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Keep That Toilet Water out of My Ground Water

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Students know that clean water is essential to life and that groundwater is a source of drinking water for many people. However, it is more difficult to understand how our groundwater can become polluted. In this computer-based laboratory exercise, students evaluate a plot of agricultural land for suitability of land application of septage. Septage is a valuable fertilizer on farms but can pollute groundwater if applied on certain types of soil. Students examine the following site properties: types of soil, depth to bedrock, slope, permeability of soils and frequency of ponding. The goal of this activity is to write a professional letter clearly explaining the reasons for supporting or denying a proposed farm field for land application of wastewater. This activity is based on the Wastewater Specialist position at the Department of Natural Resources and therefore provides a glimpse into regulatory job duties.

Keywords: environmental science, wastewater, groundwater pollution, soil science, nitrates

Introduction

Students can see visible surface water pollution, but since groundwater pollution is not as visible it is often more difficult to understand how groundwater can become polluted. To explore how groundwater is prone to contamination from surface activities, students investigate field and soil characteristics for a local farm field. This computer-based laboratory activity uses Web Soil Survey (WSS) to evaluate field and soil characteristics of a local farm field. Students assume the role of an environmental regulator, a Wastewater Specialist at the Wisconsin Department of Natural Resources (DNR), for land application of septage. Septage is household wastewater that is stored in a septic or holding tank. Septage must be pumped out on a regular basis and then is often applied to farm fields as a nutrient additive. Septage haulers usually work with farmers to identify potential farm fields for landspreading, but the fields must be approved by a Wastewater Specialist in the DNR. The ideal farm field for landspreading of septage will be relatively level to prevent run-off, have loamy soils that hold water and nutrients so that it can be taken up by plant roots, and at least 3 feet of soils above the groundwater or bedrock. The goal of this activity is to evaluate an agricultural field for landspreading of septage and then write a professional letter to a fictional septage hauler with their decision. This lab requires access to the internet and can be completed in about two hours. It has often been challenging to find lab activities that delve into the regulatory aspect of environmental science. This lab is unique in that it uses real environmental regulations to provide students a glimpse into the relationship between regulator and business (i.e. wastewater specialist and septage hauler). I have successfully used this activity with undergraduates in environmental science. The lab does not require extensive knowledge of soils; a basic understanding of the different categories of soils (eg. sandy, clay, etc.) and how water moves through soils is sufficient.

Landspreading of Manure and Septage

Concentrated animal feeding operations (CAFOs) produce millions of gallons of manure per week, but it is a valuable fertilizer for farmers. Septage, like manure, also can be applied to farm fields which provides nitrogen and phosphorous needed for plant growth. Land application of manure and septage can reduce use of chemical fertilizers and can be a means of beneficial reuse of human and bovine waste. However, land application of manure and septage can lead to contamination of wells if improperly applied or applied on sandy soils, in areas with groundwater close to the surface, or over fractured bedrock. Landspreading of septage is tightly regulated under the Environmental Protection Agency (EPA) Part 503 Rule and in Wisconsin under the Wisconsin Department of Natural Resources Chapter NR113.

Web Soil Survey

Web Soil Survey is a site hosted by the United States Department of Agriculture (USDA) Natural Resources Conservation Association. This site provides detailed soil maps for every state in the United States. Aerial photography is used to identify farm fields. Once a field is selected, a soil map is generated over the photo. The soil map includes interactive links to detailed descriptions of each soil type, including type of soil (clay, loam, sandy, etc.), depth to the water table, slope, available water holding capacity and more.

DNR Wastewater Specialist

I was a Wastewater Specialist at the Wisconsin Department of Natural Resources. My job duties included working with septage haulers to approve agricultural land for application of septage, enforcing land spreading regulations and responding to citizen complaints. Students approach this activity as if they were in the Wastewater Specialist position working with a local septage hauler. Septage haulers work with local farmers to identify farm fields for landspreading of septage. Once a field is identified the hauler sends an aerial photograph and description of the field to the Wastewater Specialist for review. Frequently, only part of a field is approvable. In these cases, it was common practice to approve a portion of the field as opposed to denying the entire farm field. I also was involved in an enforcement case that led to a business owner temporarily losing his license for releasing septage into a local creek.

