Application of Environmental Assessment in a Secondary Earth & Environmental Science Classroom: Lesson Plans on Water Quality

by
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ABSTRACT

WHITTINGTON, HOLLY NICOLE. Application of Environmental Assessment in a Secondary Earth & Environmental Science Classroom: Lesson Plans on Water Quality. (Under the direction of Dr. Tamara Pandolfo).

Water is essential for life, yet increased urbanization and industrial activities from growing populations threaten its quality and availability. Freshwater ecosystems that provide drinking water, recreation, aquatic habitat, and countless other services are being damaged by pollution, while problems like eutrophication and climate change worsen water quality. Water quality can be determined through the assessment of physical, chemical, and biological factors. Using a variety of parameter measurements from among these factors, a water quality index (WQI) can turn values into an aggregated score that describes the overall condition of a water body. WQI scores can then be used to inform policymaking, guide water management, and track the health of water bodies over time as pollution mitigation and water restoration efforts take place. Surface water classifications further the effort of resource protection by identifying appropriate uses of water. Surface water classification systems group water bodies based on physicochemical, biological, and physical characteristics. In North Carolina, these classification systems play an important role by allowing for water health assessment, resource management, and the insurance of safety and cleanliness for recreational and drinking water supplies.

Specifically in North Carolina, surface water quality is facing considerable threat from point and nonpoint source pollutions in the form of emerging contaminants and “forever chemicals.” Chemicals such as polychlorinated biphenyls (PCBs) and per- and polyfluoroalkyl substances (PFAS) persist in the environment and cause human health problems. Regulatory agencies are actively working to monitor and learn more about these chemicals so that further contamination can be prevented and water quality protected and restored.

Education offers an opportunity to address water quality issues by offering relevant and poignant lessons and projects that promote environmental stewardship. Schools are essential in teaching water conservation and sustainable practices that ultimately empower future generations to maintain clean water. For this project, lesson plans for a secondary Earth and Environmental Science course were designed to introduce and explore the topics of water quality indices, surface water classification, and water pollutants in North Carolina.

DEDICATION

I want to dedicate this work to my partner, who kept our lives going and our home together so I could make this degree happen. “SM Stewart, say say!” I would also like to dedicate this effort to my parents, Marvin (Father!) and Barbara (Mum!) for supporting me in all the opportunities I was able to take along my educational pathway. You also made this happen.

BIOGRAPHY

Holly Whittington is a secondary education science teacher with a degree in Chemistry and concentration in Comprehensive Science from the University of North Carolina – Greensboro. She enjoys teaching Chemistry and Environmental Science to teenagers, the best of the bunch! When not teaching, she can be found enjoying time with her family, dogs, and reptiles, reading as many books as possible, or traveling to faraway places.

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Introduction

Water is essential for maintenance of life as well as for supporting many aspects of human culture, society, and development. It is used for nourishment, recreation, domestic tasks, industry, production, and countless other processes. Freshwater ecosystems naturally provide a source of food, flood control, and purification of human and industrial wastes (Baron et al. 2002). However, with growing human populations and increased urbanization, surface water systems are being negatively impacted by anthropogenic activities (Liyanage and Yamada 2017). Without rigorous monitoring and intervention, the accessibility of high-quality water could decline, threatening public health and environmental integrity (Baron et al. 2002).

The need for water is a necessity, but human activities have created many challenges in maintaining clean water. The increased pressure from water consumption, irrigation, and transport for growing populations has caused many natural services provided by freshwater ecosystems to deteriorate or be destroyed (Baron et al. 2002). The construction of “hard path” infrastructure such as dams, aqueducts, and pipelines to generate hydropower and expand irrigation practices has further devastated freshwater ecosystems (Gleick 2002).

As urbanization increases, so do the implications of increased pollution in surface water systems (McGrane 2015). Runoff and disposal of material into surface water can bring a host of contaminants such as nutrients, sewage, and synthetic chemicals (McGrane 2015). With increased nutrients comes eutrophication, a worldwide water quality issue that is a visible representation of a biosphere’s alteration due to human activities (Zamparas and Zacharias 2014). Eutrophication is also increased by another human issue, climate change. As climate change ensues with variations in precipitation patterns and increasing global temperatures, nutrient loading in aquatic ecosystems escalates bacterial blooms (Rodgers 2021). In more avenues than one, humans are affecting water quality.

The ability to intensely affect the environment and subsequently water quality means that humans hold power to create change. Environmental stewardship has the potential to begin at an early age in school. Foundations of human personality form during primary school years, so simply introducing students to nature at a young age allows for a positive attitude towards the environment to form (Lamanauskas 2023). This leads to a growth of empathy for nature and eventually more environmentally conscious decisions as students age and develop into adulthood.

As students progress from primary to secondary school, environmental science classes can further amplify understanding of environmental impacts by helping students become a “practitioner.” Secondary environmental science classes provide students a path to becoming a practicing environmental citizen by offering guided inquiries to problem-solving (Iversen and Jónsdóttir 2018). Instead of only “learning” about environmental processes, secondary education classes help to develop “green behavior” and promote development of pro-environmental choices (Varela-Candamio et al. 2018). This translates directly to engaging students in water conservation practices and efforts.

It is vital for students to have access to water quality education through environmental science classes as schools have been recognized as a leading resource for learning water-conservation measures (Xiong et al. 2015). Water management initiatives targeting school age children have increased sustainable practices and community engagement in environmental awareness (Nourredine et al. 2023). Public education not only promotes efficient resource usage, but also encourages responsibility among citizens and policymakers. These efforts are particularly important as industrial activities, climate change, and agricultural runoff continue to affect water quality everywhere (WHO 2023). Developing and utilizing interactive, inquiry-based lessons in water quality can foster a new age of environmental awareness in emerging adults that lead to a future of more sustainable environmental and water practices.

Unit 1: Water Quality Index

Water quality is determined by the condition and interaction of physical, chemical, and biological factors in the water body (Omer 2020). Each of these factors can be assessed using a variety of parameters that collectively provide a detailed description of the condition of a body of water (Table 1.1; Omer 2020). The importance of monitoring water quality and maintaining water cleanliness cannot be overstated. However, it can be time and labor intensive to determine assessment plans for every water body. The development of the water quality index (WQI) aimed to streamline this process.

The first step in using a WQI is selecting parameters, which is usually done by professional experts or relevant government agencies. Parameters often target oxygen levels, eutrophication, health aspects, physical characteristics, and dissolved substances (Tyagi et al. 2013). Once parameters are chosen, they are assigned weighted values based on the relative importance of the parameter. If the WQI is being used as an overall general indication of water health, all parameters can be given equal weight. If there is a specific parameter the users of the WQI are looking to assess, i.e. a health aspect like fecal coliform, the parameters of specific interest are subjectively given a higher weighted value by the experts or agencies that chose them (Sutadian et al. 2015). With weighted values set, measurements of each parameter are converted to a unitless value and multiplied by the assigned weighted factor (IDEM 2024). The final weighted values are aggregated and summed to give an overall condition value of the water being assessed, on a scale of 1 to 100. The higher the condition value, the healthier the water is determined to be (Tyagi et al. 2013).

Table 1.1: Common physical, chemical, and biological parameters used in water quality assessments (Omer 2020).

Parameters	Unit of Measurement	Description	Common Analysis Methods
Physical Parameters			
Turbidity	Nephelometric Turbidity Unit (NTU)	Cloudiness of water caused by suspended particles; a measure of the ability of light to pass through water	Nephelometric turbidimeter
Temperature	Degrees Celsius (^{o} C)	Master parameter that influences other physical, chemical, and biological parameters	Thermometer, Temperature Probe
Color	Color Unit (CU)	Decayed organic matter and inorganic matter can imbue color to water, making it aesthetically unappealing	Colored glass discs, standard color solutions
Total Suspended Solids (TSS)	Milligrams/Liter (mg/L)	Solids suspended in solution; increased solids can lead to increased turbidity	Glass fiber filter with retained particles heated to dryness and weighed
Total Dissolved Solids (TDS)	Milligrams/Liter (mg/L)	Organic and inorganic solids dissolved in solution; can include various minerals such as calcium, magnesium, zinc	Water filtered with glass fiber filter is heated to dryness and weighed
Conductivity	MilliSiemens/meter (mS/m)	Ability of water to carry or conduct an electrical current via ions; can be used to estimate TDS	Electrometric method
Chemical Parameters			
pH	N/A	Measure of how acidic or basic the water is; excessively high or low pH can affect taste and general health of water	Electrometric method, Colorimetric Method

Table 1.1 continued.

Parameters	**Unit of Measurement**	**Description**	**Common Analysis Methods**
Alkalinity	Milligrams/Liter (mg/L) $CaCO_3$	Acid-neutralizing capacity of the water; a measure of productivity	Titration with indicator
Nitrogen (Nitrates)	Milligrams/Liter (mg/L)	Nutrient affecting algal and plant growth; indicator of sewage and fertilizer	Colorimetric method
Phosphorus (Phosphates)	Milligrams/Liter (mg/L)	Nutrient affecting algal and plant growth; indicator of sewage and fertilizer	Colorimetric method
Dissolved oxygen (DO)	Milligrams/Liter (mg/L), Percent Saturation (%)	The amount of oxygen available for use by aquatic organisms; main indicator of water quality and pollution	Colorimetric method, Winkler titration, Electrometric method
Biochemical oxygen demand (BOD)	Milligrams of Oxygen/Liter (mg/L)	The amount of oxygen consumed by aquatic microorganisms to decay organic matter	Timed measurements of DO (DO_{final} - $DO_{initial}$)
Biological Parameters			
Fecal Coliform	Coliforms/100 Milliliter (mL)	Bacteria that can cause dangerous gastroenteritis outbreaks	Colony growth on suitable nutrient medium
Algae (Chlorophyll)	Micrograms/Liter (µg/L)	Microscopic plants that contain photosynthetic pigments (chlorophyll); mainly nuisance organisms but can cause environmental and public health issues	Visual observation, Microscope

Early Water Quality Indices

In 1965, Robert Horton introduced the first documented water quality index (Jacobs et al. 1965). Horton's index-number system quantified the quality of water based on ten parameters (Table 1.2; Jacobs et al. 1965). Although many additional parameters were considered, these ten parameters were chosen by Horton because they were thought to be common across a variety of water bodies and were relatively straightforward for any agency to measure. Horton's intent was not to create an index for everyone to use, but to make the idea available so it could be further developed as needed for each individual circumstance (Brown et al. 1970).

Initially, there was concern that creating a "number" to define a body of water could be difficult because pollution, contaminants, and overall water quality is relative and determination of what parameters are focused upon can be subjective (Jacobs et al. 1965; Tyagi et al. 2013). Not recognizing this fact could lead to agencies having a tunnel-vision on water quality and not allow for flexibility in their approaches to maintaining water quality. However, an index would enable water quality thresholds to be established so agencies could work on "improving techniques" to better and/or maintain water quality (Jacobs et al. 1965). Any recognition of water quality by an agency would be a step forward.

Table 1.2: Parameters used by the Horton, NSF, Purdue Simple, and Oregon Water Quality Indices (Jacobs et al. 1965; Brown et al. 1970; Cude 2007; Purdue 2020).

Horton Index Number System Parameters	NSF Water Quality Index Parameters	Purdue Simple Water Quality Index Calculator Parameters	Oregon Water Quality Index Parameters
• Alkalinity • Carbon • Chloroform Extract • Coliforms • Dissolved Oxygen • Obvious Pollution • pH • Sewage Treatment • Specific-Conductance • Temperature	• Dissolved Oxygen • Fecal Coliform • pH • Biochemical-Oxygen Demand • Nitrate • Phosphate • Temperature • Turbidity	• Biochemical-Oxygen Demand • Conductivity • Dissolved Oxygen • Temperature • Total Suspended-Solids	• Ammonia + Nitrate-Nitrogen • Biochemical-Oxygen Demand • Dissolved Oxygen-Saturation • Fecal Coliform • pH • Total Solids

Five years after the release of Horton's Index Number System, the National Sanitation Foundation (NSF) developed a more widely applicable water quality index (WQI) (Chidiac et al. 2023). The NSF is a nonprofit organization founded in 1944 that focuses on developing public health standards using a variety of experts in the fields of interest (NSF 2024). THE NSF employed the Delphi method to create this more accepted index. The Delphi method is a set of procedures developed by the Rand Cooperation in 1967 that anonymously collects the opinions of professionals, experts, and other "knowledgeable individuals" on the subject of interest. The procedures prioritize "anonymity, controlled feedback, and statistical 'group response'" (Dalkey 1967).

The NSF anonymously interviewed 142 participants: 101 regulatory officials, 5 local public utilities managers, 6 consulting engineers, 26 academicians, and 4 others. The participants were mailed a questionnaire offering 35 various parameters for the experts to qualify as “include” or “do not include” in water quality assessment. The ones that experts chose to include were then ranked on a scale of 1 to 5 with 1 being “highest relative significance” and 5 being “lowest relative significance” when considering overall water quality. After several rounds of questionnaires and rankings, 9 parameters were chosen as most statistically significant (Table 1.2; Brown et al. 1970). In comparison with Horton’s suggested parameters, the NSF’s WQI is more specific. For example, Turbidity, and Total Solids are listed in the NSF’s WQI instead of “obvious pollution,” as it is listed in Horton’s index. Also, the NSF WQI introduces weighting factors for each parameter based on the relative importance of each parameter for water health (Table 1.3; Brown et al. 1970).

Table 1.3: NSF Water Quality Index parameters & weighting factors (w_f) (Brown et al. 1970).

NSF Parameter	Weighting Factor (w_f)
Dissolved Oxygen	0.17
Fecal Coliform	0.15
pH	0.11
Biochemical Oxygen Demand	0.11
Nitrate	0.10
Phosphate	0.10
Temperature	0.10
Turbidity	0.08
Total Solids	0.08

The Evolution of Water Quality Indices

The purpose and goals of WQIs have continued to evolve over time since Horton's initial effort in 1965. WQIs can be divided into three categories: public indices, specific indices, and planning indices (Banda and Kumarasamy 2020). Public indices are useful for general water quality assessments that can be used by anyone. They are not tailored for a specific area or user. Both Horton's index and the 1970 NSF WQI are examples of a public index. Another example of a public index would be the "Simple Water Quality Index Calculator" provided by Purdue University (Purdue 2020). As the name suggests, the Purdue WQI has simplified the process for ease of general public use by including only 5 parameters and an online calculator into which anyone can plug values (Table 1.2; Purdue 2020). Each parameter is also briefly described in "layman's terms." For example, biological oxygen demand is described as "indicates how much oxygen is needed by bacteria to break down organic matter in the water. A high BOD… may be an indication of contamination by sewage or other waste." After the values are entered, a number from 1 to 100 is given to be compared against a qualitative range (Table 1.4; Purdue 2020). The presentation of the calculator with classifications is simple and eliminates the weighted factors and complicated equations that may be daunting to those not familiar with WQIs.

Table 1.4: Qualitative water condition-based parameter values inputs (Purdue 2020).

Classification	Range
Excellent	(91-100)
Good	(71-90)
Average	(51-70)
Fair	(26-50)
Poor	(0-25)

In contrast with the general indices described above, specific water quality indices are developed with the intention of assessing water quality for a particular use and/or agency. For example, specific indices may be developed for water bodies that are used expressly for drinking, recreation, industry, or agriculture (Banda and Kumarasamy 2020). Chosen parameters are specific to the intended use of the water. An example of a specific index is the Oregon Water Quality Index (Cude 2007). The original OWQI was developed by the Oregon Department of Environmental Quality (DEQ) in 1979 via the Delphi method and included 6 parameters: ammonia + nitrate nitrogen, biochemical oxygen demand, dissolved oxygen saturation, fecal coliform, pH, and total solids (Table 1.2; Cude 2007). These parameters were utilized for general trend identification across various river basins to influence legislation in Oregon. The original OWQI was then discontinued in 1983 and updated in 1995 to include temperature and total phosphorus, allowing for a more thorough, well-rounded WQI. However, the OWQI is designed specifically for Oregon’s streams, and "its application to other geographic regions or waterbody types should be approached with caution” (Cude 2007). This statement makes clear the intended specificity the Oregon DEQ intends for this index.

