PEER One Health Curriculum	
Leader Guide	**Ecology: Antimicrobial Resistance in Water**

Summary: This One Health module delves into the intricate world of antibiotic resistance within water ecosystems. Middle school students will embark on a learning journey to comprehend the importance of antibiotic resistance and its repercussions for human, animal, and environmental well-being. Engaging activities, enlightening discussions, and in-depth research will foster a comprehensive understanding of this critical subject.

Keywords: antibiotic resistance, bacteria, One Health, water ecosystems, pollution, pathogens, environmental health

Subject TEKS:

- Biology - The student understands the interdependence and interactions within an environmental system.
- 7.10 (A) observe and describe how different environments, including microhabitats in schoolyards and biomes, support different varieties of organisms

Grade Level: 6th - 9th

Learning Objectives:

1. Define antibiotic resistance.
2. Explain the concept of One Health and its relevance to antibiotic resistance.
3. Identify sources and pathways of antibiotic resistance in water ecosystems.
4. Understand the potential consequences of antibiotic resistance for human and animal health.
5. Develop strategies to address and prevent antibiotic resistance in water ecosystems.

Time Required: This module spans three to four 45-minute class periods.

Materials:

- Devices with internet access
- Water testing kits
- Handouts on antibiotic resistance
- Bingo materials and cards
- Poster-making materials
- Markers, sharpies, art supplies

PEER One Health Curriculum	
Leader Guide	**Ecology: Antimicrobial Resistance in Water**

Background and Concepts for Teachers:

Antibiotic resistance, the ability of pathogens to withstand the drugs intended to eliminate them, is a critical global issue that affects multiple facets of life. Antibiotics, while essential for saving lives, carry the risk of causing side effects and contributing to the development of antibiotic resistance. This resistance can make infections challenging to treat, and it can spread among various pathogens, even in the absence of direct antibiotic exposure.

Antibiotic resistance is a One Health concern, meaning it affects the interconnected realms of animals, the environment, and public health. It's worth noting that antibiotic-resistant pathogens and their genetic traits have been detected in essential water sources such as streams, rivers, lakes, and oceans. These pollutants often originate from sources like hospitals, farms, or sewage systems. Even functional wastewater treatment systems may not completely eliminate resistant pathogens and their genes from the water supply.

Biofilms, which are communities of organisms living on surfaces, have been identified as an important vector for antibiotic resistance transmission. They offer an ideal habitat for antibiotic-resistant bacteria and the sharing of resistance genes. Researchers have developed innovative solutions, such as the application of phages (viruses targeting specific bacteria), to disintegrate biofilms, thus preventing the transmission of resistant bacteria, particularly in healthcare plumbing systems.

Even when resistant bacteria enter wastewater through plumbing systems, their impact extends to the environment. Antibiotic-resistant bacteria and their genes can persist in surface water, river sediment, and wildlife. This persistence underscores the importance of infection prevention, control, and antibiotic stewardship in healthcare facilities, communities, and farms to mitigate the spread of antibiotic resistance.

Antibiotics don't only enter water through wastewater systems; they can also infiltrate water sources through discharges from pharmaceutical companies, healthcare facilities, and human waste. This discharge can exert selective pressure on waterborne bacteria, fostering the development of resistance. Inadequate sewage infrastructure in certain areas further complicates the control and monitoring of resistance development.

Antibiotic resistance is intricately tied to ecology, reflecting the profound interplay between human activities, microbial communities, and the environment. Antibiotics, when released into ecosystems through various means, exert selective pressures on bacteria, fostering the emergence of resistance traits. These antibiotic-resistant bacteria, along with their resistance genes, circulate through ecological networks, affecting not only human health but also wildlife and environmental microorganisms. The shared genetic pool of resistance elements among diverse bacterial populations demonstrates the dynamic nature of antibiotic resistance in ecological

contexts. As these resistant organisms spread and adapt within ecosystems, they can potentially compromise the ecological balance and even contribute to the transmission of resistance between species. Understanding the ecological dimensions of antibiotic resistance is crucial for effective strategies to mitigate its impact and safeguard both public health and the integrity of our natural surroundings.

Vocabulary / Definitions:

1. Antibiotic resistance: The ability of pathogens to withstand the effects of antibiotics designed to combat them, making infections harder to treat.
2. Pathogens: Microorganisms that can cause disease in humans, animals, or plants.
3. Biofilms: Complex communities of microorganisms living on surfaces, which can provide an ideal habitat for antibiotic-resistant bacteria.
4. Phages: Viruses that can target and kill specific bacteria, potentially aiding in the elimination of antibiotic-resistant bacteria in biofilms.
5. Bioremediation: The use of microorganisms to clean up or mitigate pollution, including antibiotic resistance, in aquatic environments.
6. Microbiome: The collection of microorganisms, including bacteria, that inhabit a particular environment or organism, like the water microbiome.
7. Selective pressure: Conditions that favor the survival and proliferation of antibiotic-resistant bacteria, such as the presence of antibiotics in water.
8. Biodegradation: The breakdown and decomposition of organic materials, including antibiotics, by microorganisms in water.
9. Ecotoxicology: The study of the effects of pollutants, including antibiotics and antibiotic-resistant bacteria, on aquatic ecosystems and their organisms.

Lesson Introduction/Motivation:

Begin the lesson by illustrating the concept of One Health with this simple colored water activity:
https://www.canr.msu.edu/animal_science/uploads/files/4H1690_AnimalScienceAnywhere-Careers_NEW.pdf

One Health Introduction Introduce the notion of One Health, underscoring the interrelatedness of human, animal, and environmental health. Explain how antibiotic resistance is a prime instance of a One Health issue because it affects all three domains.

