Wastewater Testing and Treatment

High School Chemistry - Grades 10-12

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# Curriculum Overview

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| Stage 1: Desired Results |
| MA State StandardsMA STE Standards: HS-ESS3-1, HS-ESS3-3, HS-ETS1-3MA STE Standards: HS-PS1-2, HS-ESS3-3MA STE Standards: HS-ESS3-4, HS-ETS1-1MA STE Standards: HS-PS2-6, HS-ETS1-3MA STE Standards: HS-ESS3-3, HS-ETS1-4 | ***Essential Questions**** How does wastewater treatment help protect the environment and public health?
* What chemical processes are involved in wastewater treatment?
* How can we apply chemical principles to improve wastewater treatment efficiency?
* What role do chemistry and environmental science play in sustainable wastewater management?
* How can we use analytical techniques to monitor and assess water quality?
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| * ***Enduring Understandings***
* Wastewater treatment is essential for protecting the environment and human health by removing pollutants and contaminants.
* Chemical reactions play a critical role in the treatment of wastewater to transform and remove harmful substances.
* Applying chemistry principles and analytical techniques can lead to more effective and sustainable wastewater treatment solutions.
* Wastewater management is a multidisciplinary effort that involves collaboration among scientists, engineers, and policymakers.
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| ***Students will be able to..**** Apply knowledge of chemical reactions to understand and explain the processes involved in wastewater treatment.
* Analyze and interpret water quality data to assess the effectiveness of wastewater treatment methods.
* Design and propose innovative solutions to improve wastewater treatment processes based on chemical principles.
* Recognize the importance of environmentally responsible practices and the role of chemistry in addressing real-world challenges.
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| Stage 2: Evidence |
| ***Formative Assessment ideas:**** Class discussions and debates on wastewater-related topics.
* Quizzes and short assessments after each lesson to gauge understanding.
* Analyzing and interpreting data from water quality experiments.
* Peer reviews of proposed solutions in the culminating project.
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| ***Summative Assessment ideas:*** * A written report or presentation on the chemical processes involved in wastewater treatment and their environmental impacts.
* A water quality assessment project, where students analyze real water samples and propose treatment methods.
* The culminating group project where students design and present their improved wastewater treatment systems.
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| Lesson 1: Overview |
| ***Lesson Overview:**** This lesson serves as a foundational introduction to the concept of wastewater and its significance in environmental and public health.
* Students will explore the sources of wastewater and the different types of pollutants commonly found in it.
 | Lesson Objectives: *At the end of the unit, students will be able to…** Define wastewater and identify its sources.
* Describe common pollutants found in wastewater and their potential environmental and health impacts.
* Explain the importance of maintaining water quality for environmental protection and public health.
* Analyze case studies of waterborne diseases and identify factors contributing to their outbreak.
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| ***Standards:**** HS-ESS3-1: Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes.
* HS-ESS3-3: Create a computational simulation to illustrate the relationships among the management of natural resources, the sustainability of human populations, and biodiversity.
* HS-ETS1-3: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.
 | Timing:* *1 class period – 60-90 minutes*
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| Materials:* List of common wastewater sources for each group.
* Research materials, such as textbooks, library computers, or iPads, to find examples of pollutants associated with each wastewater source.
* Lesson 1 - Handout - Case studies of outbreaks of waterborne diseases caused by contaminated water.
 | Assessment: * Engage students in discussions about wastewater sources and water quality issues.
* Pose questions to gauge students' comprehension of the presented material.
* Divide students into groups to analyze case studies and present their findings to the class.
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| Activity  | *Procedure* |
| Wastewater Sources Scavenger Hunt | * Divide students into groups and provide them with a list of common wastewater sources (households, industries, agricultural fields).
* Instruct each group to research and find examples of specific pollutants associated with each source.
* Groups present their findings to the class, and discussions are held on the potential impact of these pollutants on water quality.
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| Case Studies of Waterborne Diseases | * Provide students with case studies of outbreaks of waterborne diseases caused by contaminated water.
* Students analyze the causes, consequences, and preventive measures taken to address the outbreaks.
* Engage in a class discussion about the importance of clean water for public health.
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| Lesson 1: Tips, Strategies, and Suggestions |
| ***Instructional Tips for Teachers:**** Encourage critical thinking and class participation through open-ended questions.

Relate the importance of water quality to broader environmental and public health issues.***Science Objectives:**** Understand the sources and characteristics of wastewater.
* Recognize the significance of water quality for environmental protection and public health.