Planning indices are used for the purpose of drafting guidelines and utilized by policy makers. However, legislators do not always have the background needed, nor the time, to study water quality data to aid in evidence-based policy making. A “bridge” between these policymakers and accessible data exists in planning indices (Hallock 2002). Planning indices focus on using water quality assessment data to identify problems and trends in an area of interest. The specific data is then used to aid in decision making and overall water resource management, leading to the development of an action plan for the specific area of interest (Banda and Kumarasamy 2020).

An example of a planning index is the Canadian Council of Ministers of the Environment (CCME) Water Quality Index (Sutadian et al. 2015). The CCME is different from the aforementioned WQIs in that it does not focus on measuring values of specific parameters and their weighted values to determine quality. The CCME WQI centers on three factors: Scope, Frequency, and Amplitude. Scope is determined by "the number of parameters whose guidelines are not met." Frequency is frequency of occurrences "with which the guidelines are not met." Amplitude is "the amount by which the guidelines are not met" (Sutadian et al. 2015). These three factors are measured and combined to provide the user with a number from 0-100 that describes the quality of water being tested (CCME 2017). This number is then utilized by policy makers in decision making and legislative planning. It is important to note that the CCME WQI is not provided with already chosen parameters. It is open-ended so that it can be used in a variety of conditions and geographic areas. The CCME WQI is referenced by the United States EPA in their Freshwater Quality Index (EPA 2024a) and has been adopted by the United Nations as a common use in the "United Nations Environment Programme" (CCME 2017).

The idea of the index-number system has been adapted from water quality to quantify environmental quality more broadly. Steinhart et al. (1982) developed an environmental quality index (EQI) to monitor the ecosystem of the Great Lakes in North America. This new index focused on four groups of factors with a total of nine parameter variables (Table 1.5; Chidiac et al. 2023). This idea has since been further developed by the EPA as a tool to assess the environmental quality of all counties within the United States (EPA 2024a).

Table 1.5: Environmental Quality Index (Chidiac et al. 2023).

Environmental Quality Index
Chloride
Chlorophyll *a*
Fecal Coliforms
Obvious Pollution/Aesthetic State
Specific Conductance/Electroconductivity
Suspended Solids
Total Phosphorus
Toxic Inorganic Contaminants
Toxic Organic Contaminants

Using Water Quality Indices

Water quality indices generally use physical, chemical, and biological indicators in a weighted equation that is summed to provide a holistic value out of 100 (Figure 1.1; Uddin et al. 2021). Each parameter's weighted value is assigned based on the importance of the effect on water health (Brown et al. 1970). For example, Dissolved Oxygen (DO) is an example of a highly weighted indicator because it is considered a vital factor for aquatic life. Any fish and aerobic aquatic creatures require adequate DO to survive (Ali et al. 2022). DO is also considered a direct measure of water quality since many other factors affect DO, including water flow, temperature, aquatic respiration rates, and contaminants (Kulkarni 2016). Meanwhile, turbidity is a lesser weighted indicator because increases in turbidity do not always signal contamination.

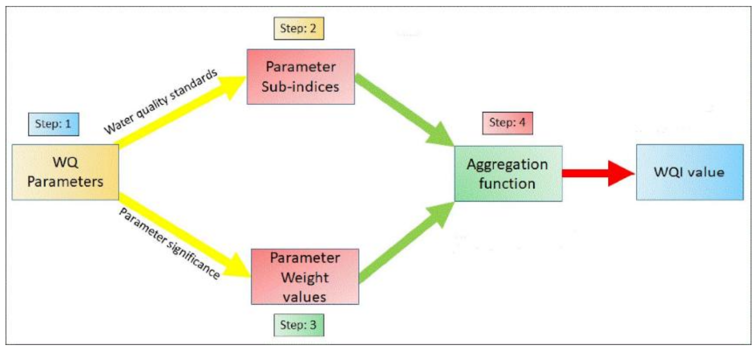


Figure 1.1: General structure of WQI (Uddin et al. 2021).

For instance, precipitation events, wind, and seasonal changes can all contribute to turbidity (Hsieh et al. 2015).

Indicators are then transformed into a unitless sub-index value using a Q-value chart for each individual indicator. Since parameters can have various units, Q-value charts were created to develop a "common unit", or universal lack of unit (IDEM 2024). Q-values range from 0 to 100, with 100 being the optimal value of a healthy stream. After Q-values are found for each parameter, the values are multiplied by the assigned weight to provide the water quality index value.

To provide an example of this process, assume that a stream sample provides a dissolved oxygen percent saturation value of 80%. Other parameter values may not have the same unit. Temperature is measured in ^{o}C, pH is unitless, turbidity in NTU, etc. (Table 1.1), so the value must be converted to a unitless Q-value. The 80% saturation value can be located on the x-axis of a provided Q-value chart, then the corresponding y-value identified using the function curve (Figure 1.2; Flinn Scientific 2018). This provides the Q-value for Dissolved Oxygen, which is approximately 89. The Q-value of 89 is then multiplied by the weighted value of 0.17 (Javid et al. 2014) to provide a WQI value of 15.13. This process is repeated for each parameter desired

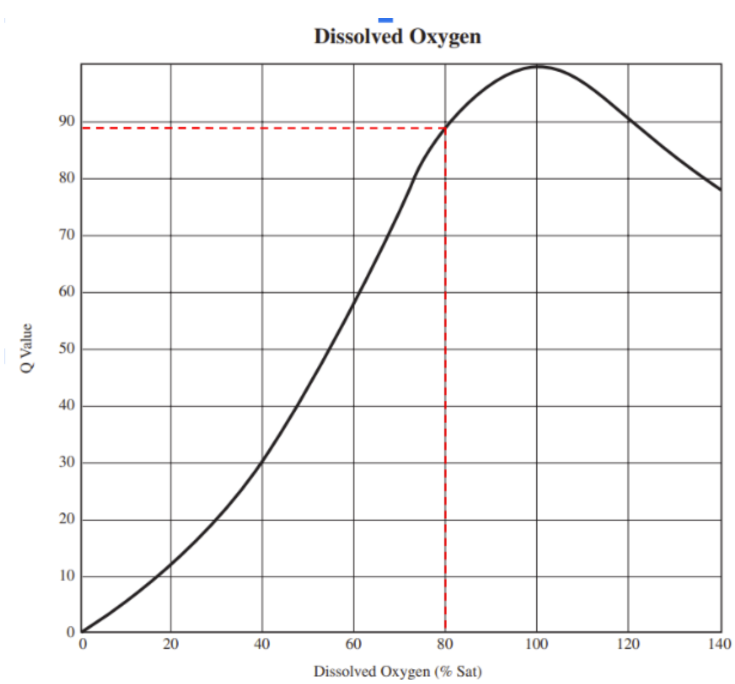


Figure 1.2: Example Q-value calculation for DO (Flinn Scientific 2018).

and then the values aggregated to provide a number to be compared to water quality classification (Purdue 2020).

Lesson Plans

For this project, a unique water quality index, the Whittington Water Quality Index, was created for student use in local North Carolina water systems (see lesson in Appendix D). Water quality parameters were chosen based on a 1980 USGS water quality study of the Neuse River, NC (Harned 1980), NCDEQ suggested indicators (2017), and an additional water quality assessment of central North Carolina (Line 2013). Physical parameters chosen include temperature, and total solids, turbidity; biological parameters include biochemical oxygen demand and fecal coliform; chemical parameters include dissolved oxygen, pH, and nutrients (phosphate, nitrate). These indicators were chosen based on their water quality relevance as well as the accessibility in the skill set of secondary students and the supplies available to a secondary science classroom. The weighting factors of each parameter were assigned by using the NSF WQI suggested weighting factors (Javid et al. 2014) and were replicated for the student WQI due to its relevance and influence on the creation of other indices such the OWQI (Swamee 2007). Once students have completed the index, the total for each parameter will be aggregated to provide the conditional value of the body of water. The condition will be determined based on the Purdue qualitative water conditions (Table 1.3; Purdue 2020).

Lesson One: Understanding Water Quality includes water quality notes on physical, chemical, and biological indicators with a student guide to ensure student participation. A summary session to discuss eutrophication helps to gauge student understanding. Lesson Two: Water Quality Parameter Investigation provides a water quality parameter investigation using a USGS (2019b) website with student presentations on specific parameters indicating understanding of the topic. Lesson Three: Introduction to Water Quality Testing Instruments and Methodologies focuses upon methodologies necessary for testing water quality indicators investigated in Lesson Two. Lesson Four: Analyzing Water Quality Parameter Data and Calculating the Water Quality asks students to analyze the water quality parameter data collected in Lesson Three and by using the Whittington Water Quality Index (see Unit 1 Lesson Four WQI Lab Sheet). A final class discussion and reflection summarizes the concept of water quality indicators and using an index to quantify the health of a waterbody.

Unit 1 Lesson Plans

Lesson One: Understanding Water Quality

Time: 80 minutes

Learning Objectives:
1. Describe the importance of water quality and the different factors used to assess it.
2. Distinguish among physical, chemical, and biological parameters of water quality.

Student "I can…" statements:
1. I can define and understand key water quality indicators (physical, chemical, biological).
2. I can explain the importance of water quality and factors affecting it.

Materials Needed:
- Water Quality: Understanding Water Quality Assessment Notes (posted on learning platform) (see Appendix A for slides)
- Unit 1 guided notes (Printed)
- Whiteboard and markers

Lesson Outline:
1) **Introduction to Water Quality (15 minutes)**
   a. Bell Ringer: Write "Water Quality" on the board and ask students to brainstorm what comes to mind when they hear the term. Students can verbally respond. (3 minutes)
   b. Pass out the Unit 1 guided student note sheet and ask students to independently answer the introduction questions. (4 minutes)
   c. After 4 minutes, ask students to turn to their desk partner and discuss their answers. (3 minutes)
   d. Ask for volunteers to share what they and their partners discussed in answer to the questions. On a projected copy of the guided notes, take brief notes of what students are saying to provide visual cues for the entire class. (5 minutes)
2) **Presentation and Discussion (45 minutes)**
   a. Provide the Unit 1 notes projected on the board for the students to view. They can also follow along on laptop devices as needed.
   b. Spend time on each slide discussing the notes and images.
   c. Verbally ask the questions on the guided notes and coax answers from students. If students will not/cannot answer, offer prompting questions.
   d. For example:
      i. "How do phosphates impact algal growth?" Prompting questions should be "What is algae?", "What are phosphates?", "How do phosphates enter the water system?", "What do you notice about the image on this slide?"
3) **Reflection and Wrap-up (20 minutes)**
   a. Eutrophication Discussion: Show the image of eutrophication on the last slide of the notes. Ask students to reflect on how excess nutrients lead to this process and discuss with their partner. Call on 1-2 pairs to provide their thoughts. (5 minutes)
   b. On white boards, ask students to answer the following questions: (5 minutes)

   i. Why are water quality assessments important for public health and ecosystems?
   ii. Which indicators did you find most surprising or significant?

c. Have one student from each pair stand up and hold the white board for a group observation. Have the student not holding the board read their answer off the board being held. Ask students to notice and comment upon any recurring themes or differences in answers. (10 minutes)

4) Assessment

a. Formative
   i. Participation in discussion and small group think-pair-shares
   ii. Guided notes completed
   iii. Reflection white board presentation

Lesson One Guided Notes

Understanding Water Quality Assessment

Introduction Questions:

1. What words come to mind when you hear “water quality”? List a few words or phrases from the class discussion that you did not include on your white board:
    -
    -
    -
2. Why is clean water important?
   Describe two reasons why clean water is essential:
    -
    -
3. Factors in Determining Clean Water:
   What are some factors you might consider to decide if water is “clean”?
    -
    -

Physical Indicators:

- *Turbidity*
    - What does turbidity measure?
    - List two causes of increased turbidity:
    - How does turbidity affect water temperature?
- *Temperature*
    - How does temperature influence other water quality indicators?
- *Color*
    - Differentiate between “apparent color” and “true color”.
- *Total Suspended Solids (TSS)*

- What is TSS?
- How does it relate to turbidity?

- *Total Dissolved Solids (TDS)*
  - Give two examples of dissolved solids in water.

Chemical Indicators:

- *pH*
  - What does pH measure in water?
  - How can pH affect organisms in the water?
- *Alkalinity*
  - Why is alkalinity important in determining water quality?
- *Nitrogen (Nitrates)*
  - What is a common source of nitrates in water?
  - Why are nitrates essential for plant growth?
- *Phosphorus (Phosphates)*
  - How do phosphates impact algal growth?
- *Dissolved Oxygen (DO)*
  - How does temperature influence DO concentrations?
  - Why is DO considered a main indicator of water quality?
- *Biochemical Oxygen Demand (BOD)*
  - Define BOD.

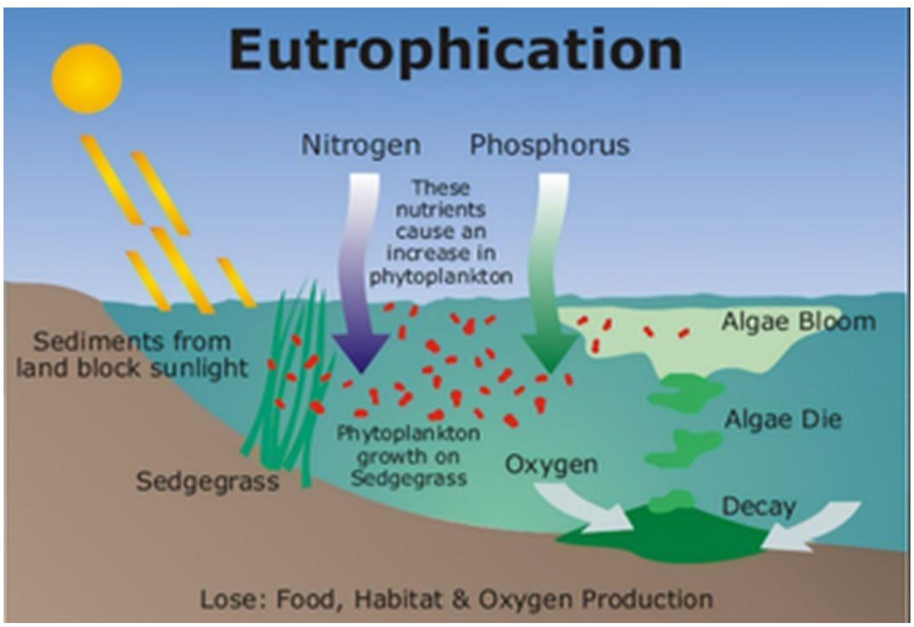
- Why do you think this is significant in assessing water quality?

Biological Indicators:

- *Fecal Coliform*
  - What are common sources of fecal coliform in surface water?
  - What health risks does it pose to humans?
- *Algae (Chlorophyll)*
  - Why can algae be problematic in water?

Reflection:

Using the following image, define Eutrophication and describe how it may form:



(OSPAR 2024)

Lesson Two: Water Quality Parameter Investigation

Time: 80 minutes

Learning Objectives:

1. Conduct research on a given water quality parameter.
2. Distinguish among physical, chemical, and biological parameters of water quality.