Student Outline

Objectives

Use a soil survey map to evaluate types of soil that are suitable for land application of wastewater.
Interpret environmental regulations for landspreading of septage and practice writing a professional letter.
Describe the potential groundwater concerns associated with land application of wastewater.

Introduction

Do you take clean water for granted? We expect clean water from our taps but it can become polluted. Surface water pollution can occur from an oil spill or run-off from land, but what about groundwater? Groundwater also is susceptible to pollution through surface activities. For example, fecal microbes were found in 60% of the wells tested in Kewaunee County, Wisconsin (Coburn, 2017). Two sources of fecal microbes are cow manure and human waste. Human waste can come from leaking septic tanks or land application of septage. Septage is wastewaster, or the contents from septic and holding tanks, and includes wastewater from toilets, baths, showers, sinks, dishwashers, washing machines, and garbage disposals. Land application of septage can improve crop production since it is high in nitrogen, a valuable fertilizer. However, it must be land applied properly to protect human health, and surface waters and groundwater. Wisconsin Administrative Code Chapter NR 113 (Servicing septic…) sets guidelines for the disposal of waste from septic tanks, holding tanks, and portable restrooms onto approved agricultural land to protect surface and groundwater from contamination by septage. Land Application of septage also is regulated by the Environmental Protection Agency (EPA) Part 503 Rule (A Plain English…). Therefore, disposal of wastewater should only be used on agricultural fields that conform to the guidelines in the Wisconsin Department of Natural Resources Chapter NR 113 or Part 503 Rule.

Chapter NR 113.08 requires a site evaluation of agricultural land used for the disposal of septage prior to landspreading of septage. The evaluation should include all of the following: soil permeability, depth to bedrock or groundwater, slope, setback requirements and potential for flooding. For this laboratory exercise, you will be asked to work with a partner. You and your laboratory partner will assume the role of a Department of Natural Resources (DNR) Wastewater Specialist. Wastewater Specialists work with septage haulers to identify farm fields that are suitable for land application of septage. First, you must identify the types of soils and field characteristics. A soil survey map provides detailed descriptions of the different soils with an aerial photo of the area to help determine if a plot of agricultural land meets the minimum requirements for land disposal of septage. There are more than 20,000 soil series throughout the United States (Soil Formation and Classification). Different soils have different permeability. Permeability is the capacity of soil to allow fluids to filter through it. Sandy soils have rapid permeability because they are porous, or have a large portion of empty spaces, while clay soils have low permeability (See Fig. 1).