***Language Objectives:**** Use appropriate scientific vocabulary to describe wastewater and water quality concepts.
* Present and communicate findings from case studies effectively.

***Targeted Academic Language/Vocabulary:**** Wastewater, influent, effluent, pollutants, contaminants, water quality, sanitation, waterborne diseases, industrial discharges, agricultural runoff.

***Anticipated Student Misconceptions:**** Assuming that wastewater only comes from domestic sources and not understanding industrial and agricultural sources.
* Confusing wastewater treatment with water purification, thinking that all wastewater can be immediately converted to clean drinking water.
* Underestimating the impact of poor water quality on the environment and human health.
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| Lesson 2: Overview |
| Lesson Overview:* This lesson is an exploration of the chemical processes applied in wastewater treatment.
* Students will learn about the different stages of treatment, namely primary, secondary, and tertiary treatment methods.
 | Lesson Objectives: *At the end of the unit, students will be able to…** Differentiate between primary, secondary, and tertiary wastewater treatment methods.
* Identify and describe key chemical processes used in each treatment stage (sedimentation, biological treatment, chemical disinfection).
* Explain the role of chemical reactions (precipitation, coagulation, flocculation, chlorination) in the removal of contaminants from wastewater.
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| Standards:* HS-PS1-2: Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.
* HS-ESS3-3: Create a computational simulation to illustrate the relationships among the management of natural resources, the sustainability of human populations, and biodiversity.
* HS-ETS1-3: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.
 | Timing:* 2 – 3 class periods at 60 minutes each
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| Materials:* Pictures illustrating the various stages of wastewater treatment and the chemical reactions involved in each stage.
* Samples of common chemicals used in wastewater treatment (alum, chlorine) for demonstrations or hands-on activities.
* Laboratory equipment:
	+ Beakers or clear plastic containers
	+ Wastewater samples (can be prepared by adding small amounts of suspended particles or food coloring to water)
	+ Various chemicals (alum, calcium chloride) for flocculation
	+ Stirring rods
	+ Stopwatch or timer
	+ Safety goggles
* Lesson 2 - Handout - Chemical Processes in Wastewater Treatment
* Lesson 2 - Handout - Case Studies of Wastewater Treatment Success Stories
 | Assessment: * Engage students in discussions about the chemical processes used in wastewater treatment and their significance.
* Observe students' participation and understanding during hands-on activities or demonstrations.
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| Activity  | *Procedure* |
| Hands-on Flocculation Experiment | * Divide students into small groups and provide each group with a container of a wastewater sample.
* Instruct each group to test different chemicals for flocculation. They should add small amounts of each chemical to their samples and stir gently.
* Start the stopwatch and observe the formation of flocs in each container.
* After a designated time (5 minutes), have students compare the effectiveness of different chemicals in promoting flocculation.
* Engage in a class discussion about the significance of flocculation in wastewater treatment and its role in removing suspended particles.
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| Analyzing Chemical Equations in Wastewater Treatment | * Provide each student with a handout containing chemical equations representing different chemical processes used in wastewater treatment (precipitation, chlorination).
* Instruct students to analyze each equation and identify the reactants, products, and key chemical species involved.
* Encourage students to explain how each reaction contributes to pollutant removal or water treatment.
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| Case Studies of Wastewater Treatment Success Stories | * Divide students into groups and provide each group with a different case study.
* Instruct the groups to research and analyze the case studies, focusing on the chemical processes and innovative solutions used in each successful wastewater treatment project.
* Have each group present their case study to the class, highlighting the chemical principles that contributed to the success of the treatment.
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| Lesson 2: Tips, Strategies, and Suggestions |
| ***Include tips, strategies, and suggestions Instructional Tips for Teachers:****Use visual aids and real-life examples to illustrate the chemical processes effectively.**Incorporate interactive activities to engage students actively in the learning process.**Encourage students to connect the chemical reactions in wastewater treatment to broader environmental implications.****Science Objectives:****Understand the chemical processes involved in primary, secondary, and tertiary wastewater treatment.**Recognize the role of chemical reactions in the removal of contaminants from wastewater.****Language Objectives:****Use accurate scientific vocabulary to describe the chemical processes and reactions in wastewater treatment.**Explain the connections between chemical principles and the effectiveness of wastewater treatment methods.****Targeted Academic Language/Vocabulary:****Primary, secondary, tertiary treatment**Sedimentation, biological treatment, chemical disinfection**Precipitation, coagulation, flocculation, chlorination****Anticipated Student Misconceptions:****Assuming that all pollutants can be removed through a single stage of treatment.**Confusing the roles of different treatment stages, such as mistaking coagulation for flocculation.**Believing that chemical treatment alone can eliminate all pollutants, without considering other treatment processes.* |