Student "I can…" statements:

1. I can create a visual representation and present/explain my assigned water quality parameter.

Materials Needed:

- Parameter Investigation Worksheet (Posted on Learning Platform)
- Computer for access to "USGS Water Science School" website and slide show construction

Lesson Outline:

1. **Introduction to the Parameter Investigation (10 minutes)**
    a. Bell Ringer: Have students list as many of the parameters as possible on their white board. Roam the room as they complete this to check their recall. Ask students to verbally identify the parameters as either physical, chemical, or biological to further assess their understanding from the previous lesson. (5 minutes)
    b. Explain the objectives by informing students they will become "experts" on one assigned parameter and that they will share their learnings with the rest of the class. (3 minutes)
    c. Assign each pair of students one parameter from the worksheet (color, temperature, turbidity, etc.) (2 minutes)
2. **Independent Research and Slide Construction Time (30 minutes)**
    a. Demonstrate how to access the assignment on the learning platform and locate the website for their research. (3 minutes)
    b. Emphasize that students should make sure to answer the questions listed on the worksheet for their parameter, but are encouraged to provide more information. (3 minutes)
    c. Show students how to access the shared slide show on the learning platform that they can edit. (2 minutes) Have the slides pre-labeled with the parameter for easier organization. Students should create 1-2 slides with their key information.
    d. Encourage concise, clear information. Reference the slides from the last lesson as an example. (2 minutes)
    e. Roam around the room to provide help and redirection as students complete their research and slide construction. (20 minutes)
3. **Class Presentations (30 minutes)**
    a. Each pair of students will present their findings to the class, explaining their parameter's role in water quality. (2-3 minutes per pair)
    b. Allow peers to ask questions. Students should also be filling in the rest of their assignment sheet as presentations are made. (1-2 minutes)

c. Provide feedback for the students as needed to clarify any misconceptions. Coach students to an answer with questions instead of just correcting them. (1-2 minutes)

4. **Reflection and Wrap-up (10 minutes)**
    a. Lead a brief discussion on the interconnectedness of the parameters. (5 minutes)
    b. Ask students to share their thoughts on the following questions. (5 minutes)
        i. Which parameter surprised you based on its impact on water quality?
        ii. How do you think monitoring these water quality parameters could help prevent environmental issues (algal blooms, etc.)?
5. **Assessment**
    a. Formative
        i. Participation in discussion
        ii. Assignment sheet completed
    b. Summative
        i. Slideshow presentation

Lesson Two Parameter Investigation Worksheet

Parameter Investigation
You are about to become an expert on a single parameter and explain it to the class! Mrs. Whittington will assign you and your partner one of the following parameters to investigate. Visit the "USGS Water Science School" website to investigate your factor and answer AT LEAST the questions asked for your given parameter. After you complete the investigation, you and your partner will add **1-2 slides** of your information in the shared class Google slideshow. Once the class is done, we will take turns presenting our specific slides to the rest of the class and complete the rest of this assignment.

Source:
USGS. 2019b. Water Properties Information by Topic. [Internet]. Washington (D.C.). [cited 2024 Nov 16]. Available from: https://www.usgs.gov/special-topics/water-science-school/science/water-properties-information-topic#overview

Physical Properties
Water Color
1. Find or draw an image to help define the significance of water color in determining water quality.
2. What does color tell us about the materials in the water?
3. How can color indicate the presence of pollutants or organic matter?

Sediment and Suspended Sediment
1. Find or draw an image to help explain the difference between sediment and suspended sediment.
2. How can sediment levels affect aquatic ecosystems and water quality?
3. What are two sources of sediment in water, and how can high sediment levels impact aquatic life?

Water Temperature
1. Find or draw an image to help summarize the effect of temperature on dissolved oxygen levels.
2. Why is temperature monitoring important for stream ecosystems?

Turbidity
1. Find or draw an image to help explain what turbidity measures and how it is related to water quality.
2. Describe how turbidity affects the sunlight penetration in water and the photosynthesis process for aquatic plants.

Conductivity
1. Find or draw an image to help explain conductivity.
2. How do ions contribute to conductivity?
3. Explain how conductivity levels could indicate pollution or runoff from nearby land.

Chemical Properties

Alkalinity

1. Find or draw an image to help define alkalinity and explain how it affects pH.
2. Describe one way alkalinity can affect aquatic life.
3. How does alkalinity help to stabilize pH in aquatic systems?

Dissolved Oxygen (DO)

1. Find or draw an image to help explain the importance of dissolved oxygen for aquatic organisms.
2. What other factors affect DO levels in water.
3. How can temperature and organic matter specifically affect DO levels?
4. Why is DO critical for aquatic health?

pH

1. Find or draw an image to define pH and explain how it generally influences water chemistry.
2. What pH range is considered healthy for most aquatic ecosystems?
3. Why can water that is too acidic or too basic be harmful?

Nutrients (Nitrogen and Phosphorus)

1. Find or draw an image to explain how nutrients like nitrogen and phosphorus contribute to algal blooms.
2. Define and generally explain Eutrophication.
3. Describe the possible impacts of excess nutrients on water quality and aquatic ecosystems.

Lesson Three: Introduction to Water Quality Testing Instruments and Methodologies

Time: 80 minutes

Learning Objectives:
1. Demonstrate how to use Vernier labware to measure water quality parameters.
2. Calibrate probes for accurate measurements.
3. Perform chemical tests for measurements of water quality parameters.

Student "I can…" statements:
1. I can use instrumentation and chemical tests to take water quality measurements.

Materials Needed:
- Vernier Probe Interface (Labquest software)
- pH meter
- Conductivity meter
- Temperature probe
- Carolina Biological Freshwater Master Kit
- Safety Goggles
- Distilled water bottle
- Freshwater samples
- Test tubes with caps

Preparation:
Take students outside to the retention pond near the parking lot. Demonstrate how to measure turbidity using the Secchi Disk. Record the measurement for later use. Allow students to collect a sample of water and bring it back to the classroom. This can be done before starting this lesson. Have all listed materials set out at each lab station for students. One set up should be provided for each lab group (2-3 students).

Lesson Outline:
Model all calibration steps for the students at the front of the classroom. Walk around the room after modeling to aid in student application.
1. **Prelab (15 minutes)**
    a. Ask students to bring a piece of paper and pencil to a lab station to take inventory of the supplies. (6 minutes)
    b. Once they are done taking inventory, ask them to identify each object and for what it should be used. On the board, write down the parameters being tested as students mention them. (5 minutes)
    c. Ask students to create a data table that makes sense to them for collecting freshwater measurements. Walk around and offer suggestions to groups that are struggling with creating the data table. (3 minutes)
    d. Instruct students that lab goggles should be worn at all times. (1 minute)
2. **Calibrate the Vernier Probes (15 minutes)**
    a. pH probe calibration

i. Have buffer solutions with pH 4, 5, and 10 prepared and at student stations.
ii. Rinse the pH probe with distilled water, then place it into the pH 7 buffer.
iii. Calibrate to pH 7 with LabQuest by following the instructions on the interface.
iv. Rinse with distilled water and repeat with pH 4 and 10.
v. Rinse with distilled water before testing samples.

b. Conductivity Probe Calibration
   i. Have prepared solutions of 1000 µS/cm prepared and at student stations.
   ii. Rinse the conductivity probe with distilled water, then place it into the standard solution.
   iii. Calibrate to 1000 µS/cm with LabQuest by following the instructions on the interface.
   iv. Rinse with distilled water before testing samples.
c. Temperature Probe Calibration
   i. Temperature probe should already be factory calibrated.

3. **Using Vernier Probes to Measure Water Quality (15 minutes)**
   a. Instruct students to record all measurements in their data table.
   b. Rinse the temperature probe with distilled water. Take the prepared sample of collected freshwater and place the temperature probe into the sample. Record the temperature given from the Vernier interface. Remove the temperature probe and rinse with distilled water.
   c. Rinse the pH probe with distilled water and place it into the freshwater sample. Record the pH given from the Vernier interface. Remove the probe and rinse with distilled water.
   d. Rinse the conductivity probe with distilled water and place it into the freshwater sample. Record the conductivity reading given from the Vernier interface. Remove the probe and rinse with distilled water.
4. **Testing with the Carolina Freshwater Master Test Kit (25 minutes)**
   a. Instruct all students that the chemical waste should be placed into a large waste container in the fume hood of the lab room.
   b. All instructions and color charts are included with the kit.
   c. Ammonia Test
      i. Add the specified drops of ammonia reagent to a test tube filled with a water sample. Cap, shake, and wait for the color to develop.
      ii. Compare the color to the kit's ammonia chart to determine concentration. Record the measurement in the data table.
      iii. Dispose of waste in the fume hood waste container.
   d. pH Test:
      i. Add the specified drops of pH reagent to a test tube filled with a water sample. Cap, shake, and wait for the color to develop.
      ii. Compare the color to the kit's pH chart to determine concentration. Record the measurement in the data table.
      iii. Dispose of waste in the fume hood waste container.
   e. Nitrite and Nitrate Tests:

i. Add the specified drops of Nitrite and Nitrate reagent to a test tube filled with a water sample. Cap, shake, and wait for the color to develop.
ii. Compare the color to the kit's Nitrate and Nitrite charts to determine concentration. Record the measurements in the data table.
iii. Dispose of waste in the fume hood waste container.

f. Add the specified drops of Dissolved Oxygen reagent to a test tube filled with a water sample. Cap, shake, and wait for the color to develop.
g. Compare the color to the kit's Dissolved Oxygen charts to determine concentration. Record the measurements in the data table.
h. Dispose of waste in the fume hood waste container.

5. Clean up (10 minutes)

a. Have students:
   i. Rinse all probes and test tubes with distilled water and replace them for the next class.
   ii. Wipe down the tables with a cleaning solution.
   iii. Place goggles in the UV cabinet for cleaning between classes.
   iv. Wash hands.

6. Analysis and Reflection will be completed in Lesson 4

7. Assessment

a. Formative
   i. Lab Participation
   ii. Data Table

Lesson Four: Analyzing Water Quality Parameter Data and Calculating the Water Quality Index Value

Time: 80 minutes

Learning Objectives:
1. Calculate the Water Quality Index (WQI) value for a water sample based on data.
2. Reflect on how specific parameters affect overall water health.

Student "I can…" statements:

1. I can analyze the importance and weighting of various water quality parameters.
2. I can calculate and discuss a WQI value for a sample of water.

Materials Needed:
- Water Quality Index Calculator Slideshow (posted on learning platform) (see Appendix B for slides)
- Water Quality Index Lab Sheet (printed)
- Q-value graphs and charts (printed from WQI Calculator slideshow)
- Calculator

Lesson Outline:
1. **Introduction to the Parameter Investigation (15 minutes)**
    a. Bell Ringer: Have students bring out the data sheet they created during the previous lesson and ask them how they can use this information to give an overall quality description of the water sample. Allow for or call upon students to give ideas. (10 minutes)
    b. Project the Water Quality Index Calculator slideshow for student view.
    c. Discuss how the WQI calculator provides a single value to represent overall water quality. Point out the ranges and their qualitative descriptor (excellent, good, etc.) (5 minutes)
    d. Pass out a Water Quality Index Lab sheet to each lab group and ask them to transfer their data to the first "measured value" column. Provide the measured value of turbidity since students were not able to collect this data.
2. **Group Calculation of Q-Values (20 minutes)**
    a. Using the slideshow, define Q-values. Explain that they represent a "quality rating" of each parameter and are used to create a single, unitless value since parameters can have all different kinds of units.
    b. Pass out the printed Q-value charts and as a class, complete a Q-value conversion as an example.
    c. In their lab groups, have students use the data from the previous lesson to calculate the Q-values and record them in the chart on the lab sheet. Roam the classroom to help as needed.

3. **Applying Weighting Factors (15 minutes)**
    a. Using the slideshow, discuss why certain parameters are weighted more heavily in calculating WQI values. Ask students to discuss what they believe should be the most heavily weighted and allow for student responses.
    b. Reference the “Weighting Factor” column on the lab worksheet to compare with student verbal responses.
    c. As a class, complete a weighted score calculation as an example.
    d. In their lab groups, have students complete the remaining Q value calculations.
4. **Class Discussion and Reflection (30 minutes)**
    a. Compare WQI values across groups. Discuss any differences and potential reasons for variation. (10 minutes)
    b. Ask students to complete the lab sheet conclusion questions. Roam around the room to provide help and feedback to students. (10 minutes)
    c. Review student answers to the conclusion questions as a class discussion. Take volunteers or call upon groups to provide answers and comments. (10 minutes)
    d. Students should submit these sheets for grading.
5. **Assessment**
    a. Formative
        i. Participation in discussion
    b. Summative
        i. Submission and grading of water quality index lab sheet

Lesson Four Water Quality Index Lab Sheet

Water Quality Index Lab Sheet

Instructions:
Using your resources (Q-value graphs and charts), complete the following water quality index based on the parameter data you collected.

Table 1.6: Whittington Water Quality Index

Physical Indicators	**Sample Data Reading**	**Sub-Indices (Q-Value)**	**Weighting Factor**	**Total**
Temperature			0.10	
Total Solids			0.07	
Turbidity			0.08	
Biological Indicators	**Sample Data Reading**	**Sub-Indices (Q-Value)**	**Weighting Factor**	**Total**
Biochemical Oxygen Demand (BOD)			0.11	
Fecal Coliform			0.16	
Chemical Indicators	**Sample Data Reading**	**Sub-Indices (Q-Value)**	**Weighting Factor**	**Total**
Dissolved Oxygen (DO)			0.17	
pH			0.11	
Nutrient- Total Phosphate			0.10	
Nutrient- Nitrates			0.10	
Comments & Observations				**WQI Value**

Conclusion Questions:

1. How does the classification you calculated for the water body compare to what you saw when you collected water? Did you expect this level of classification?

Classification	Range	Classification	Range
Excellent	(91-100)	Fair	(26-50)
Good	(71-90)	Poor	(0-25)
Average	(5-70)		

2. Which parameter is the most difficult to test for? Why?

3. Which test has the greatest chance of having a large experimental error? Explain?

4. Which parameter is weighted the most heavily when determining the health of water? Why do you think so much importance is placed on this test?

5. Which parameter is weighted the least heavily when determining the health of water? Why do you think so little importance is placed on this test?

6. Choose one water quality parameter tested. What could be done to the environment to improve the Q-value of this parameter?

7. Which parameter tested should be of the greatest concern to the public? Why?

8. Which parameter tested should be of the least concern to the public? Why?

9. How might WQIs be used by environmental agencies to inform the public and guide water management decisions?

10. If you were a policymaker, how would you prioritize improving water quality based on WQI results?

Unit 2: Surface Water Classifications

Surface classifications serve as a tool for grouping water bodies based on characteristics or observations that highlight relevant structural and functional similarities or differences (Naiman et al. 1998; Dahl et al. 2007). Early attempts at classifying water bodies using broad-scale characteristics were ineffectual because these systems were too large and variable to singularly label. Surface water classification systems have since evolved to include comprehensive assessments of the physical, chemical, and biological characteristics of a water body, as well as their use and impairment status (Naiman et al. 1998; NCDEQ 2024a).

Physical, Chemical, and Biological Classification Systems

An original concept of stream order, developed by Robert Horton, was used to classify streams based on placement in a drainage basin (Horton 1945; Scheidegger 1968). Tributaries, known as fingertip streams that do not branch, are assigned a 1st order stream number. 1st order streams will flow into 2nd order streams. 3rd order streams can then receive waters from 1st or 2nd streams, and so on (Horton 1945). The main stream is designated the same stream order all the way to the headwater (beginning tributary), so a lower order stream must be reordered every time two streams of the same order join together (Figure 2.1a; Scheidegger 1968; Hodgkinson 2009).