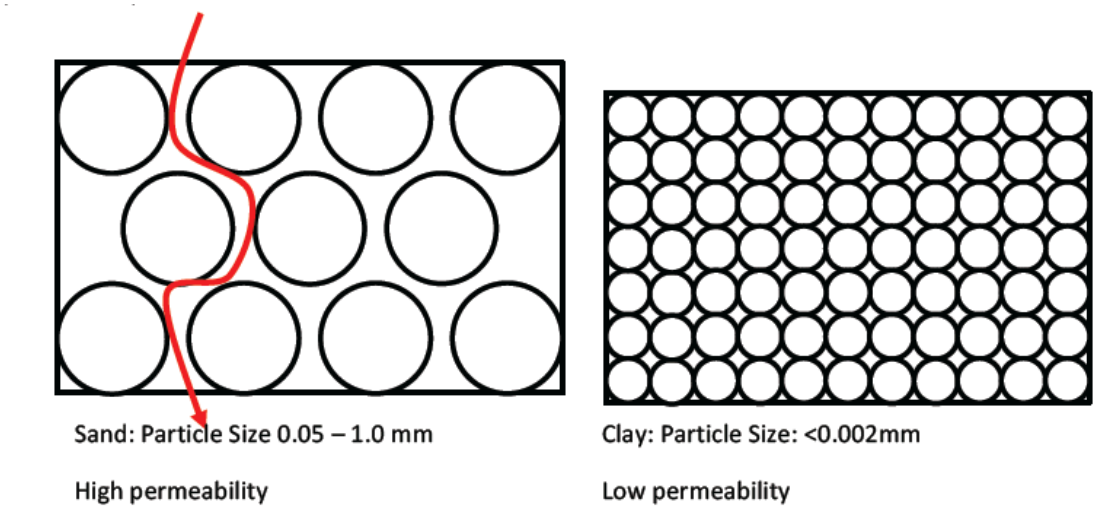


Figure 1. Permeability of sandy versus clay soils. Sandy soils have a larger particle size and more rapid permeability than clay soils. Water tends to pond on top of clay soils while water drains quickly on sandy soils making it difficult for plants to grow.

To protect groundwater, soils should have a permeability greater than 0.2 inches per hour to prevent ponding and less than 6 inches per hour to prevent contamination of groundwater (See Table 1). Saturated hydraulic conductivity, or Ksat, can be used as an estimate for soil permeability. Loamy soils are a mix of sand, silt and clay and are generally suitable for land application of septage because the permeability is neither too fast or too slow. In addition, loamy soils often have an optimal water holding capacity. If soils have a permeability rate greater than six inches per hour the field can still be approved for land application of septage if the soil has a water holding capacity of at least 5 inches. You can, and should, calculate the water holding capacity for the different soil types on your selected field. The soil map will identify the different soil types (silt loam, silty clay loam, etc.) under the heading "Typical profile" then you will multiply the number of inches of that type of soil by the water capacity (in./in.) provided in the table on page 121 in NR 113. Note that there are also example calculations on that page.

Depth to groundwater also is an important consideration when evaluating a farm field. In some cases, groundwater may be within 12 inches of the surface. In this case, septage could infiltrate shallow soils and enter the groundwater before plant roots could use the nutrients or pathogens could contaminate the groundwater. Bedrock that is close to the surface also can provide a conduit to groundwater if the bedrock is fractured. Land application of manure on farm land that sits atop fractured bedrock is believed to have contributed to the contamination of wells in Kewaunee County. It is important to note that septage that is land applied must be treated with lime to raise the pH to 12 or higher for 30 minutes to reduce pathogens. Perhaps a bigger concern with land application of septage is nitrate contamination of groundwater and wells. A recent study suggested that 94,000 household wells in Wisconsin have high nitrate levels (Knobeloch, 2013). Nitrogen in septage is converted to nitrates by soil bacteria and high nitrates in drinking water can lead to blue baby syndrome. Infants given formula reconstituted with water that has high nitrates have a reduced ability to transport oxygen in the blood and therefore may appear blue in color. While there have not been many recent cases of blue baby syndrome in Wisconsin, there is mounting concern about a potential link of high nitrates in drinking water and birth defects (Golden, 2015). To protect groundwater and household wells NR 113 has set a minimum distance to bedrock or groundwater as three feet.

A maximum of 13,000 gallons per acre per week of septage may be land applied, this is called the hydraulic loading rate. Other considerations when evaluating a farm field include the slope and distance to surface waters. The steeper a slope the more prone the field will be to run-off, therefore the maximum slope that is approvable is 6.0%. If a field has some areas with slopes greater than 6.0%, you will need to decide whether to approve or deny the field. You might consider other soil and field characteristics to make this judgement. For example, if the slope of a portion of the field is greater than 6.0% and a stream is nearby you might deny the entire field. On the other hand, if the slope is greater than 6.0% and the soils have a permeability of 2 inches per hour and a water holding capacity of 5 inches you may decide to approve the entire field but limit the application to half (6,500 gallons per acre per week).

Table 1. Selected regulations from Wisconsin Administrative Code Chapter NR 113 for land application of septage. For a more detailed list of regulations see Table 3 on p. 128 in NR 113 (Servicing septic…, 2001).