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| Lesson 3: Overview |
| Lesson Overview:* In this lesson, students will delve into the significance of sustainable wastewater management.
* The focus is on eco-friendly treatment techniques that align with principles of sustainability.
 | Lesson Objectives: *At the end of the unit, students will be able to…** Explain the concept of sustainable wastewater management and its importance for environmental protection and resource conservation.
* Identify and describe eco-friendly treatment techniques such as phytoremediation and bioremediation used for pollutant removal in wastewater.
* Discuss the concept of water reuse and its role in sustainable water resource management.
* Analyze and compare the environmental impact of different wastewater treatment approaches and propose more sustainable solutions.
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| Standards:* HS-ESS3-3: Create a computational simulation to illustrate the relationships among the management of natural resources, the sustainability of human populations, and biodiversity.
* HS-ESS3-4: Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
* HS-LS2-7: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.
 | Timing:* 2 – 3 class periods at 60 minutes each
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| Materials:* Lab equipment:
	+ Clear plastic containers or aquariums
	+ Contaminated water samples (can be prepared in advance or sourced from a local water source)
	+ Various aquatic plants known for phytoremediation (water hyacinth, duckweed, cattails)
	+ Water testing kits (optional but beneficial to monitor water quality changes)
	+ Safety goggles
* Flipchart or whiteboard
* Markers
* Debate topic cards (pre-prepared cards with different wastewater treatment approaches, both conventional and sustainable)
* Timer
* Lesson 3 – Debate Topic ideas
 | Assessment: * Engage students in group discussions about the environmental impact of different wastewater treatment methods and their sustainability.
* Group presentation analysis
* Debate debrief
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| Activity  | *Procedure* |
| Phytoremediation experiment | * Divide students into small groups and provide each group with a container of contaminated water sample.
* Instruct each group to place different aquatic plants in their containers and set up a controlled experiment to observe the effectiveness of phytoremediation.
* Monitor the containers over several days or weeks, noting any visible changes in water quality, such as reduced turbidity or changes in color.
* If possible, use water testing kits to analyze water parameters before and after the phytoremediation process.
* Have each group present their findings and discuss the role of plants in removing contaminants from the water.
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| Water Reuse Brainstorming Session | * Conduct a brainstorming session with the whole class on the concept of water reuse and its importance in sustainable wastewater management.
* Use the flipchart or whiteboard to record students' ideas, suggestions, and potential applications for water reuse in various sectors (agriculture, industry, urban landscaping).
* Engage students in discussions about the challenges and benefits of water reuse, including its impact on resource conservation and environmental sustainability.
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| Environmental Impact Debate | * Divide the class into two groups: one group representing conventional wastewater treatment methods and the other group representing sustainable wastewater management approaches.
* Provide each group with a debate topic card, outlining the specific treatment approach they will be representing.
* Set a timer and allow each group to present their arguments, focusing on the environmental impact and sustainability of their assigned method.
* Encourage respectful and well-reasoned arguments from both groups, fostering critical thinking and understanding of different perspectives
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| Lesson 3: Tips, Strategies, and Suggestions |
| ***Instructional Tips for Teachers:****Encourage students to think critically about the environmental consequences of various wastewater treatment methods and propose alternative sustainable solutions.**Facilitate group discussions to promote active learning and peer-to-peer interaction.**Relate sustainable wastewater management to broader environmental issues and the importance of resource conservation**.****Science Objectives:****Understand the concept of sustainable wastewater management.**Explore eco-friendly treatment techniques like phytoremediation and bioremediation for pollutant removal.****Language Objectives:****Use appropriate scientific vocabulary to describe sustainable wastewater management techniques and environmental impacts.**Present and communicate findings from case studies effectively.****Targeted Academic Language/Vocabulary:****Sustainable wastewater management**Phytoremediation, bioremediation**Water reuse, reclaimed water**Pollutant removal, resource conservation****Anticipated Student Misconceptions:****Assuming that conventional wastewater treatment methods are inherently sustainable and do not require further exploration of eco-friendly alternatives.**Misunderstanding the concept of water reuse and its role in water resource conservation.**Overlooking the importance of considering the environmental impact of various wastewater management approaches.* |