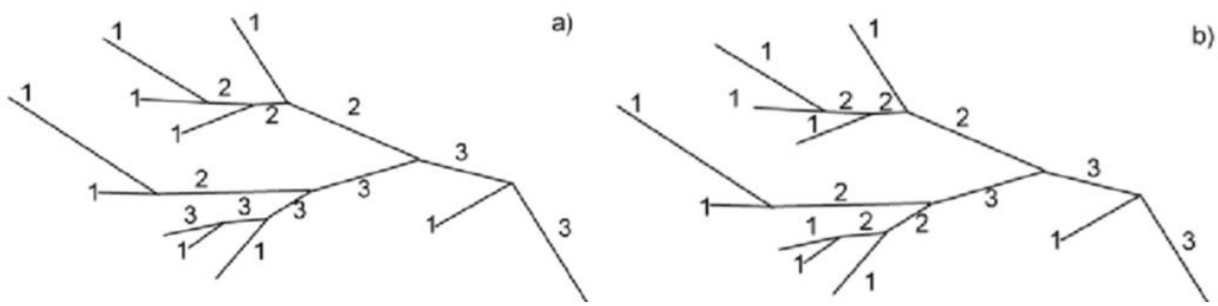


Figure 2.1: a) Horton stream order example; b) Strahler stream order example (Hodgkinson 2009).

Arthur Strahler took Horton's concept of stream order and modified it by removing the need for stream order to remain the same all the way back to headwater tributaries (Strahler 1952; Scheidegger 1968). Strahler's system assigns all tributaries lower numbers than the bodies of water into which they are flowing. Source streams with no tributaries of their own are labeled as 1st order streams. When two 1st order streams consolidate, they form a 2nd order stream. Two 2nd order streams join to form a 3rd order stream, etc. (Figure 2.1b; Strahler 1952; Hodgkinson 2009). Higher stream orders represent larger rivers that ultimately culminate in the highest order stream leaving the basin (Lister et al. 2005).

The determination of a headwater stream can vary, but stream orders 1-3 are generally considered headwaters (Richardson 2019). This classification means that headwater streams make up most of the streams on the globe. First order streams are most prevalent at approximately 79% abundance, 2nd order streams are approximately 16.6%, and 3rd order streams are approximately 3.5% (Downing et al. 2012). This puts headwater abundance on the globe at a combined 99.1%.

The River Continuum Concept expands on the stream order concept to describe how the physical characteristics of a stream influence the flow of energy and biological communities within them (Vannote et al. 1980). For example, the greatest carbon source in lower stream orders is allochthonous organic matter, or material received from outside the river system such as leaf detritus because they naturally occur in higher elevations with shaded canopies that limit photosynthesis (Vannote et al. 1980; Sitati et al. 2024). The allochthonous organic matter in 1st and 2nd order streams attracts macroinvertebrate feeding guilds including shredders, scrapers, predators, collector-filterers, and collector-gatherers (Sitati et al. 2024). Fish assemblage is less diverse in lower order streams with mainly insectivores populating headwaters (Paller 1994).

As stream order increases, streams are populated by different organisms that have adapted to the changing stream characteristics. Stream orders 4-6 will be occupied less by shredders and more by collectors and grazers. Collectors will trap fine particles suspended in water for consumption and grazers will consume algae growth in the water as photosynthesis increases from more sun exposure and less canopy coverage (Zaimes et al. 2007). A more diverse fish assemblage can be found in higher stream orders (4+) as larger fishes such as piscivores and benthic insectivores join the smaller insectivore fish population (Paller 1994). As stream order increases to greater than 6, the terrain flattens and water slows which leads to the finest sediments settling out. If turbidity increases, fewer grazers will be present because algae growth is reduced due to lack of sunlight penetration. Consumers will subsequently dominate. Predators remain constant as there are always either shredders, collectors, or grazers to consume (Figure 2.2; Zaimes et al. 2007).

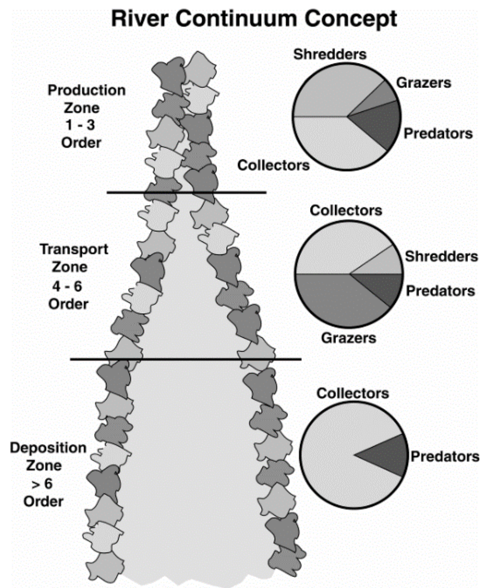


Figure 2.2: Distribution of macroinvertebrate feeding guilds across stream order (Zaimes et al.) 2007

Classification systems such as those developed by Horton and Strahler categorize streams based on size and structure. However, classification systems can also be determined by a stream’s hydrogeomorphic characteristics, such as flow regime and general morphology. Flow regimes refer to patterns of water flow quantity, timing, and variability (Poff et al. 1997). For instance, streams with consistent groundwater input will have stable steam discharge; these streams can be classified as perennial (Poff et al. 1997; Gore and Banning 2017). Alternatively, streams with specific seasonal precipitation events such as snowmelt, rainy season or storm events can exhibit fluxes in steam flow and discharge. These streams may be classified as intermittent or ephemeral (Poff et al. 1997).

Morphology describes the overall form and structure of stream channels, including width and depth of cross-sectional areas of streams, as well as stream patterns (Dahl et al. 2007). The Rosgen classification system categorizes streams based on channel morphology. The Rosgen classification system has been shown to be consistent and reproducible and therefore is useful for predicting hydrology based on stream appearance (Rosgen 1994). Stream patterns are formed due to variations in stream flow. Examples include meandering and braiding (Figure 2.3; Allen 2014) and various other patterns such as dendritic, parallel, and trellis. (Figure 2.4; Howard 1967).

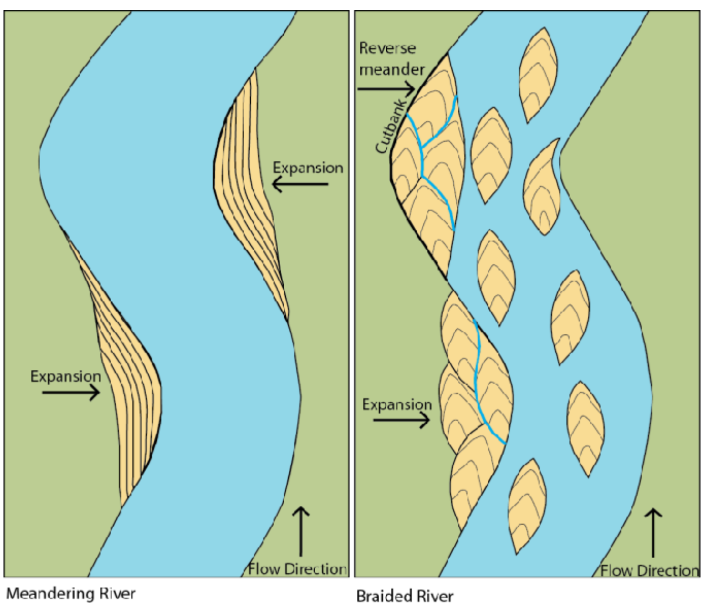


Figure 2.3: Meandering vs braided streams Allen 2014).

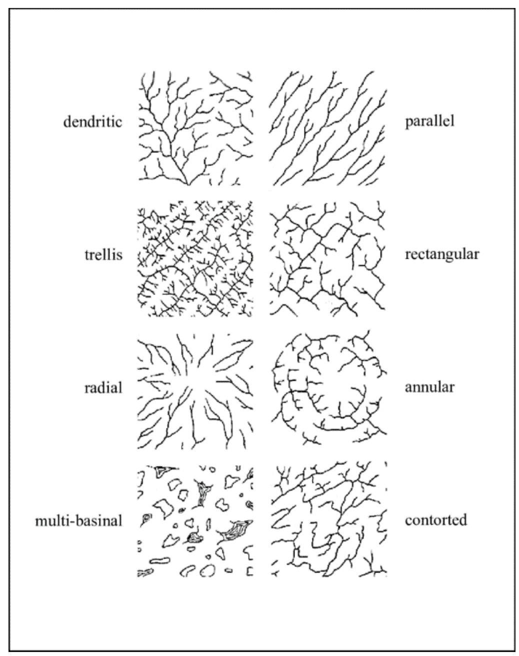


Figure 2.4: Examples of basic drainage patterns (Howard 1967).

Streams can also be classified according to physicochemical factors. Physicochemical elements used in stream classification include many of the physical and chemical indicators discussed in Unit 1, but emphasis is placed on temperature, nutrients, and contaminants (Fritz et al. 2018). Temperature is an essential limiting physical element since many organisms occupying streams can thrive in only a very narrow range of water temperatures (EPA 2016). Temperature is a master variable that controls many other physicochemical elements. For example, a temperature increase would lower dissolved oxygen levels in a stream, reducing the amount of oxygen available for organisms. Consistently higher water temperatures may also stimulate natural chemical reactions in water, leading to the release of excess nutrients (EPA 2016). Nitrates are one type of nutrient, which, when in excess and in presence of higher water temperatures, can lead to advanced eutrophication of a waterbody (Pearce et al. 2021).

Stream classification schemes based on physical, chemical, and biological characteristics ultimately provide mechanisms for understanding stream diversity and provide a framework for the conservation and management of aquatic systems (McManamay and DeRolph 2019). For example, the U.S. Stream Classification System (USSCS) was created to assemble 2.6 million streams in the United States based on physical properties. The USSCS utilizes a “Stream Classification Web App” developed by the Oak Ridge National Laboratory (2024) for industry, stakeholders, and other relevant agencies to utilize for planning and research purposes. On this app, the nation’s streams can be accessed by users for the purpose of predicting stream responses to human interactions. The USSCS groups streams according to hydrology, size, and other biological, hydrogeomorphic, and physicochemical characteristics. Hydrology includes measurements of streamflow (discharge), whereas size is determined by both the mean annual discharge and the Strahler stream order (McManamay and DeRolph 2019). Combining hydrology and size with the various biological, hydromorphic, and physicochemical elements allow for a comprehensive classification system useful for industry, restoration, and mitigation planning.

Water Body Use and Impairment Classification Systems

Surface freshwater systems may extend to bodies of water other than rivers and streams, so previously discussed classification systems may not directly apply. However, all types of water bodies are used by communities for recreation and to supply drinking water, so water health is important to monitor for human safety. Water quality monitoring (WQM) networks for surface freshwaters offer a consistent strategy for collecting information on all bodies of water (Strobl and Robillard 2008). WQM programs were organized in the mid-19th century because of poor water quality due to industrialization (Behmel et al. 2016). Monitoring systems typically focus on the hydrology, morphology, biology, and physicochemical elements of a specific body of water. For example, the type of water body is considered (lake, river, etc.) and how the body of water does or does not flow. Rivers and lakes will typically be monitored for nutrients, acidification, morphology, pollution, and invasive species, but rivers will be further monitored for flow regulation (Strobl and Robillard 2008). Parameters can be tailored to fit the location and intended use of the water.

In North Carolina, classifications that designate protected use categories are applied to all surface water bodies, including streams, rivers and lakes. Examples of protected uses include swimming, fishing, general recreation, and drinking water supply (NCDEQ 2024d). Surface water classifications become important when it comes time to buy property, construct roads, or plan any other land activities because many of the classifications on NC surface water bodies are designed to protect drinking water supplies and other high-quality waters. Consequently, there are many rules that regulate development that may influence water quality (NCAC 2004).

The North Carolina Administrative Code (NCAC) is a legislatively appointed group of state agencies and offices that guide rulemaking on public health and safety. Among these rules are the decisions made for NC surface water classifications (NCAC 2004). The NC Department of Environmental Quality (NCDEQ) uses the NCAC to classify bodies of water and establish best practices to keep the bodies of water from deteriorating (Table 2.1; NCDEQ 2024d; NCAC 2004;). All surface waters within the state of NC are provided a primary classification to describe appropriate use of the water, but extra supplemental classifications are sometimes provided to further provide special protection for sensitive or highly valued resources (Table 2.1; NCDEQ 2007). For example, a Trout Water (TW) supplemental classification can be added to waters stocked with trout or water that is naturally used in trout propagation. This means that waters can have multiple classifications to protect various specific resources, when necessary.

Table 2.1: NC surface water classification descriptions (NCDEQ 2024d; NCAC 2004; NCDEQ 2007).

Primary Classification	**Description/Allowable Uses**
C	Suitable for aquatic life propagation and survival, fishing, wildlife, secondary recreation*, and agriculture.
B	Suitable for all Class C uses and primary recreation**.
Water Supply I (WS-I)	Suitable for all Class C uses and drinking, culinary, or food processing for users desiring maximum protection; located in underdeveloped watersheds; HWQ supplemental classification applies.
Water Supply II (WS-II)	Same as WS-I except located in predominantly undeveloped watersheds; HWQ supplemental classification applies
Water Supply III (WS-III)	Same as WS-I except located in low to moderately developed watersheds; No HWQ supplemental classification
Water Supply IV (WS-IV)	Same as WS-I except located in moderately to highly developed watersheds; No HWQ supplemental classification

Table 2.1 continued.

Primary Classification	Description/Allowable Uses
Water Supply V (WS-V)	Suitable for all Class C uses; water is found upstream and draining into Class WS-IV; raw water can be supplied to industries to their employees as drinking water, but not provided to counties or municipalities; CA supplemental classification applies
Supplemental Classification	**Description/Allowable Uses**
Nutrient Sensitive Waters (NSW)	Require limitations on nutrient inputs; Additional supports in nutrient management needed as it is indicating excessive growths of microscopic or macroscopic vegetation.
High Quality Waters (HWQ)	Further protects waters rated excellent based on biological and physical/chemical monitoring; usually primary and other functional nursery areas designed by the Marine Fisheries Commission
Critical Area (CA)	Area adjacent (½ mile) extending upstream and/or downstream of location where risk associated with pollution is greater than the remaining portion of the watershed
Protected Areas (PA)	Area adjoining upstream of the CA (5-10 miles) to provide further protection measures even if the classification changes
Trout Waters (TW)	Provides protection to freshwaters for natural trout propagation and survival of stocked trout.

**secondary recreation: human activities such as wading, boating, and other activities where human body contact with water is infrequent, unorganized, or incidental.*
***primary recreation: human body contact with water in activities such as swimming, diving, water skiing, and other activities that are organized and occur frequently.*

Lesson Plans

Lesson One: Stream Order and River Continuum Concept teaches vocabulary and the basic concepts necessary for success in the rest of the unit. Guided notes and classroom discussions allow students to practice using these terms and ideas. Lesson Two: Analyzing Surface Water Classifications helps students to understand how surface water classification systems in North Carolina are determined and why they are used. This builds on the lessons learned in Unit 1, since water quality testing is used to monitor these streams and assign classifications. Lesson Three: Exploring Water Body Classifications in North Carolina helps students visualize locations of differently classified water and highlights the common theme of how urbanization affects surface water quality.

Unit 2 Lesson Plans

Lesson One: Stream Order and River Continuum Concept

Time: 80 minutes

Learning Objectives:
1. Describe and classify stream order.
2. Analyze the River Continuum Concept to describe energy flow, biological communities, and physical characteristics.

Student "I can…" statements:
1. I can classify stream order.
2. I can discuss energy flow and ecosystem dynamics from headwaters to higher order streams and rivers.