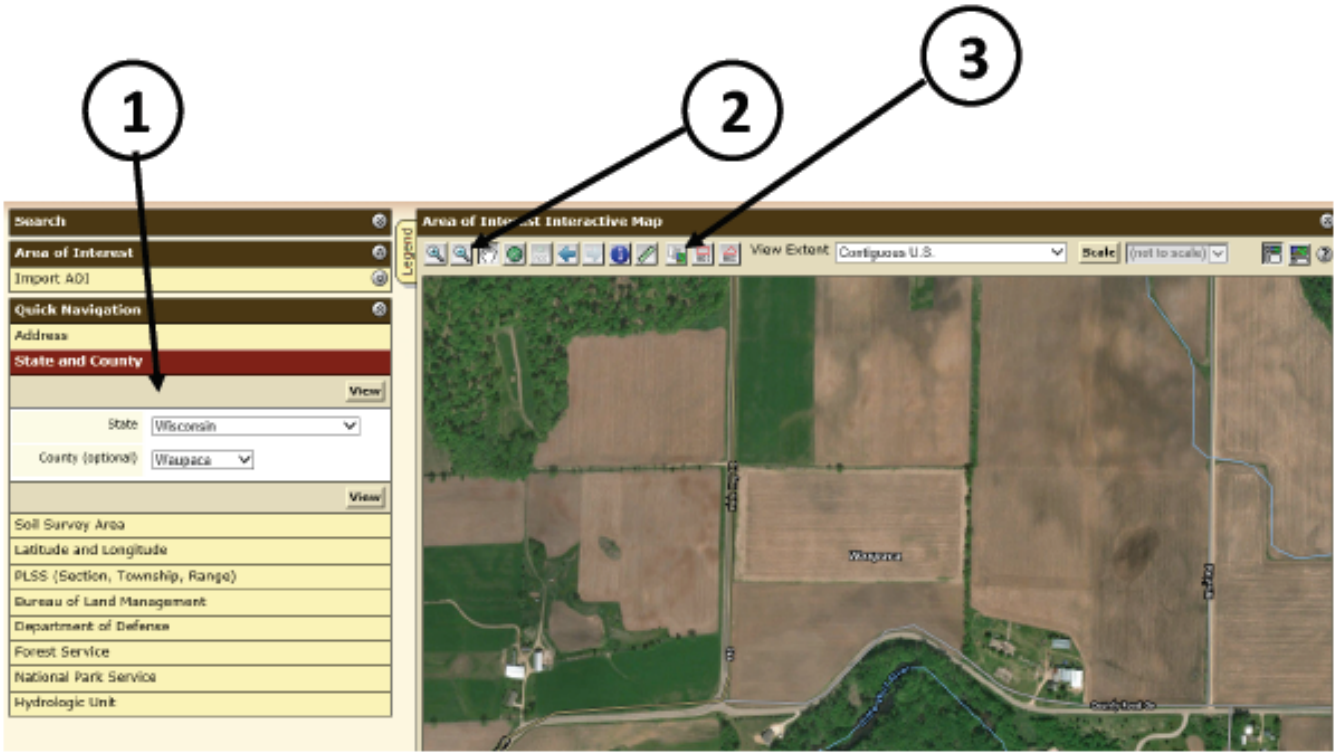
Soil or Field Characteristic	Regulation
Minimum depth from surface to bedrock and groundwater	3.0 ft.
Maximum allowable slope (nonwinter)	6.0%
Minimum distance to a well	250 ft.
Minimum distance to a stream, river, pond, lake, sinkhole, flowage, ditch or wetland	200 ft.
Permeability (use Ksat)	>0.2 in./hr and < 6 in./hr.
Water holding capacity (top 60 in. of soil profile)	>5 in.