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| Lesson 4: Overview |
| Lesson Overview:* This lesson focuses on the essential tools and techniques used in assessing water quality.
* Students will learn about various analytical methods, including spectrophotometry and chromatography, that enable scientists to measure specific water quality parameters accurately.
 | Lesson Objectives: *At the end of the unit, students will be able to…** Identify and describe various analytical techniques used in water quality assessment.
* Conduct water quality tests using spectrophotometry and chromatography.
* Interpret and analyze water quality data to evaluate the health of a water body.
* Understand the significance of accurate water quality monitoring in effective wastewater management.
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| Standards:* HS-ESS3-3: Create a computational simulation to illustrate the relationships among the management of natural resources, the sustainability of human populations, and biodiversity.
* HS-ESS3-4: Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
* HS-ETS1-3: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.
 | Timing:* 3 – 4 class periods at 60 minutes each
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| Materials:* Lab equipment:
	+ Water quality testing kits (pH, dissolved oxygen, nitrate, phosphate, etc.)
	+ Spectrophotometers
	+ Sample water sources (freshwater, polluted water, wastewater)
	+ Chromatography paper or filter paper strips
	+ Water samples with different contaminants (food coloring, ink, pollutants)
	+ Capillary tubes or pipettes
	+ Solvent (water or rubbing alcohol)
	+ Safety goggles
* Data sheets from Activity 1 with water quality measurements
* Water quality standards or guidelines (from environmental agencies or health departments)
 | Assessment: * Observing students' engagement and accuracy during hands-on water quality testing.
* Reviewing students' data sheets and analysis of water quality measurements.
* Conducting class discussions to gauge students' comprehension of the implications of water quality readings.
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| Activity  | *Procedure* |
| Water Quality Testing with Spectrophotometry | * Divide students into small groups and provide each group with a water quality testing kit and a sample of water from different sources.
* Instruct students to use the testing kit to measure various water quality parameters, such as pH, dissolved oxygen, nitrate, and phosphate levels.
* For more accurate readings, guide students in using the spectrophotometer to measure specific parameters.
* Have students record their observations and data on data sheets.
* Engage the class in discussions about the implications of the water quality measurements and how they relate to the health of the water bodies.
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| Chromatography Experiment | * Explain the principle of chromatography to the students and demonstrate how it separates components of a mixture based on their affinity for the chromatography paper and solvent.
* Provide each student with a chromatography paper strip and a capillary tube or pipette.
* Instruct students to place a small sample of a contaminated water source (food coloring) on the chromatography paper, slightly above the water level.
* Dip the chromatography paper in the solvent, making sure the sample spot does not touch the solvent.
* Allow the solvent to travel up the paper, separating the components of the sample.
* Have students analyze and interpret the chromatograms, identifying the different components present in the water samples.
 |
| Data Analysis and Water Quality Assessment | * Instruct students to analyze the data collected in Activity 1, comparing the water quality measurements for different samples.
* Provide water quality standards or guidelines, and have students compare their data with these standards to assess the health of the water sources.
* Engage students in discussions about the implications of the data, such as potential pollution sources or environmental impacts.
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| Lesson 4: Tips, Strategies, and Suggestions |
| **Instructional Tips for Teachers:***Prioritize safety during hands-on activities involving chemicals and equipment.**Provide clear instructions on using spectrophotometers and chromatography equipment.**Encourage students to ask questions and make connections between water quality data and the overall health of the environment.***Science Objectives:***Understand various analytical techniques used in water quality assessment.**Gain practical experience in conducting water quality tests and interpreting data.***Language Objectives:***Use scientific vocabulary to describe water quality parameters and analytical methods.**Communicate findings and interpretations of water quality data effectively.***Targeted Academic Language/Vocabulary:***Spectrophotometry**Chromatography**Water quality parameters (pH, dissolved oxygen, turbidity)**Data analysis**Water quality assessment***Anticipated Student Misconceptions:***Assuming that all water quality parameters can be accurately assessed using a single method.**Overlooking the importance of reliable data and its implications for effective wastewater management.**Misunderstanding the significance of using analytical techniques for understanding the health of water bodies.* |