Materials Needed:
- Stream Order and River Continuum Notes (posted on learning platform) (see Appendix C for slides)
- Unit 2 guided notes (printed)
- Whiteboard and markers

Lesson Outline:
1) **Introduction to the Parameter Investigation (10 minutes)**
    a. Bell Ringer: Have students list as many of the parameters as possible on their white board. Roam the room as they complete this to check their recall. Ask students to verbally identify the parameters as either physical, chemical, or biological to further assess their understanding from the previous lesson. (5 minutes)
        i. Expect students to reply with "lake," "pond," "ocean," "river."
        ii. Try to provoke more student thought by asking them to be more specific and providing examples of close by streams and/or lakes they may know.
    b. Distribute Unit 2 guided notes and ask students to independently answer the introduction questions. (5 minutes)
    c. After 5 minutes, ask students to turn to their desk partner and discuss their answers. (3 minutes)
    d. Ask for volunteers to share what they and their partners discussed in answer to the questions. On a projected copy of the guided notes, take brief notes of what students are saying to provoke visual cues for the entire class. (7 minutes)
2) **Presentation and Discussion (45 minutes)**
    a. Provide the slide show notes on the projector for the students.
    b. Spend time on each slide discussing the notes and images.
    c. Verbally ask the questions on the student guide and coach answers from students. If students will not/cannot answer, offer prompting questions.
        i. "How do upstream changes affect downstream areas?" Prompting questions should be "What changes can occur?", "What happens when an organism's ecosystem suddenly changes?"

d. Students should have time to complete all notes and the conclusion questions within the time frame. Roam the room during notes and student worktime to help with questions and provide feedback.

3) Reflection and Wrap-up (15 minutes)

a. Wrap-up discussion: Present the guided notes sheet with the projector and highlight the conclusion question #17: How can stream order information help manage water systems? Students should have already individually answered this. Ask them to discuss their answers with their table partner (3 minutes)
b. With table partners on white boards, ask students to write a collaborative response (2 minutes).
c. Have one student from each pair stand up and hold the white board for a group observation. Ask the student not holding the board to read their answer off the board being held. Prompt students to notice and comment upon any recurring themes or differences in student answers. (10 minutes)

4) Assessment:

a. Formative
    i. Participation in discussion and small group think-pair-shares
    ii. Guided notes completed
    iii. Reflection white board presentation

Lesson One Guided Notes

Stream Order and River Continuum Concept Notes
Please complete the following guided notes sheet as we review the notes together.

Introduction Questions:

1. Have you ever noticed how small streams flow into larger rivers? What do you think determines how these waterways are connected and classified?

2. Why do you think scientists and environmentalists might want to classify streams and rivers? How could doing so help protect water ecosystems?

Stream Order Systems

3. What are stream orders?

4. Define River Basins.

5. What are tributaries and how do they fit into river basins?

Strahler Stream Order

6. What identifies a stream as 1st order?

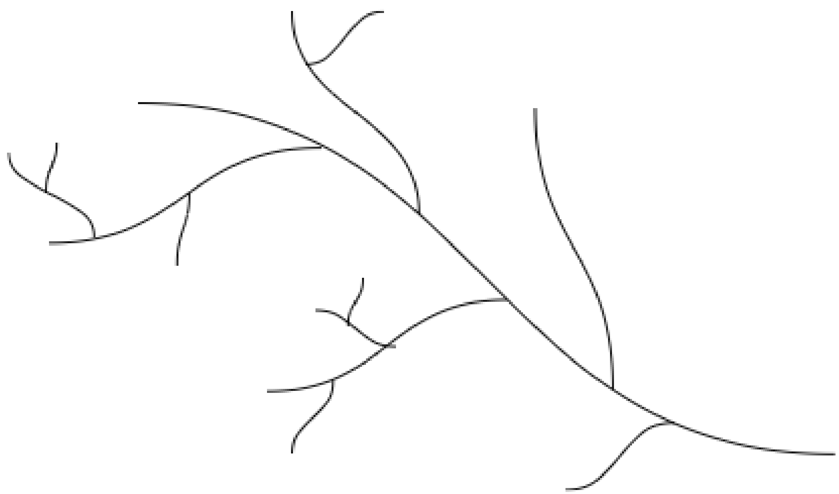
7. How are higher order streams formed?

Global Distribution of Stream Order

8. What are headwaters?

9. How are stream orders distributed across the globe (which is most abundant)?

10. Label the following figure with the correct stream order:



The River Continuum Concept (RCC)

11. What three factors does the RCC consider?

12. Describe the ecosystems and flow of energy in Headwaters.
    -
    -
    -
    -
    -

13. List the types of Macroinvertebrates and give an example of each.
    -
    -
    -

14. Describe the ecosystems and flow of energy in Mid Order Streams (4th - 6th order).
    -
    -
    -
    -
    -
    -

15. Describe the ecosystems and flow of energy in Large Rivers (7th+ order).
    -
    -
    -
    -
    -

Conclusion

16. Using what you've learning about stream order and RCC, describe how a 1st order stream would differ from a 7th order river in terms of:
    -
    -
    -

17. How can stream order information help manage water systems?

18. How do upstream changes affect downstream areas?

Lesson Two: Analyzing Surface Water Classifications

Time: 80 minutes

Learning Objectives:

1. Navigate dense text to answer specific content questions.
2. Analyze how different surface water classifications influence the use, protection, and management of water resources.

Student "I can…" statements:

1. Students can differentiate between primary and supplementary surface water classifications.
2. Students can identify the potential uses of surface water based on classifications.

Materials Needed:

- Analyzing Surface Water Classifications Worksheet (printed)
- NC Surface Water Classification table (printed and posted on the learning platform).

Lesson Outline:

1) **Introduction to Surface Water Classifications (25 minutes)**
    a. Bell Ringer: Write the following questions on the board and ask students to discuss their thoughts with their desk partner: "Why do you think water bodies are classified based on their uses and qualities?"; "How do these classifications help protect aquatic life and water resources?"; "What do you think determines whether a river is safe for swimming or a drinking water source?" (5 minutes)
    b. Assign each group a bell ringer question to write on a white board. (5 minutes)
    c. Have one student from each pair stand up and hold the white board for a group observation. Ask the student not holding the board to read their answer off the board. Ask all groups for question 1 to present, then all groups for questions 2, then all groups for question 3. Prompt students to notice and comment upon any recurring themes or differences in student answers. (15 minutes)
2) **Activity: Analyzing Water Classification Worksheet (35 minutes)**
    a. Distribute the classification table handout and complementary worksheet to the students. Go over the handout and worksheet with the students, explaining what information the handout is providing. Model how to use the handout by answering question 1 on the worksheet. (5 minutes)
    b. Allow for independent student work time. Roam around the classroom to offer help and feedback to the students. (20 minutes)
    c. Verbally review the answers by asking for or calling on volunteers to answer the questions. Take notes on their answers on a blank copy of the worksheet presented for students to see. (10 minutes)
    d. Students should submit their worksheets for grading.
3) **Assessment**
    a. Formative
        i. Participation in discussion and small group think-pair-shares
    b. Summative
        i. Submission and grading of Water Classifications Worksheet

Lesson Two Surface Water Classifications Handout

Table 2.1: NC surface water classification descriptions.
(NCDEQ 2024d; NCAC 2004; NCDEQ 2007)

Primary Classification	Description/Allowable Uses
C	Suitable for aquatic life propagation and survival, fishing, wildlife, secondary recreation*, and agriculture.
B	Suitable for all Class C uses and primary recreation**.
Water Supply I (WS-I)	Suitable for all Class C uses and drinking, culinary, or food processing for users desiring maximum protection; located in underdeveloped watersheds; HWQ supplemental classification applies.
Water Supply II (WS-II)	Same as WS-I except located in predominantly undeveloped watersheds; HWQ supplemental classification applies
Water Supply III (WS-III)	Same as WS-I except located in low to moderately developed watersheds; No HWQ supplemental classification
Water Supply IV (WS-IV)	Same as WS-I except located in moderately to highly developed watersheds; No HWQ supplemental classification
Water Supply V (WS-V)	Suitable for all Class C uses; water is found upstream and draining into Class WS-IV; raw water can be supplied to industries to their employees as drinking water, but not provided to counties or municipalities; CA supplemental classification applies
Supplemental Classification	**Description/Allowable Uses**
Nutrient Sensitive Waters (NSW)	Require limitations on nutrient inputs; Additional supports in nutrient management needed as it is indicating excessive growths of microscopic or macroscopic vegetation.

NC Surface Water Classification Descriptions continued.

Supplemental Classification	Description/Allowable Uses
High Quality Waters (HWQ)	Further protects waters rated excellent based on biological and physical/chemical monitoring; usually primary and other functional nursery areas designed by the Marine Fisheries Commission
Critical Area (CA)	Area adjacent (½ mile) extending upstream and/or downstream of location where risk associated with pollution is greater than the remaining portion of the watershed
Protected Areas (PA)	Area adjoining upstream of the CA (5-10 miles) to provide further protection measures even if the classification changes
Trout Waters (TW)	Provides protection to freshwaters for natural trout propagation and survival of stocked trout.

Lesson Two Analyzing Surface Water Classifications Assignment

Analyzing Surface Water Classifications
Instructions: Use the provided classification table to answer the following questions. Write your answers in the spaces provided.

Section 1: Primary Classifications

1. What activities are allowed in Class C waters?
2. How does Class B differ from Class C in terms of allowable uses?
3. What makes WS-I water different from WS-II waters?
4. Which classification (WS-III, WS-IV, or WS-V) is most likely to be found near highly developed areas? Why?
5. Which primary classification would be most suitable for a reservoir supplying drinking water to a rural community? Explain your reasoning.

Section 2: Supplemental Classifications

6. What additional protections are provided to High Quality Waters (HWQ)?
7. Why might a water body with Trout Waters (TW) classification need special rules?
8. How are Critical Areas (CA) and Protected Areas (PA) different?

Section 3: Real-World Applications

9. Imagine you are planning to build a park near a local river. The river is classified as WS-II with the HWQ supplemental classification. What restrictions or considerations might you need to keep in mind?

10. What could happen if a Nutrient Sensitive Water (NSA) becomes overloaded with nutrients? How might this affect aquatic life?

11. Why do you think it is important to classify water bodies based on their uses and quality?

Lesson Three: Exploring Water Body Classifications in North Carolina

Time: 80 minutes

Learning Objectives:
1. Interpret and analyze water body classifications in North Carolina.
2. Use maps to identify water body classifications.

Student "I can…" statements:
1. I can understand and analyze the implications of water body classification for environmental planning and conservation.

Materials Needed:
- NC Surface Water Classification table (printed and posted on the learning platform)
- Analyzing Water Classification in NC Worksheet (printed)
- Colored Pencils
- Access to computers

Lesson Outline:
1. **Introduction to Assignment (15 minutes)**
   a. Ask students "Can you think of any rules or restrictions you've heard of for lakes, rivers, or other bodies of water near you? Allow for student responses and discussion. (5 minutes)
   b. Review the primary classifications and supplemental classifications discussed in Unit 2 Lesson two. Ask students to refer to the handout of the classifications table from that lesson as well. Point out their importance in protecting water resources and guiding land use decisions. Allow for student comments and questions. (10 minutes)
2. **Activity: Exploring Classifications on a Map (50 minutes)**
   a. Distribute the Analyzing Water Classification in NC worksheet to students. Instruct and give them time to silently read the instructions. (5 minutes)
   b. While they are reading the instructions, pull up the NCDOT website to display.
   c. After 5 minutes of silent reading, review the instructions with students and show them how to zoom into the interactive map, add layers, and extract information. (5 minutes)
   d. Allow for independent student work time. Roam around the classroom to offer help and feedback to the students. (40 minutes)
3. **Reflection and Wrap-up (15 minutes)**
   a. As table partners on white boards, assign each conclusion question from the worksheet to students to write a collaborative response (5 minutes).
   b. Have one student from each pair stand up and hold the white board for a group observation. Ask the student not holding the board to read their answer off the board being held. Prompt students to notice and comment upon any recurring themes or differences in student answers (10 minutes)
   c. Students should submit their worksheets for grading.
4. **Assessment**
   a. Formative
      i. Participation in discussion and small group think-pair-shares
   b. Summative
      ii. Submission and grading of Water Body Classifications in NC Worksheet

Lesson Three Analyzing Water Classifications in North Carolina Assignment

Introduction:
Water classifications help determine how water bodies in North Carolina can be used and protected. In this activity, you will explore the classifications of water bodies using maps and the NCDOT website to understand their uses, protections, and implications for conservation.

Source:
NCDOT. 2024. North Carolina Country Outline Map. [Internet]. Raleigh (NC). [cited 2024 Nov 11]. Available from: https://connect.ncdot.gov/resources/State-Mapping/Documents/nc_ statemapcountyoutline.pdf

Instructions:

Part 1: Using the NCDEQ Website
1. Access the NCDEQ Interactive Map at **http://bit.ly/3CB3lli**
2. Search locations by using the search bar to type in a specific location, such as a river, lake, or county.
3. You can also zoom into the map manually to focus on smaller streams, lakes, and bodies of water.
4. Identify classification by clicking on the highlighted water body to view detailed formation about its primary classification and any supplemental classifications it may have.
5. Use layers and filters to view additional information and to narrow your search by classification type or area.

Part 2: Map Labeling
1. Search for a water body with each type of classification (primary and supplemental) in North Carolina using the NCDEQ website.
2. Color each location on the NC Counties map included with this activity.
3. Use a different color for each classification and make sure to include a key on your map.
4. Include the name of the body of water on the map or with the key.

Conclusion
Answer each of the following questions using your map and the NCDEQ website.
1. Identify a body of water you identified as having a primary classification. Does it also have any supplemental classifications? If yes, list them and explain their importance. If no supplemental classification, what does this mean?
2. Select another water body with a different classification. How do the classification of these two bodies of water (from number 1) differ? Why do you think they have different classifications?
3. Discuss any patterns you notice on your map. For example, where are high-quality waters located vs. highly developed areas?
4. Explore additional features on the NCDEQ website such as impaired waters, conservation areas, or water quality monitoring data. Write 1-2 interesting facts or observations you found


WEST VIRGINIA
VIRGINIA
TENNESSEE
GEORGIA
SOUTH CAROLINA
NORTH CAROLINA
COUNTY OUTLINE MAP
0 10 20 40 60 80 100 Miles
ALLEGHANY
ASHE
SURRY
STOKES
ROCKINGHAM
CASWELL
PERSON
GRANVILLE
VANCE
WARREN
NORTHAMPTON
GATES
CURRITUCK
CAMDEN
PASQUOTANK
PERQUIMANS
HERTFORD
CHOWAN
WATAUGA
WILKES
YADKIN
FORSYTH
GUILFORD
ALAMANCE
ORANGE
DURHAM
FRANKLIN
HALIFAX
BERTIE
MITCHELL
AVERY
CALDWELL
ALEXANDER
YANCEY
MADISON
DAVIE
IREDELL
DAVIDSON
RANDOLPH
CHATHAM
WAKE
NASH
EDGECOMBE
MARTIN
WASHINGTON
TYRRELL
DARE
BUNCOMBE
McDOWELL
BURKE
CATAWBA
ROWAN
HAYWOOD
SWAIN
GRAHAM
CHEROKEE
CLAY
MACON
JACKSON
TRANSYLVANIA
HENDERSON
POLK
RUTHERFORD
CLEVELAND
LINCOLN
GASTON
MECKLENBURG
CABARRUS
STANLY
MONTGOMERY
MOORE
LEE
HARNETT
JOHNSTON
WILSON
PITT
BEAUFORT
HYDE
GREENE
WAYNE
LENOIR
CRAVEN
PAMLICO
UNION
ANSON
RICHMOND
SCOTLAND
HOKE
CUMBERLAND
SAMPSON
DUPLIN
JONES
ONSLOW
CARTERET
ROBESON
BLADEN
PENDER
COLUMBUS
NEW HANOVER
BRUNSWICK

Unit 3: Pollution in North Carolina Waters

North Carolina surface water quality can be negatively affected by various contaminants from multiple sources. Point source pollutants are introduced to surface water through identifiable locations such as industrial effluents and piped discharges from various treatment plants. More dispersed introduction of pollutants from nonpoint sources can be attributed to anthropogenic activities such as mining, urban development, agriculture, and stormwater runoff (NCDEQ 2001). These activities ultimately contribute contaminants such as sediments, heavy metals and synthetic chemicals into the water. Chemical pollutants of particular concern in North Carolina include polychlorinated biphenyls (PCBs) and per-and polyfluoroalkyl substances (PFAS) (NCDHHS 2019; Scruggs 2019).