Methods and Data Collection

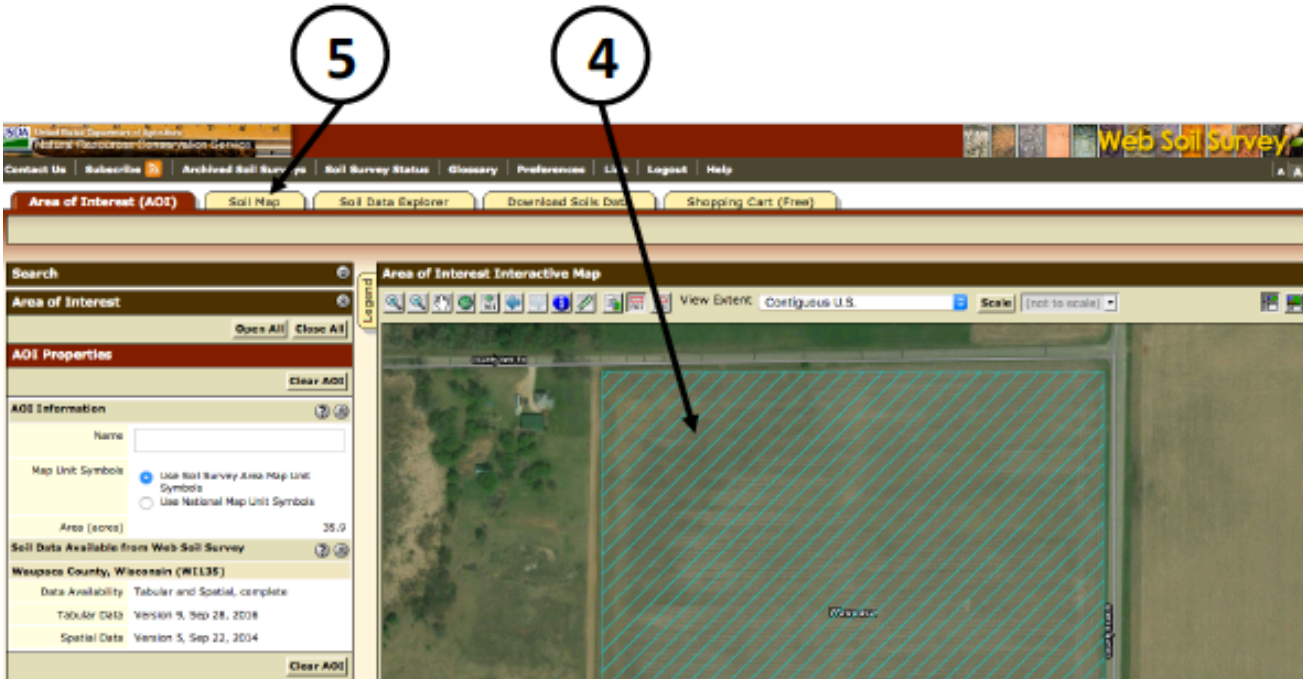
Part A: Mapping Soils on an Agricultural Field

We will be using Web Soil Survey (WSS), which is hosted by the Natural Resources Conservation Service (NRCS), to evaluate the field and soil characteristics of an agricultural site for land disposal of septage. You will begin by identifying an agricultural field from 20 to 50 acres in Wisconsin. Follow the steps and screenshots below to use WSS.

