-32)

This section covers macroinvertebrates and waterborne pathogens. Lessons on municipal runoff and a look at water quality in the developing world are also included here.

Assignment 4 – Macroinvertebrates and fecal indicator bacteria

This assignment requires students to:

- Calculate a pollution tolerance index score two streams using simple macroinvertebrate data
- Interpret fecal bacteria water quality to determine if a waterbody is meeting water quality standards

Lesson 27. Municipal Stormwater Runoff

The lesson

This lesson explores municipal stormwater management as an issue currently in transition in many communities from unregulated to regulated under federal law. Municipal stormwater starts dispersed over the landscape and is associated with precipitation which is characteristic of nonpoint source pollution. However, once the water is collected into pipes for discharge to surface water, it becomes a point source and is regulated under federal law. Municipal stormwater was addressed under the Clean Water Act in two phases. The first phase addressed large cities and began in 1990; the second phase addresses smaller urban areas and began around 2000. Sediment, bacteria, metals, and oil and grease are all common constituents in stormwater. Sources of these pollutants come from a variety of people and landuses within urban areas so a combination of public education and best management practice implementation is fundamental for reducing impacts. This lesson addresses some of the approaches for reducing stormwater runoff and improving the quality of the water that does runoff.

Student Preparation

- None

Additional Information Resources

- Lecture Notes
- EPA websites
    - Clean Water Act Tutorial Website (See slides 46-54)
        - http://www.epa.gov/watertrain/cwa/cwa45.htm
    - Municipal Separate Storm Sewer Systems (MS4s)
        - http://cfpub.epa.gov/npdes/stormwater/munic.cfm?program_id=6
    - Combined Sewer Overflows (CSOs)
        - http://cfpub.epa.gov/npdes/home.cfm?program_id=5

Class Topics

1. Overview of where municipal stormwater runoff comes from
2. Clean Water Act regulatory framework for managing storm water
3. Focus the Portneuf River through Pocatello, ID
    a. City storm water permit
    b. Monitoring efforts
    c. Practices being implemented – constructed wetland
4. Focus on Bozeman, MT
    a. Mandeville Creek through the MSU Campus, results from student research
    b. Stormwater management in Bozeman

Review Questions

1. Is municipal stormwater a point or nonpoint source of pollution?
2. What is a CSO? What is the concern?
3. What is a MS4?
4. What are some of the water quality issues associated with MS4 discharges?
5. What is the purpose of constructing a wetland to capture stormwater runoff?
6. What are some BMPS for increasing stormwater infiltration on site?

Lesson 28. Macroinvertebrates

The lesson

This lesson covers macroinvertebrates in aquatic systems and their use as indicators of stream health. Chemical sampling of water bodies is generally conducted through grab samples which represent the quality of the water at one point in time. This type of sampling gives no indication of what the quality of water was for the last month or even five minutes before the sample was taken. However, macroinvertebrates live in the stream and their survival depends on the quality of the water that passes by them. For this reason, bug communities in rivers can be thought to represent water quality through time and can be used as more holistic indicators of stream health. Different macroinvertebrates have different tolerance thresholds for pollutants. By comparing the bugs that are present in a given stream reach against the bugs that are usually present in that type of stream reach, we can get an idea of the level of impairment to the stream.

Student Preparation

- Read:
  - Field Manual for Water Quality Monitoring, Mark Mitchell – Chapter 6 – Benthic Macroinvertebrates
  - Methods in Stream Ecology, Richard Hauer – Chapter 35 – Macroinvertebrates as Biotic Indicators of Environmental Quality

Additional Information Resources

- Lecture Notes

Class Topics

1. Why look at macroinvertebrates to assess water quality
2. Caddis flies, Stoneflies, and Mayflies
3. Grouping macroinvertebrates, taxonomy and functional feeding groups
4. River continuum concept related to macroinvertebrates
5. Collection methods
6. Macro invertebrates as indicators of stream health: species Richness, Pollution Tolerance Index, Family Biotic Index, and EPT Richness
7. Macroinvertebrate dispersal

Review Questions

1. What advantage does the use of macroinvertebrates have in assessing water quality?
2. What are the common names for the three primary macroinvertebrate species used as pollution intolerant indicators?
3. What are a few of the most pollution tolerant macroinvertebrate species?
4. What does it mean if you find only pollution tolerant species in a section of river?
5. What factors besides pollution will influence the community of bugs in a river?

Lesson 29.
Waterborne Pathogens and E. coli as an Indicator Organism

The lesson

This lecture explores the monitoring and management of pathogens as waterborne disease vectors starting with early cholera outbreaks in England up to modern day drinking water protection. The lesson starts with an overview of the four main categories of pathogens and highlights members of these categories commonly responsible for disease outbreaks. Key points about different pathogens are emphasized and this overview of the diversity of pathogens sets the stage for the reason the indicator organism concept came about. With the vast array of pathogens potentially present in the environment and the complexity of the analytical methods for these pathogens, the concept of testing for an indicator organism which is relatively simple and easy to quantify becomes attractive. The lessons finish with an overview of the epidemiological research conducted by the USEPA which drew correlations between the concentration of indicator bacteria in recreational water and waterborne illness.