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| Lesson 5: Overview |
| Lesson Overview:* In the final lesson of the unit, students will put their knowledge into action by engaging in a culminating project.
* Working in teams, they will be tasked with designing improved wastewater treatment systems.
 | Lesson Objectives: *At the end of the unit, students will be able to…** Apply their knowledge of chemical processes, sustainable wastewater management, and analytical techniques to design improved wastewater treatment systems.
* Demonstrate their understanding of the importance of sustainability and environmental impact in wastewater treatment design.
* Work collaboratively in teams to propose innovative solutions for wastewater treatment challenges.
* Effectively present their wastewater treatment system designs, showcasing their scientific reasoning and problem-solving skills.
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| Standards:* HS-ESS3-3: Create a computational simulation to illustrate the relationships among the management of natural resources, the sustainability of human populations, and biodiversity.
* HS-ESS3-4: Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
* HS-ETS1-2: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
 | Timing:* 4-5 class periods, depending on the complexity of the projects
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| Materials:* Various, depending on designs
* Project guidelines and rubric
* Water quality testing kits
* Peer evaluation sheet
 | Assessment: * Observing team collaboration and engagement during the design process.
* Providing feedback during the project development stage, ensuring teams are integrating appropriate chemical processes and sustainable practices in their designs.
* Assessing the clarity and effectiveness of team presentations, including their ability to articulate the scientific rationale behind their wastewater treatment system designs.
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| Activity  | *Procedure* |
| Wastewater Treatment Design Challenge | * Divide students into teams and provide each team with the project guidelines and rubrics.
* Instruct each team to design an improved wastewater treatment system that addresses specific challenges or targets specific contaminants.
* Teams should conduct water quality testing using the provided testing kits to assess the characteristics of the wastewater they will be treating.
* Allow teams sufficient time to brainstorm and research different chemical processes, sustainable practices, and analytical techniques to incorporate into their designs.
* Have each team create a presentation showcasing their wastewater treatment system design, highlighting its effectiveness, sustainability, and environmental impact.
 |
| Wastewater Treatment System Presentations | * Have each team present their wastewater treatment system designs to the class.
* Each presentation should include an overview of the challenges they addressed, the chemical processes used, and the sustainability considerations incorporated into their design.
* Encourage teams to use visual aids, data from water quality testing, and simulation results (if applicable) to support their presentations.
* Allow time for questions and feedback from the audience after each presentation.
 |
| Peer Review and Feedback | * After each presentation, distribute feedback forms or peer evaluation sheets to students in the audience.
* Instruct students to provide constructive feedback on the strengths and areas for improvement of each team's wastewater treatment system design.
* Emphasize the importance of respectful and constructive feedback to help teams refine their designs further.
* Encourage teams to reflect on the feedback received and make necessary revisions to their designs if time allows.
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| Lesson 5: Tips, Strategies, and Suggestions |
| **Instructional Tips for Teachers:***Encourage creativity and open-ended thinking during the design process.**Facilitate team discussions and problem-solving strategies.**Provide guidance and support as needed, while allowing students autonomy in their design decisions.***Science Objectives:***Apply knowledge of chemical processes and sustainable practices to design effective wastewater treatment systems.**Understand the importance of considering environmental impact and sustainability in wastewater treatment design.***Language Objectives:***Effectively communicate scientific reasoning and design solutions during team presentations.**Use appropriate scientific vocabulary and terminology to describe their wastewater treatment system designs.***Targeted Academic Language/Vocabulary:***Improved wastewater treatment systems**Sustainability in wastewater management**Chemical processes and reactions**Analytical techniques**Environmental impact and conservation***Anticipated Student Misconceptions:***Assuming that the best wastewater treatment systems solely rely on traditional chemical methods without considering sustainable alternatives.**Overlooking the importance of considering the overall environmental impact and resource conservation in wastewater treatment designs.**Underestimating the complexity of designing effective and comprehensive wastewater treatment systems.* |

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# Resources

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| Resources to support teacher learning - *help teachers to develop background content knowledge for this unit.*  |
| United States Environmental Protection Agency (EPA):* The EPA provides a wealth of resources on water quality, wastewater treatment, and environmental regulations. Teachers can explore their educational materials and fact sheets to gain a deeper understanding of the topic.

American Chemical Society (ACS):* The ACS offers educational resources for teachers that cover various chemistry topics, including water quality and treatment.

National Science Foundation (NSF) - Wastewater Treatment Videos:* NSF provides informative videos that explain different aspects of wastewater treatment, which can be helpful for both teachers and students.

Massachusetts Department of Environmental Protection (MassDEP):* The MassDEP website offers information about water quality standards, regulations, and environmental protection efforts in Massachusetts.

Project WET Foundation:* Project WET offers water education resources and activities for teachers. While it's not specific to wastewater treatment, it covers various water-related topics.

MASSTC* MASSTC offers presentations, Podcasts, and videos about topics regarding septic systems and water quality
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