Polychlorinated Biphenyls (PCBs)

In North Carolina, a liquid containing PCBs was illegally disposed of along 240 miles of highway from June to August 1978 by a trucking company across 14 of North Carolina's most rural counties (NCDNCR 2013; EPA 2024d). While these sites were successfully treated and cleaned, further small-scale dumping, spilling, and leaking of PCB-containing liquids has continued to allow for PCB contamination to enter NC waterways (EPA 2024d). The term PCB applies to 209 synthetic, organic chemicals with a structure consisting of 2-10 chlorine atoms attached to a biphenyl molecule. The locations of the chlorine atoms attached to the biphenyl compound determine the specific characteristics and chemical properties of each congener (EPA 2024a). PCBs are thermally and chemically stable, so they tend to persist in the environment instead of breaking down into less harmful compounds (Pal et al. 1980). Historically, PCBs were commercially produced in the US between 1929 and 1977 as industrial coolants and lubricants. Uses of PCBs include adhesives, inks, pesticide extenders, and sealant/caulking compounds

(Faroon et al. 2000). Even though commercial PCB manufacturing, processing, and distribution in the US was banned by the Toxic Substances Control Act in 1979, effects are long lasting and still evident today. Even with new manufacturing being disallowed, any PCB still in use could possibly leak (Erikson 2001). No matter how the contaminant is introduced, PCB contamination is enduring. PCB is known as the original "Forever Chemical" because of its environmental persistence and tendency to bioaccumulate (Mackay and Fraser 2000; Yaghoobi 2021).

PCB molecules are nonpolar and lipophilic, meaning they are insoluble in water, but can adsorb to sediments and organic materials. These sediments move to surface water through the process of erosion, and water becomes contaminated (ATSDR 2014). Once organic chemicals enter surface waters, bioaccumulation within aquatic organisms such as fish may occur. Bioaccumulation is the process by which the uptake of a chemical from the environment via respiration, dermal diffusion, and food consumption results in an increase of the chemical concentration within an organism (Streit 1992; Mackay and Fraser 2000). Once consumed, the lipophilicity of these chemicals allows them to cross biological membranes and partition in the fatty tissue of the organism (Nowicki and Pizzorno 2020). These chemicals will continue to accumulate over time, causing the organism to build a reserve of the chemical in their fatty tissue.

Because PCBs are lipophilic, drinking water will contain negligible concentrations. However, the recreational use of PCB contaminated water will provide a route of exposure for humans (EPA 2024b). Inadvertent consumption of sediments, dermal absorption, inhalation of particles, and consumption of PCB-laden fish all offer human exposure to PCBs. Acute exposure of PCBs can cause symptoms such as diarrhea, respiratory depression, dehydration, and upper respiratory tract irritations. (ATSDR 2014). However, continued human exposure to PCBs via recreational water access and fish consumption could result in long-term exposure. PCBs are potential carcinogens, and chronic exposure can impact the immune, reproductive, nervous, and endocrine systems (ATSDR 2014).

Possibly most at risk to PCBs toxic effects are youth with developing nervous systems (Yaghoobi 2021). During development, molecular processes are highly regulated and PCB can cause a disturbance to neurological development. Although exposure to PCB through consumption of contaminated fish and/or soil, dermal absorption, and inhalation are all possible for children, exposure can begin prenatally through the mother. The lipophilicity of PCB allows for exposure to fetuses through the placenta and to infants through breast milk after birth. Exposure to young children via these methods are thought to cause autism spectrum disorder, attention-deficit/hyperactivity disorder, and general cognitive impairment (Yaghoobi 2021).

Fish consumption advisories are state-regulated and usually issued for specific species within a water system (Cleary et al. 2021). At state levels, consumption advisories are broken down in many ways, but the general method is by targeting “sensitive populations”. Sensitive populations generally consist of women of childbearing age, women who are pregnant, women who plan to become pregnant, women who breastfeed, children, and people with depressed immune systems (Tan et al. 2011). Further, age ranges can be added to blanket statements such as “women of childbearing age.” For example, North Carolina specifically defines women of childbearing age as ages 15 to 44 years old (Scherer et al. 2008). Currently, the state action level for PCBs found in fish is 0.05 mg/kg and sixteen locations within North Carolina are currently under fish consumption advisories from the NC Department of Health and Human Services (NCDHHS) due to elevated levels (Table 8; NCDNCR 2024). Avoiding consumption of these fish can reduce PCB exposure in both adults and children.

Table 3.1: NCDHHS current fish advisories (NCDNCR 2024).

Date Issued	Body of Water	Fish Species	Affected Counties
11-Feb-09	Badin Lake	Catfish, largemouth bass	Montgomery, Stanly
7-May-04	Brier Creek	All	Wake
31-Mar-06	Crabtree Creek	Carp, catfish, largemouth bass	Wake
13-Mar-13	Falls Reservoir	Catfish	Montgomery, Stanly
13-Mar-13	High Rock Lake	Catfish	Davidson, Rowan
7-May-04	Lake Crabtree	Carp, Catfish	Wake
9-Apr-13 Aug-17	Lake Norman	Hybrid striped bass	Catawba, Iredell, Lincoln, Mecklenburg
13-Mar-13	Lake Tillery	Catfish	Montgomery, Stanly
23-Dec-11	Lake Wylie	Largemouth bass	Gaston, Mecklenburg
8-Dec-03	Little Brier Creek	All	Wake
25-Apr-13	Mountain Island Lake	Largemouth bass, blue catfish, channel catfish	Gaston, Mecklenburg
2-Apr-08	Neuse River	Carp, catfish	Wake
2-Apr-08	Rocky Branch	Carp, catfish	Wake
2-Apr-08	Walnut Creek	Carp, catfish	Wake
13-Mar-13	Yadkin-Pee Dee River System	Catfish	Davidson, Montgomery, Rowan, Stanly

Per- and Polyfluoroalkyl Substances (PFAS)

Another “Forever Chemical” of concern in North Carolina water is an emerging group of contaminants known as PFAS (Scruggs 2019). In June of 2017, the NCDEQ and NCDHHS began investigating the contamination of the Cape Fear River with a PFAS chemical known as

GenX; a company known as Chemours (formerly DuPont) was identified as the origin of the pollution. The Chemours facility in Fayetteville was producing goods with the use of GenX and then discharging the chemical with wastewater into the Cape Fear River (NCDEQ 2024b.)

PFAS refers to a class of 6000+ substances that contain an alkyl chain typically 2 to 16 carbons long. The carbon atoms of the chain are attached to a varying number of fluorine, and hydrogens, and can have a terminal functional group (EPA 2024c). PFAS have been produced since the 1940s and are widely used in both industrial implementation and consumer products. The use of PFAS chemicals as an ingredient in synthesizing wire and cable insulators allows it to be applied in industries such as biotechnology, aerospace, chemical industry, and building and construction. More consumer-based uses of PFAS include pesticides, cook and baking ware, varnishes, lubricants, and medical utensils (Glüge et al. 2020).

Of particular concern in North Carolina is the presence of GenX in ground and surface waters. GenX is a name for a commercialized PFAS chemical specifically used as an emulsifying agent for production of nonstick coatings such as Teflon (Cahoon 2019). GenX is an emerging contaminant, meaning it is newly produced and newly recognized as environmentally problematic. The hazards posed by emerging contaminants such as GenX are not completely known and mechanistic interactions are hard to predict (Cahoon 2019). Unlike PCBs, which are lipophilic and tend to adsorb to soil particles, PFAS can be both hydrophobic and lipophobic. The backbone alkyl chain with bonded fluorides is hydrophobic while the terminal functional group gives the chain an additional lipophobic end. This causes the PFAS compounds to partition to interfaces such as water and air. The terminal functional group will reside in water while the fluorinated alkyl chain will reside in air (EPA 2024c). GenX is a surfactant molecule with both hydrophobic and lipophobic ends, causing part of the molecule to be water soluble and part to be insoluble. This can elicit the self-assembly of GenX molecules into micelles with a hydrophobic core and hydrophilic outside ring, which is pertinent to GenX's impact on human health and the environment (Nealon 2022). Even if the concentration of GenX in water is low, the formation into micelles allows for a higher concentration near the surface of water, causing clustering and a higher possibility of interaction (Nealon 2022). Higher concentrations near the surface of water will allow for enhanced exposure to humans and wildlife as they come in contact with the water for recreation and consumption.

While the main route of human exposure discussed for PCB was by consumption of contaminated fish, individuals are exposed to PFAS, specifically GenX, via oral ingestion of contaminated drinking water (EPA 2023). Oral exposure to GenX can affect the liver, kidneys, immune system, prenatal development, and is associated with cancer. Particularly, the liver shows negative effects from oral exposure to GenX (EPA 2023). Further, research has shown that general PFAS exposure can increase cholesterol levels, lower antibody response to some vaccines, affect growth and learning behaviors in infants and older children, and lower a woman's chance of getting pregnant (Anderko and Pennea 2020). With PFAS consisting of emerging contaminants like GenX, health effects are still being researched and understood.

Because PFAS (GenX) is considered an emerging contaminant in North Carolina waters, progress of addressing the pollution in the Cape Fear River is ongoing (Cahoon 2019). Surveys of residents near the Chemours plant were conducted in 2019 to gather information on community needs. Researchers are regularly working on PFAS testing networks, and health education for the public is continuous. Public health assessments and consultation programs are in place to aid local communities and the NCDHHS has developed and released new guidelines for medical practices to use when working with patients exposed to PFAS (NCDHHS 2024).

North Carolina is one of the most affected states in America, so all research efforts being put in are helping to create a response guide for other places with emerging PFAS contamination (Ehsan et al. 2023).

As of April 2024, the EPA has finalized the National Primary Drinking Water Regulation (NPDWR) for six PFAS compounds. The maximum contaminant level (MCL) of a substance is the highest concentration level a contaminant is allowed to be in drinking water. The level is decided based on cost benefit analysis and what is realistically enforceable (Ramasamy et al. 2015). MCLs for six PFAS compounds, including GenX, allows for legal enforcement of levels in the drinking water (Table 9; EPA 2024c).

Table 3.2: PFAS chemical MCL from April 2024 (EPA 2024c)

Compound	Final MCL
PFOA	4.0 ppt
PFOS	4.0 ppt
PFHxS	10 ppt
GenX	10 ppt
Mixtures containing two or more of above	1 (unitless) Hazard Index*

*Hazard Index is an approach by the EPA to understand the health risks associated with chemical mixtures. The number developed is a sum of the fractions of each PFAS compound in question. Fractions compare the level of the PFAS chemical measured in water to the health-based concentration.

Lesson Plans

Lesson One: Understanding Point vs. Non-point Source Pollution sets the stage for this unit by teaching students about point source vs nonpoint sources of pollution. This is necessary as the unit progresses and lessons become more comprehensive. The first lesson plan also allows students to personally connect to pollution as they try to identify common sources in their communities. Lesson Two: Introduction to Forever Chemicals focuses on emerging contaminants and “forever chemicals” in North Carolina. Teaching about pollution in North Carolina specifically allows for the material to become personal for the students. This works to increase their buy-in on the content and encourages students to look beyond the classroom to realize pollution and clean water access is an ongoing issue with direct relevance to their health and future. Lesson Three: Researching Other Emerging Contaminants in North Carolina is a summative project that requires students to research an emerging contaminant other than PFAS. This lesson also directly teaches research and scientific literacy skills, a practice that is important to develop for future science classes.

Unit 3 Lesson Plans

Lesson One: Understanding Point vs Non-Point Source Pollution

Time: 90 minutes

Learning Objectives:
1. Define and identify point source and nonpoint source water pollution
2. Explain the impacts of each type of pollution on water quality.

Student "I can…" statements:
1. I can distinguish between different sources of pollution.
2. I can analyze and connect real-world examples of water pollution to their local community.
3. I can propose steps to mitigate nonpoint source pollution.

Materials Needed:
- Understanding Point vs Nonpoint Source Water Pollution Webquest Assignment (printed)
- Computer access
- White board and markers

Lesson Outline:

1) **Introduction to the Assignment (15 minutes)**
    a. Bell Ringer: Have two images displayed on the board for students to see. Ask students to differentiate between the two types of pollution being displayed. Ask for volunteers or call on students to answer (5 minutes)
        i. Image 1 should be an example of a factor discharging wastewater (point source)
        ii. Image 2 should be an example of runoff from a neighborhood lawn (nonpoint source)
    b. Explain the images by highlighting the concepts of point and nonpoint source pollutants. Refer to images and student responses. (5 minutes)
        i. Point source: Pollution form a single, identifiable source
        ii. Nonpoint source: Pollution from scattered, unidentifiable sources
    c. Transition to the webquest assignment by stating that sources of pollution will be investigated using a NOAA article and class discussion. Pass out the "Understanding Point vs Nonpoint Source Water Pollution" worksheet. Direct students to open their computers and use the link on the worksheet to access the NOAA article. Project a computer on the board to show students what the article should look like. (5 minutes)
2) **Guided Webquest Assignment (55 minutes)**
    a. Part 1: Definitions (5 minutes)
        i. Model how students should find the definition of point source pollution using the article. Model writing the answer to the first question on the webquest assignment. (2 minutes)

ii. Give students time to find the definition of nonpoint source pollution using the article. Ask for a volunteer to define the term and model writing their answer on the webquest assignment. (3 minutes)

b. Part 2: Examples (10 minutes)
   i. Have students list examples from the article and record on the model webquest assignment. (2 minutes)
   ii. Ask students to brainstorm examples not listed in the article and discuss with their table partner. (3 minutes)
   iii. Go around the room and have each pair of students try to list examples that were not listed in the article. (5 minutes)

c. Part 3: Impacts on Water Quality (10 minutes)
   i. Discuss as a class prior to completing this section:
      (1) How point source pollution might create intense damage in one specific location.
      (2) Why nonpoint sources of pollution are more difficult to control.
   ii. Direct students to complete this section individually or with their table partner. Go around the room and have each pair of students try to list examples that were not listed in the article. (5 minutes)

d. Part 4: Real-World Connections (10 minutes)
   i. Encourage students to think about their community and ask: “Where do you think water pollution might come from in your area?” If students are struggling to come up with ideas, point out some places around the school building that are sources they can identify with. (5 minutes)
   ii. Ask students to write their responses and take for volunteers to share their answers with the class. (5 minutes)

e. Part 5: Extension (20 minutes)
   i. Give students time to independently answer questions 9 and 10 on the webquest worksheet. (5 minutes)
   ii. Direct students to share their answers with their table partner and collaborate on a single answer to write on a white board for class discussion. (5 minutes)
   iii. Have one student from each pair stand up and hold the white board for a group observation. Ask the student not holding the board to read their answer off the board being held. Prompt students to notice and comment upon any recurring themes or differences in student answers. (10 minutes)

3) Assessment

a. Formative
   i. Participation in discussion and small group think-pair-shares

b. Summative
   ii. Submission and grading of Guided webquest assignment

Lesson One Understanding Point vs Nonpoint Source Water Pollution Webquest Assignment

Understanding Point vs Nonpoint Source Water Pollution Webquest Assignment

Introduction
Water pollution can come from many sources, but scientists classify them into two major categories: point source pollution and nonpoint source pollution. The National Oceanic and Atmospheric Administration (NOAA 2024) explains the differences between these pollution types and their impacts on water quality in the article "Point vs. Nonpoint Water Pollution", accessed at **https://bit.ly/4fxx90s**. Access and review this journal as you complete the following guided webquest:

Sources:
NOAA. 2024. Point vs Non-Point Water Pollution: What's the difference? [Internet] Washington (D.C.). [cited 2024 Nov 17]. Available from: https://response.restoration.noaa.gov/point-vs- non-point-water-pollution-what-s-difference

Part 1: Definitions

1. What is point source pollution? (Hint: Look for key features like the origin of the pollution.)

2. What is nonpoint source pollution? (Hint: Consider how this type of pollution spreads.)

Part 2: Examples

3. Identify two examples of point source pollution:
    -
    -
4. Identify two examples of nonpoint source pollution:
    -
    -

Part 3: Impacts on Water Quality

5. Explain how point source pollution can affect water quality.

6. Explain how non-point source pollution might be harder to control than point source pollution

Part 4: Real-World Connections

7. Think about your local community. Describe a possible source of point source pollution nearby.

8. Describe a possible source of nonpoint source pollution in your area.

Part 5: Extension

9. Why do you think reducing nonpoint source pollution requires more community effort compared to point source pollution?

