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 Standards  MA STE Standards: HS-ESS3-1, HS-ESS3-3, HS-ETS1-3  MA STE Standards: HS-PS1-2, HS-ESS3-3  MA STE Standards: HS-ESS3-4, HS-ETS1-1  MA STE Standards: HS-PS2-6, HS-ETS1-3  MA 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? |
| * ***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. |
| ***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. |
| ***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. |
| ***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* |
| 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. |
| 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. |
| 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 |
| 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. |
| 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. |
| 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. |
| 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 |
| 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. |
| 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. |
| 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. |
| 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 |
| 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. |
| 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. |
| 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 |
| 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 |