Student Preparation

- Read:
  - Aquatic Pollution, Edward Laws, Chapter 7 – Pathogens in Natural Waters
  - The Coliform Index and Waterborne Disease, Cara Gleeson - Chapter 2 – Indicator Organisms and the Coliform Concept

Additional Information Resources

- Lecture Notes
- The Coliform Index and Waterborne Disease, Cara Gleeson - Chapter 1 – Microbial Water Quality
- Waterborne Pathogens, Manual of Water Supply Practices, American Water Works Association, 2006

Class Topics

1. The beginnings of epidemiology and understanding of waterborne disease, John Snow
2. Categories of pathogens: helminthes, protozoa, bacteria, viruses
3. Disease outbreaks in the US
4. Viruses: Rotavirus, norovirus, hepatitis A,
5. Bacteria: Vibrio cholerae, Pseudomonas, Shigella, E. coli, Campylobacter, Salmonella
6. Protozoa: Cryptosporidium parvum, Giardia lamblia, Naegleria fowleri
7. Helminths: Schistosoma
8. Drinking water treatment
9. Pathogen analysis: microscopy and molecular methods
10. Pathogen monitoring challenges and the indicator organism concept
11. EPA epidemiological research and suggested recreation water quality standards for *E. coli*

Review Questions

1. Who is John Snow, and why is he introduced in this lesson?
2. What are the 4 categories of pathogens covered in order of size from smallest to largest?
3. What is the event in US history that puts Cryptosporidium at the top of the list for causes of waterborne disease cases while it is not number one for the number of outbreaks?
4. Why is the concept of an indicator organism useful in assessing waterborne disease outbreak?
5. How does the concept of an indicator organism for assessing risk of waterborne disease work?
6. What is the underlying principle used by the EPA to set recreational water quality standards for *E. coli*?

Lesson 30. Water Quality, a Developing World Perspective, Khwisero Kenya Case Study

The lesson

This lesson overviews water and soil issues associated with the water development project that the MSU chapter of Engineers Without Borders is conducting in Khwisero, Kenya. Population growth in this area of Kenya has lead to deforestation and increasing pressure on the landscape as people struggle to meet their daily needs for food and fuel. The people of Khwisero primarily depend on springs for drinking water supply and with increasing numbers of pit latrines dotting the landscape, the potential for disease transmission is of great concern. EWBMSU is involved in a long term project to provide clean water and sanitation to 58 primary schools in the Khwisero Division of Kenya. This lesson provides insight about how the concepts covered in this course and other environmental science courses are extremely important to the lives of people in developing countries who are so intimately connected to their soil and water resources.

Student Preparation

- Lecture Notes

Additional Information Resources

- MSU Engineers Without Borders Website
  - http://www.ewb-msu.org/projects.php

Class Topics

1. Overview of Kenya: connections between precipitation and population distribution
2. The wet equatorial region near Lake Victoria versus the drier South Rift Valley
3. Kakamega rain forest preserve versus the division of Khwisero where the rain forest has been cleared for subsistence agriculture
4. Home life in Khwisero: what goes on during daily life in the patchwork of cleared landscape
5. Water sources and collection
6. Sanitation and the connection to water supply, composting toilets as part of the solution
7. Preliminary water quality results for springs used as drinking water sources
8. Erosion problems
9. Rural versus urban poverty and environmental health concerns
10. What MSU Engineers Without Borders is doing to help

Review Questions

1. What are some of the water sources that people in Khwisero rely on?
2. What is the primary method of human waste disposal and how does that relate to water quality?
3. What are two ways that water is reducing soil productivity in Khwisero?
4. What are two benefits that EWB hopes to accomplish through building composting latrines?

Lesson 31. Concept Matrix

The lesson

This lesson is an opportunity for students to lay out what they have learned in the class in a systematic way. The process of writing down what they know about all of the parameters covered in class will begin a well rounded review process for the final. While discussing the concepts learned throughout the course, there will be an opportunity to discover connections, differences, and similarities between the parameters and concepts.

Student Preparation

- Option 1: Fill out the concept matrix before coming to class using notes and readings
- Option 2: Students fill out the concept matrix in class from memory

Additional Information Resources

- Example concept matrix included with curriculum materials

Class Topics

1. Walk through the concept matrix calling on students to explain what they have written

Lesson 32. Comprehensive Test

Student Preparation

- Review notes and review questions from the end of each lecture.

Additional Information Resources

- Possible test questions are included in the curriculum materials