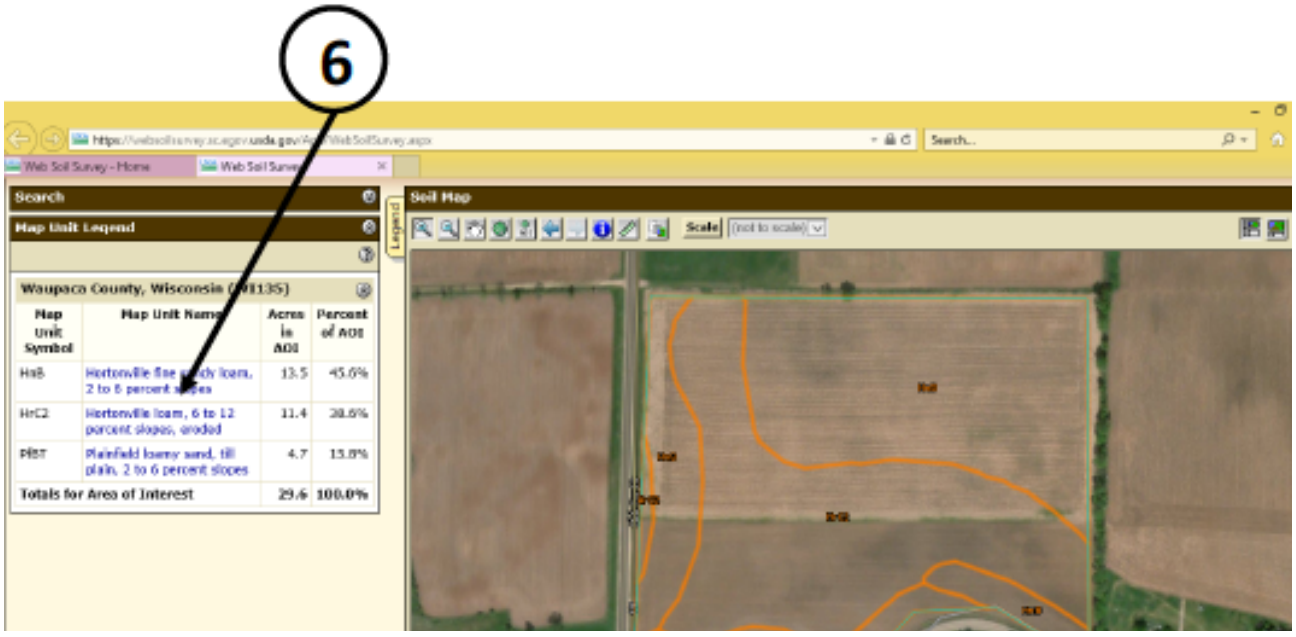
1. Go to the Web Soil Survey page at https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm Read Welcome to Web Soil Survey and the Four Basic Steps then click on the green Start WSS button at the top right of the page.
2. Use the State and County search box to narrow your search (1 in screenshot below). Click on View after making your selection.
3. Zoom in using the + magnifying glass at the top of the map (2 in screenshot below). Continue to zoom in until you can see topographic details (eg. houses, roads, field outlines, etc.). Identify a potential agricultural field.
4. Click on the image of the hand (next to the magnifying glass) to move the map around and center the field, if necessary.
5. Record the location of the field as accurately as possible, including city, county and adjacent roads.
6. Select AOI (Area of Interest) at the top of the map (3 in screenshot below). Use the AOI to draw a box around the field. You can choose the rectangle if your field is perfectly rectangular, otherwise you should use the polygon. The boundaries of the field should follow the natural boundaries of the field in the aerial photo. Do not include houses, roads, or non-agricultural land since a septage hauler is not permitted to apply wastewater on these areas.



7. The selected area will be filled in with colored lines (4 in screenshot below). Select Soil Map at the top of the page (5 in screenshot below). The soil map will identify the names (and abbreviations) of the different types of soils on the site and the total acreage. Record the total acreage (under acres in AOI), and soil name and slope for each type of soil. Your site should have a minimum of 4 different soils types to evaluate. You should select a new AOI if the field has less than four soil types or more than six.



8. Click on the blue highlighted soil name in the table to get more information for each type of soil (6 in screenshot below). You will want to print this information or write it down, since you will be using it to determine if the field is suitable for land application of septage.
9. Print map. Take a screenshot of your soil map and copy into a Word document.



Part B: Evaluation of Soil and Field Characteristics

Chapter NR 113 from the Wisconsin DNR sets guidelines for the disposal of waste from septic tanks, holding tanks and portable restrooms onto approved agricultural land to protect surface and groundwater from contamination. You can access the full NR 113 document at: https://docs.legis.wisconsin.gov/code/admin_code/nr/100/113.pdf#page=8 You should consider, at a minimum, the following in your decision to approve or deny your selected farm field: 1) depth to groundwater or bedrock, 2) water holding capacity, 3) permeability, 4) slope of the field, 5) frequency of ponding or flooding, and 6) distance to surface water and residential well (See Table 1).