10. What are some steps individuals can take to reduce nonpoint source pollution? Provide two suggestions.
    -
    -

Lesson Two Introduction to Forever Chemicals

Time: 90 minutes

Learning Objectives:
1. Understand and explain the concept of emerging contaminants and their sources.
2. Define "forever chemicals" and list their health impacts.

Student "I can…" statements:
1. I can explain the basics of why PFAS is considered a "forever chemical."
2. I can analyze a case study on PFAS contamination.

Materials Needed:
- PBS Video: "Are We Stuck With Forever Chemicals Forever?"
- Emerging Contaminants and Forever Chemicals Slide Show (posted on learning platform) (see Appendix D for slides)
- Case Study Analysis Activity (posted on learning platform)
- Computer Access

Lesson Outline:
1. **Introduction to Forever Chemicals (10 minutes)**
    a. Show the PBS Video: "Are We Stuck With Forever Chemicals Forever?"
    b. Pause at key moments to ask questions
        i. "What products in our daily lives might contribute to this issue?'
        ii. Why are these chemicals so difficult to remove from the environment?"
2. **Direct Instruction of "Emerging Contaminants and Forever Chemicals" Slide Show (15 minutes)**
    a. Have the notes slide show posted on the student learning platform for students to access and follow along.
    b. Go through notes and ask students to connect them to the video they watched. Stop periodically for student comments and questions
3. **Case Study Activity (30 minutes)**
    a. Direct students to access the Case Study Analysis Activity on the learning platform and model how to access the website that is given in the assignment. (3 minutes)
    b. Briefly explain the activity and show students how to access the shared slide show on the learning platform that they can edit. Have the slides pre-labeled with partner names for easier organization. Students should create 1-2 slides with their key information. (5 minutes)
    c. Encourage concise, clear information. Reference the slides from the last slideshow as an example. (2 minutes)
    d. Roam around the room to provide help and redirection as students complete their research and slide construction. (20 minutes)
4. **Class Presentations (25 minutes)**
    a. Each pair of students will present their findings to the class, explaining their case study analysis. (2-3 minutes per pair)

   b. Allow peers to ask questions. Students should also be filling in the rest of their assignment sheet as presentations are made. (1-2 minutes)
   c. Provide feedback for the students as needed to clarify any misconceptions. Coach students to an answer with questions instead of just correcting them. (1-2 minutes)

5. **Reflection and Wrap-up (10 minutes)**
   a. Lead a brief discussion on commonalities noticed in the different case study analysis presentations. (5 minutes)
   b. Ask students to share their thoughts on the following question. (5 minutes)
   c. What surprised you the most about the information you have learned today?
6. **Assessment**
   a. Formative
      i. Participation in discussion
   b. Summative
      i. Slideshow presentation

Lesson Two Case Study Analysis Assignment

Case Study Analysis Activity

Instructions:

1. Access the EPA Case Studies:
    - Visit the EPA's PFAS case studies webpage: https://bit.ly/3AU9JTW
    - Choose an article you find interesting. Look for detailed reports on PFAS contamination in a specific location.
2. Analyze the Case Study:
    - Review the case study and focus on these key aspects:
        - Source of Contamination: What industries, products, or activities caused PFAS pollution?
        - Environmental Impact: How has the contamination affected water systems, wildlife, or ecosystems?
        - Health Impact: What health issues are linked to PFAS exposure in the community?
        - Actions Taken: What has been done to address the contamination? (ex: clean-up efforts, regulations, or lawsuits, etc.)
3. Document your Findings:
    - Record your findings on a slide in the shared class slideshow (located on the learning platform).
    - Use the following template to organize your information:
        - Case study location
        - Source of PFAS contamination
        - Environmental impact
        - Health impact
        - Solutions or Mitigation Efforts
4. Submit your Work and Present:
    - Complete your slide with clear, concise points. You will get a chance to explain more thoroughly when you present.
    - Ensure your slide is organized and easy to read.
    - Include a picture!
    - Share your completed slide in the shared class slideshow

Lesson Three: Researching Other Emerging Contaminants in North Carolina

Time: 400 minutes (5 days)

Learning Objectives:

1. Gather and analyze information from credible sources.
2. Explain how emerging contaminants are affecting water quality and human health in North Carolina.

Student "I can…" statements:

1. I can identify and appropriately cite credible sources of information.
2. I can describe how emerging contaminants are affecting water and human health in North Carolina.
3. I can efficiently organize information for presentation.

Materials Needed:

- Emerging Contaminants Research Project and Rubric (on learning platform)
- Researching Emerging Contaminants in North Carolina Guide (on learning platform)

Lesson Outline:

Day 1: Understanding Water Quality Issues (80 minutes; 1 day)

1. **Introduction (10 minutes)**
    a. Start by asking students to reflect on what information they learned in the prior lessons of this unit. Instruct them to record their thoughts somewhere (notebook, laptop, etc. (3 minutes)
    b. Ask students to shout out terms and vocabulary they wrote down. Write these on the board. Make a point to prompt students into mentioning point source pollution, nonpoint source pollution, emerging contaminants, PFAS, etc. (5 minutes)
    c. Conclude the discussion by stating that students have learned specifically about PFAS, but they are about to specifically research a new emerging contaminant of their choice for a project. (2 minutes)
2. **Project and Rubric Review (10 minutes)**
    a. Tell students they can form groups of up to 3 or work alone.
    b. Project the project instructions with rubric on the board and review it with the students. Allow for any questions and clarification (10 minutes)
3. **Begin Research (55 minutes)**
    a. Direct students to begin their research using the Water Contaminant Research Worksheet.
    b. Roam the room to aid in student research (55 minutes)
4. **Wrap-up (5 minutes)**
    a. Ensure students they would not have probably gotten the entire worksheet completed, but they will have time during the next class period to complete their research.
5. **Assessment**
    a. Formative
        i. Participation in discussion
        ii. Work completed on Research Worksheet

Day 2: Research Methodology and Finishing the Research Document

1. **Research and Citation Instruction (15 minutes)**
   a. Demonstrate how to find reliable sources by using databases, academic journals, government websites, and search engines such as Google Scholar. (10 minutes)
   b. Choose an example of a credible source and walk students through how to cite it using an appropriate citation style (can vary). (5 minutes)
2. **Hands-On Practice (15 minutes)**
   a. Have students review their sources collected yesterday and determine if they are credible. Roam the room as students work to offer feedback and answer questions. (5 minutes)
   b. Direct students to choose one of their credible sources and practice citing it. (5 minutes)
   c. Have students share their efforts in small groups and check each other's citations. Roam the room to offer feedback and answer questions.
3. **Continue Research (45 minutes)**
   a. Direct students to continue working on their Water Contaminant Research Worksheet with intentions to finish it during class time. Allow for independent work time as you roam the room to offer feedback and answer questions. (45 minutes)
4. **Wrap-up (5 minutes)**
   a. Indicate to the students that they should finish the research worksheet for homework so they can begin working on the presentation during the next class. (5 minutes)
5. **Assessment**
   a. Formative
      i. Participation in discussion
      ii. Work completed on Research Worksheet

Day 3-4: Presentation Synthesis (Complete the following each day)

1. **Presentation Work-time (60 minutes)**
   a. Students are likely to be at different stages of the process, so keep structure loose so everyone has time to work on what needs to be done.
   b. Guide students in organizing their research into a coherent format for presentation. Roam the room to offer feedback and answer questions (60 minutes)
2. **Peer Review Checkpoint (20 minutes)**
   a. Pair groups randomly and ask them to present their findings to one another. Indicate that each group should respectively offer suggestions and feedback. Practice doing this with a group in demonstration. (10 minutes)
   b. Roam the room to observe and listen to peer feedback being given. Offer suggestions and corrections as needed. (10 minutes)
3. **Assessments**
   a. Formative
      i. Participation in peer feedback activity
      ii. Work completed on presentation synthesis

Day 5+: Presentations and Reflection

1. **Presentations (60 minutes)**
   a. Students present their finding to the class in 5-10 minutes presentations.

   b. Encourage active listening by having students in the audience to take notes and ask questions.
   c. Take notes and complete a rubric as you view the presentations.
2. **Class Discussion (5 minutes)**
   a. Initiate a discussion on the diversity of topics presented about water quality in North Carolina. Ask students to volunteer answers on how they believe their research and presentations connect to global water issues. (5 minutes)
3. **Final Reflections**
   a. Assign a written reflection to be turned in during the next class. Ask them to reflect on what they learned, what were challenges they faced during the research process, and what action they think they can take to address water contamination.
4. **Assessment**
   a. Formative
      i. Participation in peer feedback activity
   b. Summative
      i. Final Presentation Rubric
      ii. Final Reflection

Unit 3 Lesson Three Emerging Contaminant Research Project

Emerging Contaminant Research Project

Your task is to create a presentation on North Carolina's water quality issues, focusing specifically on emerging contaminants. Through this project you will:

1. Research the origins, environmental impacts, and human health effects of these contaminants.
2. Investigate current measures being taken to address these issues in North Carolina.
3. Present your findings in a creative, engaging, and well-organized format of your choice (ex: video, slideshow, Canva, etc.)

Your presentation should include accurate information supported by credible sources, incorporate visual or multimedia elements, and clearly demonstrate your understanding of the material. Be prepared to explain your findings clearly and answer questions from your teacher and peers.

Rubric

Criteria	**Exemplary (4 pts)**	**Proficient (3 pts)**	**Developing (2 pts)**	**Needs Improvement (1 pt)**	**Notes**
Research	Demonstrate thorough research; all questions answered with detailed, accurate, and well-cited information.	Demonstrates adequate research; most questions are answered with accurate and cited information, but some details are lacking.	Demonstrates limited research; several questions are unanswered or contain inaccuracies.	Minimal or no research evident; most questions are unanswered or contain inaccuracies.	
Organization	Project is well-structured, logical, and easy to follow. Ideas are coherently presented.	Project is organized and mostly logical, with minor issues in flow or clarity.	Project shows some organization, but ideas are scattered or difficult to follow.	Project is disorganized and lacks a clear structure, making it hard to understand.	
Creativity	Presentation is highly engaging and includes a variety of creative elements to enhance understanding.	Presentation is engaging with some creative elements, but they may not completely enhance the content.	Presentation has few creative elements and lacks engagement or originality.	Presentation is plain and lacks any creative effort, leading to minimal engagement	

Rubric Continued

Criteria	Exemplary (4 pts)	Proficient (3 pts)	Developing (2 pts)	Needs Improvement (1 pt)	Notes
Content Accuracy	All information is accurate, relevant, and supports the project's purpose	Most information is accurate and relevant, with minor errors or omissions	Information includes some inaccuracies or irrelevant details that distract from the project's purpose	Information is largely inaccurate, irrelevant, or unsupported by evidence.	
Visual/Multi-media Use	Uses a variety of visuals and multimedia to enhance the research and presentation	Uses visuals and multimedia, but some may not effectively support the research and presentation	Uses minimal visuals and multimedia; connections to the research and presentation is unclear	Visuals and multimedia is absent or irrelevant, offering no added value to the presentation	
Presentation Skills	Presenter(s) demonstrate confidence, clarity, and enthusiasm; effectively make eye contact and communicate	Presenter(s) are clear and confident, with minor issues in eye contact and communication.	Presenter(s) have lack of engagement with the audience; delivery may be unclear at times.	Presenters lack confidence, clarity, and/or engagement that significantly impacts delivery	
Citations	All sources correctly cited in an appropriate format; sources are credible	Most sources are correctly cited and credible with minor formatting issues	Some sources are cited, but there are issues with credibility or formatting	Few or no sources are cited, and/or they are not credible or relevant	
Overall Effort	Demonstrates exceptional effort and thoughtfulness; exceeds project requirements	Demonstrates adequate effort and meets project requirements	Demonstrates minimal effort and does not fully meet project requirements	Demonstrates little to no effort, failing to meet project requirements	
Total Points					

Unit 3 Lesson Three Researching Emerging Contaminants in North Carolina Guide

Water Contaminant Research Guide

Research Topic:

Part 1: Contaminant Overview

1. What is the name of the contaminant you are researching?
2. What are its origins? What activities or industries are responsible for its introduction into the environment?
3. What are its physical and chemical properties?
   a. Does it dissolve in water, bind to soil, bioaccumulate?
   b. Is it stable in the environment or does it break down over time?

Part 2: Environmental and Human Health Impacts

4. How does the contaminant affect the environment?
   a. What ecosystems or species are most affected?
   b. Are there specific bodies of water in North Carolina with this known contaminant?
5. What are the impacts on human health?
   a. How does exposure occur? (drinking water, consuming, recreation, etc.)
   b. What are the short-term (acute) and long-term (chronic) health effects?

Part 3: Current Regulations and Mitigation Efforts

6. What regulations are in place to address this contaminant?
   a. Are there state or federal guidelines, such as maximum contaminant levels (MCLs)?
   b. Are there fish consumption advisories related to this contaminant? If so, for which species and locations?
7. What measures are being taken to clean up or prevent contamination?
   a. Are there any ongoing remediation projects in North Carolina
   b. What role do government agencies play? (NCDEQ, EPA, etc.)
8. How are communities and individuals affected by contamination being supported?
   a. Are there public health initiatives, educational campaigns, or financial resources available?

Part 4: Proposed Solutions and Personal Reflection

9. What additional measures do you think should be taken to address this issue?
10. What can individuals do to protect themselves and reduce their contribution to contamination?
11. Reflections:
    a. What surprised you the most during your research?
    b. How does this topic relate to your community or personal experiences?

Resources Log: Use this section to keep tract of sources you find during your research.

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APPENDICES

Appendix A: Water Quality: Understanding Water Quality Assessment Notes

Water Quality: Understanding Water Quality Assessment

Holly Whittington

What is Water Quality?

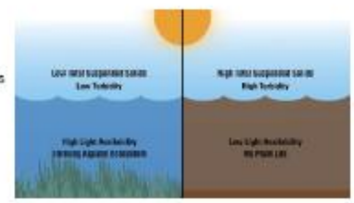
On a white board, answer the following questions with your partner. Be prepared to share!

- What words come to mind when you hear "water quality?"
- What is the importance of clean water?
- What ***factors*** should be considered when determining if water is "clean?"

Physical Indicators of Water Quality

Turbidity

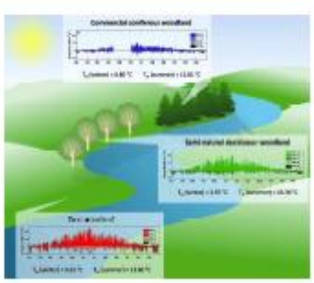
- Cloudiness of water
- Measure of the ability of light to pass through
- Can be caused by suspended materials
  - Clay
  - Silt
  - Organic material
  - Other particulates
- Esthetic Appeal
- May increase temperature of water!



Omer 2020; USGS 2024

Temperature

- Measure of how hot or cold the water is
- Affects taste, viscosity, solubility
- Influences other chemical and biological parameter
- Specifically affects Dissolved Oxygen!