PEER One Health Curriculum	
Leader Guide	**Ecology: Antimicrobial Resistance in Water**

Leaders could then introduce the ideas of water quality and One Health to their classes by watching the College Station news about a water crisis in College Station during the summer of 2022.
https://www.kbtx.com/2022/07/14/wellborn-sud-issues-boil-water-notice-implements-stage-5-water-conservation/

After watching, students discuss if they have ever encountered a similar situation and what their families did. How might this issue impact humans or the environment? How does boiling water help? Encourage students to think of issues beyond illness.

Exploration/Explanation: Day 1
Introduction to Ecology and Antibiotic Resistance
Embark on our journey to understand antibiotic resistance in water ecosystems. To set the stage, we will explore the fundamental concepts, standards, and the One Health approach through our Essential Knowledge - "Ecology" module. This exploration can be undertaken as a whole group, in small groups, with partners, or as an individual activity.

- **Essential Knowledge: Ecosystem Organization,** slides 1 – 4 "Ecology", "Ecosystem", "Biotic Factors", and "Abiotic Factors'
- **"Living or Nonliving Knowledge Check" -** (use as whole group activity, or create friendly competition – boys v. girls, etc.)
- **Essential Knowledge: "Biomes"**, slide 1 & 19 – 20 "Biomes", "Aquatic Biomes", "Freshwater"

Antimicrobial Resistance (AMR) in Water
Introduce the concept of antimicrobial resistance by showing the following video.
https://www.youtube.com/watch?v=HZ4udzNJbrs

- Discussion: Following the video ask students to summarize what they learned. Then have them explain the connections between antimicrobial resistance, ecology, and One Health. This could be a great place to incorporate the use of a Venn diagram.

Sources of antimicrobial resistance: Have students study the illustration (https://pubs.acs.org/cms/10.1021/acs.est.1c08918/asset/images/large/es1c08918_0001.jpeg) and list all the sources of antimicrobial resistance they see. Discuss why each one might be a source of antimicrobial resistance in water.

PEER One Health Curriculum	
Leader Guide	**Ecology: Antimicrobial Resistance in Water**

Elaborate: Day 2

Case Study: Friends of the Old (FOTO)

Per the World Health Organization's data, an estimated 2.2 billion individuals across the globe continue to face challenges in securing consistent access to safe drinking water. American Society for Microbiology member Bob Metcalf has harnessed fundamental microbiological techniques to create an uncomplicated, affordable procedure aimed at identifying and eradicating E. coli contamination from water supplies. Bob works closely with the organization Friends Of the Old (FOTO) to share this approach within the Lower Nyakach communities in Kenya. This initiative empowers local residents to take on the role of microbiologists, enabling them to proactively combat waterborne diseases and their transmission.

- **Video: " Microbiology Is ... Safe Drinking Water"** https://www.youtube.com/watch?v=zoPzpM3ymx0
- Discussion: What possible sources of contamination did you see in the video? Could these sources also promote antimicrobial resistance? How or Why? How could antimicrobial resistance magnify illnesses related to contaminated water? What are the people of Lower Nyakach doing to protect themselves from contaminated water? What else could they do?

Water Testing Lab - test kits are widely available; some sources are included below.

- **https://www.acornnaturalists.com/products/field-equipment-supplies/sampling-testing-equipment/water-quality-testing/water-quality-test-kits.html**
- **https://www.carolina.com/environmental-science-water-quality/carolina-bacterial-pollution-of-water-kit/652704.pr?question=water+test+kits+bacteria**
- **https://www.wardsci.com/store/product/25214751/lamotte-total-coliform-test-kit**

- Prior to beginning the lab, have students watch the introductory video for the Water Testing Interactive Lab (https://conserve.nmsu.edu/conserve-testing-app/index.html). This will provide background information on how water is tested and the meaning behind the results found.
- The leader will either need to acquire water samples from various clean and potentially polluted sources or create water samples by adding contaminants such as dishwashing detergent, fertilizer, and/or decaying organic matter (leaf litter)

- Students will follow the instructions specific to the water testing kit provided and then answer the questions on the accompanying worksheet (note: not all water testing kits test for the same contaminants, you may need to adjust data collection and analysis based on the test kit available).
    - o water testing lab.docx

Water Testing Virtual Lab

If water testing kits are not available, students can take part in an online water testing simulation found here: https://conserve.nmsu.edu/educational-suppliment/water-testing-rem.pdf This activity is also great preparation for the in class lab.

Assessment/Evaluation:

- **Antibiotic Resistance Bingo**

  Materials:

  1. Antibiotic Resistance Bingo cards
  2. Bingo markers (small tokens or stickers)
  3. Prizes (optional)
  4. Whiteboard and markers

  Instructions:

  Setup:

  1. Each student receives a different antibiotic resistance bingo card.

  Game Rules:

  1. Explain the game to the students. Each scenario on the bingo card represents a situation related to antibiotic resistance.
  2. Instruct the students that as you read aloud different scenarios from a list (corresponding to the cells on their bingo cards), they should mark off the matching scenario on their card if they have it.
  3. The first student to complete a row, column, or diagonal on their bingo card shouts "Bingo!" and wins a prize if you choose to offer one.
  4. After a round, discuss the scenarios that were called out, focusing on how each situation relates to antibiotic resistance and its effects on humans, animals, or the environment.
  5. Play multiple rounds with different bingo cards to reinforce learning and understanding.

  Discussion:

6. After playing several rounds, lead a group discussion to recap what the students have learned about antibiotic resistance and how it affects various aspects of One Health (humans, animals, and the environment).

- **Quiz or Kahoot!:** Create a quiz or interactive Kahoot! game with multiple-choice questions, true/false questions, and short-answer questions related to antibiotic resistance in water. Middle schoolers can answer questions individually or in teams to test their