Part C: Write a Professional Letter

Write a professional letter to the septage business stating whether the selected field was approved or denied for landspreading of septage. Your letter must clearly explain to the recipient (i.e. septage hauler) the reasons for accepting or rejecting the proposed farm field. Your letter will be graded with the rubric below.

Grading Rubric

7 pts.	5 pts.	3 pts.	2 pts.	3 pts.
Rationale for accepting or denying the site for landspreading of septage clearly explained.	Table with at least 4 different soil types that lists: Name and type of soil Permeability and/or water holding capacity Slope for each type of soil	Description of the location of the field: County City or town Adjacent roads Size of field (in acres) Other landmarks	Map of the site with portions of the field where landspreading of septage would be permitted (and/or not permitted) clearly identified	Professional letter: Heading Inside address Greeting Body Complimentary close Signature No spelling or grammatical errors.

Cited References

Coburn D. 2017. Fecal microbes found in 60 percent of sampled wells, raising concerns about dairy manure, septic waste. [Internet]. [cited 2017 Sept 27]. Available from: http://wisconsinwatch.org/2017/06/fecal-microbes-found-in-60-percent-of-sampled-wells-raising-concerns-about-dairy-manure-septic-waste/

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A plain English guide to the EPA Part 503 biosolids rule (US). [Internet]. Washington DC: Environmental Protection Agency (US); 1994 Sept [cited 2017 Sept 27]. Available from: https://www.epa.gov/sites/production/files/2015-05/documents/a_plain_english_guide_to_the_epa_part_503_biosolids_rule.pdf

Servicing septic or holding tanks, pumping chambers, grease interceptors, seepage beds, seepage pits, seepage trenches, privies, or portable restrooms, Chapter NR 113. Stats. Register, Sept. 2001; No. 549: 121-122.

Soil formation and classification. [Internet]. Washington DC: United States Department of Agriculture, Natural Resources Conservation Service [cited 2017 Sept 27]. Available from: https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/edu/?cid=nrcs142p2_054278

Web Soil Survey [Internet]. 2016. Washington D.C.: United States Department of Agriculture, Natural Resources Conservation Service; [cited 2017 Sept 27]. Available from: https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

Materials

A computer with Internet access is required for each pair of students. LCD projector and computer for the instructor are helpful to guide students through the steps in identifying an area of interest in Web Soil Survey.

Notes for the Instructor

The lab is conducted during a regularly scheduled laboratory section in an introductory environmental science course. Prior to lab, I provide students the link to the Golden (2017) article. This reading provides context for the issue of groundwater and surface water pollution. I describe the Wastewater Specialist position at the Wisconsin Department of Natural Resources the day of the lab. I emphasize that a Wastewater Specialist must protect the environment and enforce regulations while building a good relationship with septage haulers. That means that when working with septage haulers you must fully explain your reasoning if you are alleging illegal activities or denying a piece of land for landspreading of septage. I also usually bring up a current job listing for a Wastewater Specialist and share the knowledge required and current pay for someone in that position. I use the Septage Business License Requirements web page http://dnr.wi.gov/regulations/opcert/septagebusiness.html hosted by the Wisconsin DNR as a resource. It provides access to relevant regulations, list of septage businesses, and the land application request forms (under Dispose and Report tab). I have found that taking the time to fully explain the Wastewater Specialist position makes the lab activity more engaging to the students, and I will often have students ask about DNR jobs after the lab.

I begin the lab activity with a brief overview of the Web Soil Survey then I let students explore the website and follow the steps in the Student Outline. I also show students a soil textural triangle to explain that there are 12 categories of soils based on particle size. I highlight that loamy soils are a mix of sand, silt and clay which usually have good water-infiltration and water-holding capacity which is desirable for landspreading of septage. Invariably, students ask questions about what to do if only part of a field is approvable. I explain that, in general, you want to approve land if possible. If a small percentage of the overall acreage is not approvable than the student can draw lines through that part of the field, but the lines should block off an easily identifiable square or rectangular section and not follow the soil type lines since it would be impossible for a hauler to know where those soil type lines are on the field.