Omer 2020; Dugdale et al. 2018

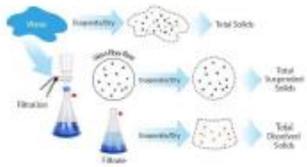
Color

- Color change can occur from decayed matter
- Apparent color
  - Entire water sample color containing dissolved and suspended substances
- True color
  - Measured after filtering the water sample to remove suspended material
- Affects esthetical appeal

Omer 2020; Maris 2024

Total Suspended Solids (TSS)

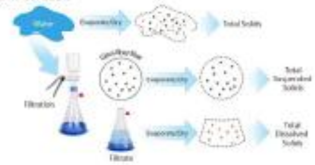
- Solids suspended in solution
  - Sediments
  - Organic matter
- Increased solids can increase turbidity



Omer 2020; Rocker 2023

Total Dissolved Solids (TSS)

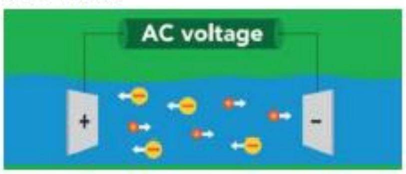
- Organic and inorganic solids dissolved in solution
- Can include various minerals
  - Calcium
  - Magnesium
  - Zinc



Omer 2020; Rocker 2023

Conductivity

- Ability of water to carry or conduct an electrical current via ions
- Can be used to estimate TDS

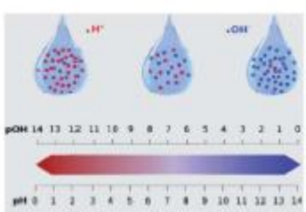


Omer 2020; Atlas Scientific 2021

Water Quality – Chemical Indicators

pH

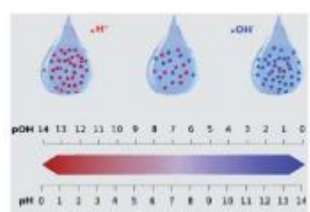
- Measures of how acidic or basic the water is
- Excessively high or low pH can affect:
  - Taste
  - Organisms
  - General health of water



Omer 2020

Alkalinity

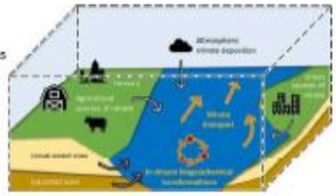
- Acid-neutralizing capacity of the water
- Necessary to determining how to "soften" water for consumption and domestic use



Omer 2020

Nitrogen (Nitrates)

- Indicator or sewage and fertilizer
- Basic nutrient for the growth of plants



Omer 2020; Matiatos et al. 2023

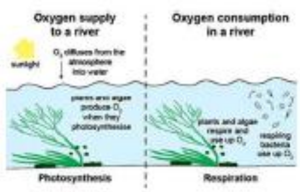
Phosphorus (Phosphates)

- Nutrient that affects algal growth
- Indicator of sewage and fertilizer

Omer 2020

Dissolved Oxygen (DO)

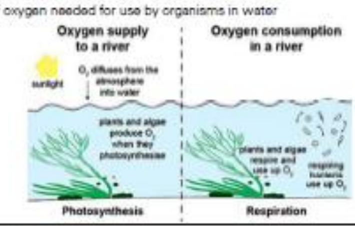
- Amount of oxygen dissolved in water and available for use by organisms
- Directly affected by temperature
- No direct effect on public health
- Can affect taste
- Main indicator of water quality and pollution



Omer 2020; QMUL 2024

Biochemical Oxygen Demand (BOD)

- The amount of oxygen needed for use by organisms in water



Omer 2020; QMUL 2024

Water Quality – Biological Indicators

Fecal Coliform

- Bacteria
- Can cause gastroenteritis
- From both animals and humans

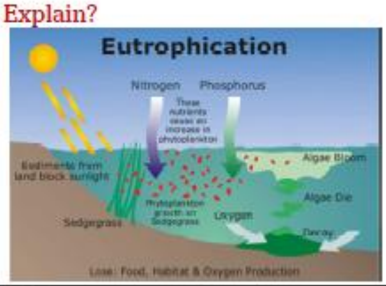
Omer 2020; Xu 2022

Algae (Chlorophyll)

- Microscopic plants that contain chlorophyll
- Nuisance organisms
- Can cause environmental and public health issues

Omer 2020; Wells and Kudela 2024

Can You Explain?



Omer 2020; OSPAR 2024

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Appendix B: Water Quality Index Calculator Slideshow

Whittington Quality Index Calculator

Holly Whittington

Water Quality Index (WQI)

- Water quality is split into "Ranges" like a grade on an assignment:
  - 90-100 Excellent!
  - 70-90 Good
  - 50-70 Medium
  - 25-50 Bad
  - 0-25 Very Bad

Per the EPA:

- WQI scores from ***80-100 indicate high water quality***, meaning that water quality rarely exceeds guidelines, and if so, only by a narrow margin.
- WQI scores from ***70-79 indicates fair or marginal water quality***, that sometimes exceeds guidelines, possibly by a wide margin.
- WQI scores below ***69 indicate poor water quality*** that often exceeds guidelines by a wide margin.

EPA 2021

What does this mean?

ABSTRACT: Various authorities and regulating agencies have set standards for deciding the suitability of a water for drinking purposes. These standards prescribe the permissible concentrations of quality variables. When some variables exceed the permissible levels, a decision for permitting further use of the water supply has to be based on the importance of those variables with exceeded concentrations. It is proposed that standards for a drinking water supply should be set through a single number representing the integrated effect of all the variables, keeping due regard to the importance of each variable. Such an integrated water quality index (WQI) would help in decision making. Models and curves have been presented to evolve a WQI for drinking water supplies. It is suggested that water with a WQI lower than 90 should not be permitted. The acceptable quality therefore, should be in the 90–100 range of the WQI.

Bhargave 1985

Which indicator is most important?

These are the parameters we can test with available supplies. Decide with your group which is most important and why?

- Temperature
- pH
- TDS
- Turbidity
- Nitrates
- DO
- Ammonia/Fecal Matter

Omer 2020; Matiatos et al. 2023

Whittington WQI Suggested Breakdown

Test	Class Median Test Results	Q-Value	Weighting Factor	Total
1. DO	% saturation		0.17	
2. Fecal coliform	col/ 100 mL		0.16	
3. pH			0.11	
4. BOD	ppm		0.11	
5. Temperature	°C		0.10	
6. Total Phosphate	ppm		0.10	
7. Nitrates	ppm		0.10	
8. Turbidity	ft inches		0.08	
9. Total Solids	ppm		0.07	
Q-Values and WQI Ranges 90-100 = Excellent 70-90 = Good 50-70 = Medium 25-50 = Bad 0-25 = Very Bad				WQI =

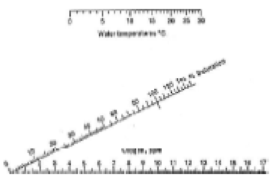
Let's tweak this! You decide how to redistribute… but be able to defend your answer!

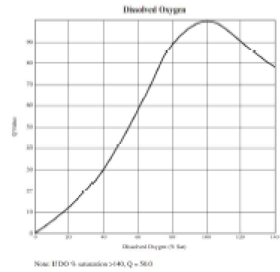
WQI Calculation Chart

Test	Class Median Test Results	Q-Value	Weighting Factor	Total
1. DO	% saturation		0.17	
2. Fecal coliform	col/ 100 mL		0.16	
3. pH			0.11	
~~4. BOD~~	~~ppm~~		0.11	
5. Temperature	°C		0.10	
~~6. Total Phosphate~~	~~ppm~~		0.10	
7. Nitrates	ppm		0.10	
8. Turbidity	ft inches		0.08	
9. Total Solids	ppm		0.07	
Q-Values and WQI Ranges 90-100 = Excellent 70-90 = Good 50-70 = Medium 25-50 = Bad 0-25 = Very Bad				WQI =

Use Average Q Values

Step 1: Convert ppm to Percent Saturation





Step 2: Plug into chart

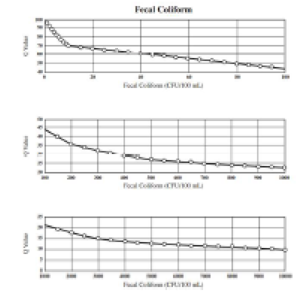
Opresn et al. 2008; Flinn 2018

Ammonia/Fecal Coliform

Step 1:

PPM x 1000 = CFU/100 mL

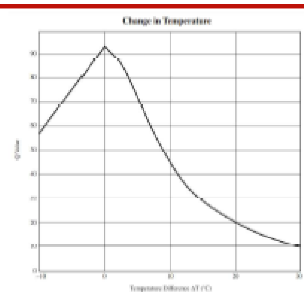
Plug into graph!



Flinn 2018

pH

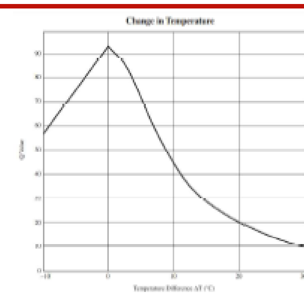
- Step 1: Plug into chart



Flinn 2018

Temperature

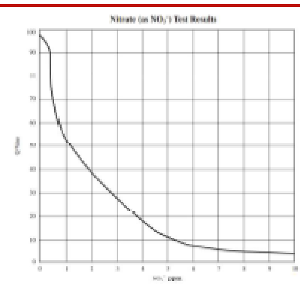
- Step 1: Plug into chart



Flinn 2018

Nitrates

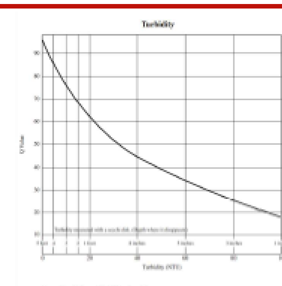
- Step 1: Plug into chart



Flinn 2018

Turbidity

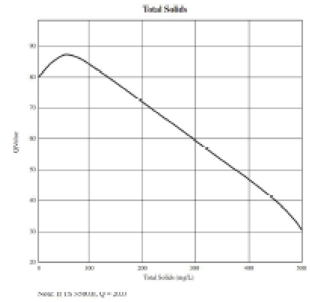
- Step 1: Plug into chart



Flinn 2018

Total Dissolved Solids

- Step 1: Plug into chart



Flinn 2018

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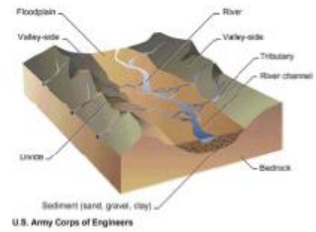
Appendix C: Stream Order and River Continuum Slideshow

Stream Order and River Continuum

Holly Whittington

Introduction

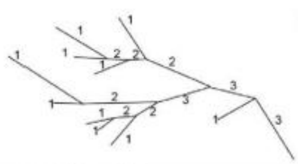
- Stream order categorizes streams based on their position in a basin
- River Basins are areas of land where all water drains to a common river
- Tributaries are rivers or streams that flow into a larger body of water



Horton 1945; Scheidegger 1968; Islam T., Ryan J. 2016

Strahler Stream Order

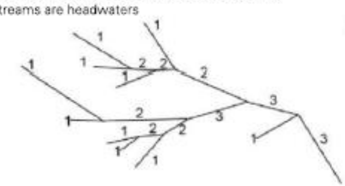
- Tributaries that do not branch are assigned 1st order.
- When two first order streams meet, they form a 2nd order.
- Two 2nd order streams join to form a 3rd order, etc.



Strahler 1952; Scheidegger, 1968; Hodgkinson 2009

Global Distribution of Stream Order

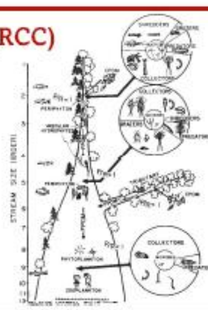
- Headwater streams are identified as 1st – 3rd order streams
- 99.1% of all streams are headwaters



Downing et al., 2012; Richardson 2019; Hodgkinson 2009

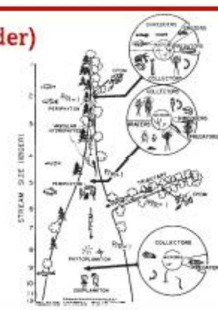
The River Continuum Concept (RCC)

- Developed to describe how a stream's physical characteristics shape biological communities as it flows
- Includes stream order, ecosystem structure, flow of energy



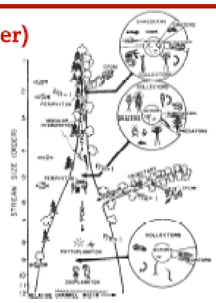
Headwaters (1^{st} – 3^{rd} stream order)

- Narrow
- Shaded with limited sunlight
- Lots of organic matter (leaf litter)
- Limited photosynthesis



Headwaters (1st – 3rd stream order)

- Biological Communities Include:
  - Macroinvertebrates
    - Shredders
    - Predators
    - Collector-filters
  - Fish
    - Insectivores



Sitati et al., 2024; Vannote et al., 1980

Mid Order Streams (4th-6th order)

- Wider streams
- Increased sunlight
- Less shade
- Less leaf litter
- Increased photosynthesis
  - Algae and aquatic plants contribute
- More grazers and collectors
- Increased fish diversity

Zaimes et al., 2007

Large Rivers (7th+ order)

- Broad
- Slow-moving water
- Flat land
- Increased turbidity and reduce photosynthesis
- Steady presence of collectors and predators
- Larger, more diverse fish species

Zaimes et al., 2007; Paller 1994.

Sources

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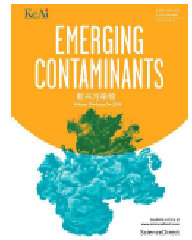
Appendix D: Emerging Contaminants and Forever Chemicals Slideshow

Emerging Contaminants and Forever Chemicals

Holly Whittington

Introduction: Emerging Contaminants

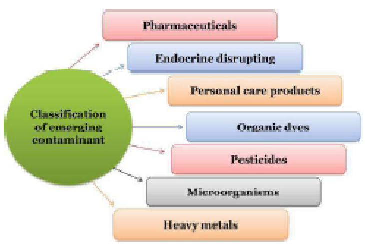
- Definitions
  - Chemicals or materials that have been identified as potential threats due to increasing research
  - Substances that have been recently recognized as posing environmental risks but may not yet be regulated



USGS 2019a; Yu and Harrad 2024.

Sources of Emerging Contaminants

- Agricultural Runoff (pesticides and fertilizers)
- Wastewater and sewage
- Pharmaceuticals
- Personal Care Products



USGS 2019a; Mahmood et al. 2022

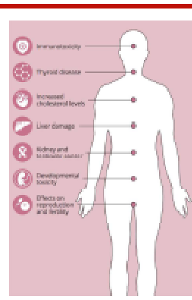
Forever Chemicals: PFAS

- PFAS (per-and polyfluoroalkyl substances
- Highly durable chemicals that do not break down in the environment
- Can travel long distances through different mediums and accumulate in human tissues
- Considered "forever chemicals" because they do not break down
- Useful in a wide variety of products

Glüge et al. 2020; EPA. 2024d

Impact of PFAS

- PFAS persists in water, leading to contamination of drinking water
- PFAS contamination has been documented across the U.S. in surface water systems
- Can cause human health Issues:
  - Cancer
  - Immune System damage
  - Developmental effects
  - Immune system and kidney disorders



Anderko and Pennea 2020; EPA 2023; Brunn et al. 2023

Protection Efforts: Maximum Contaminant Levels

- The highest concentration level a contaminant is allowed to be in drinking water
- Legally enforced
- Created using cost benefit analysis and reasonable enforcement expectations

Compound	Final MCL
PFOA	4.0 ppt
PFOS	4.0 ppt
PFHxS	10 ppt
GenX	10 ppt
Mixtures containing two or more of above	1 (unitless) Hazard Index*

Ramasamy et al. 2015; EPA 2024d

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