The graded component of the lab is a professional letter to the septage hauler. I share a sample letter so that students can see the format of a professional letter (See Appendix A). I tell students that they can make-up the name of the hauler; some of the students had very colorful and creative business names, which is not unlike some of the names for the septage haulers currently in business. The associated grading rubric for this activity was designed to emphasize the importance of clearly explaining the reasons for accepting or denying the field for landspreading of septage. Students need to understand basic soil and field characteristics to evaluate a field and clearly explain their reasoning in their letter to the septage hauler. My students complete the letter during lab and I usually scan the letter to provide some preliminary feedback before final submission of the letter.

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Golden K. 2015. Failure at the faucet: nitrate in water widespread, current rules no match for it. [Internet]. [cited 2017 Sept 27]. Available from: http://wisconsinwatch.org/2015/11/nitrate-in-water-widespread-current-rules-no-match-for-it/

Septage business license requirements [Internet]. 2016. Wisconsin Department of Natural Resources. [cited 2017 Sept 27]. Available from: http://dnr.wi.gov/regulations/opcert/septagebusiness.html

Acknowledgments

Thank you to all the Environmental Science students who have helped improve this laboratory exercise over the last several years. A special thanks to Kelley O'Connor, my former supervisor at the Wisconsin Department of Natural Resources, who was always supportive of my work and continues to be a valuable resource.

About the Author

Teresa Weglarz has a Ph.D. in Environmental Toxicology from the University of Wisconsin – Madison and is currently an Associate Professor in the Biological Sciences Department at the University of Wisconsin – Fox Valley. She currently teaches introductory biology, heredity, ecology and environmental science and is involved in campus sustainability issues and promotes composting at school and in the community.

Appendix A

TO: ABC SANITATION

123 MAIN ST.

MENASHA WI

FROM: WEGLARZ, TERESA, DNR WASTEWATER SPECIALIST

SUBJECT: SITE EVALUATION FOR LAND DISPOSAL OF SEPATGE

DATE: SEPTEMBER 28, 2017

Dear ABC Sanitation,

I am pleased to inform you that the 62-acre field in Kewaunee County in the town of Kiehl R24E T22N at the northeast corner of Pleasantview Rd. and Pine Rd. is approved for the land disposal of septage. The majority of the soils in this field are loamy and have a permeability rate of 2 in./hour. Approximately 12 acres of the field is Manawa soil which has a permeability rate of 0-2in.hour. Septage may not be landspread on soils with a permeability rate of less than 0.2 in./hour, so please avoid the area marked in red on the attached map. It is important to avoid this area since application of septage on this area of the field could lead to ponding.

Soil Name	**Soil Type**	**Permeability**	**Slope**
Kewaunee	Loam	2 in./hour	3%
Manawa	Silt Loam	0-2in./hour	2%

The slope in the southwest corner of the field has slopes in excess of 2%, therefore please be sure to have 2 ft. wide grass strip on the downslope of this area. Also, do not land apply septage in this area during or immediately after heavy rainfall events. Observing these guidelines will reduce runoff of septage from the site.

Several homes border the property. Please note that the minimum setback distance to residence is 500 ft. unless you have permission of the property owner. The septage must be incorporated within 6 hours after land application.

Landspreading of septage should follow the regulations in chapter NR 113. You will need to keep a log book of all septage applications on file for 5 years. The log book should include the location of the system serviced, gallons collected, and, location, date and time of disposal. If you have any questions, please call me at (920)444-4444.

Sincerely,

Teresa Weglarz

Teresa Weglarz, DNR Wastewater Specialist

Mission, Review Process & Disclaimer

The Association for Biology Laboratory Education (ABLE) was founded in 1979 to promote information exchange among university and college educators actively concerned with teaching biology in a laboratory setting. The focus of ABLE is to improve the undergraduate biology laboratory experience by promoting the development and dissemination of interesting, innovative, and reliable laboratory exercises. For more information about ABLE, please visit **http://www.ableweb.org/.**

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