Garbage Juice: Waste Management and Leachate Generation

Imagine you live in the year 1976. You are part of a task force studying solid waste disposal methods and their impact on the environment. You must decide if these methods adequately protect the environment. Should there be specific laws about solid waste disposal methods? If the methods are inadequate, how might they be improved? The questions you face in your imaginary situation are similar to real life questions. In 1976, the Resource Conservation and Recovery Act established strict federal guidelines for the management of hazardous waste as well as the construction and operation of landfills in the U.S. Prior to 1976, sites for waste disposal were places in the ground where trash was "dumped" and minimally compacted. A full site was covered and a new location was found. Modern, sanitary landfills are much different from these old-style sites as they are designed and engineered to protect human health and the environment.

In this Activity, you will construct a model of an old-style (prior to 1976) waste disposal site and evaluate its environmental impact. Based on your observations, you will design and build a revised model of a modern waste disposal site.

Be Safe! Do not taste or eat any food that has been in the laboratory or that has been in contact with laboratory equipment.

photo by Jenna R. Landeck

A bulldozer and compactor compact waste at a landfill.

Try This

You will need: two modified clear, plastic beverage bottles (obtain from your instructor); multi-colored o-shaped breakfast cereal (e.g., "Froot Loops"); balance; device for compacting cereal (e.g., pestle, potato masher); milk or water; marker; bowls; and graduated cylinder.

__1. Obtain from your instructor two clear, plastic beverage bottles with their tops cut off: one with 4–5 holes poked in its bottom outside edge (represents an old-style landfill) and another, without holes. Place a bowl under the old-style landfill bottle.

__2. Measure and record the mass of ~240 mL (1 cup) of o-shaped multi-colored breakfast cereal. Place the cereal in the old-style landfill bottle to represent solid waste. Compact the cereal with a pestle or potato masher by pressing on it five times.

__3. Determine the volume of the compacted cereal using the second bottle bottom (no holes in its bottom edge). Place the two bottles side by side. Mark the cereal level on the empty bottle. Fill the empty bottle with water to the marked line. Using a graduated cylinder, measure and record the water volume.

__4. Measure 120 mL (1/2 cup) milk or water. Slowly pour the liquid over the cereal "waste" to represent precipitation such as rain. Examine the milk or water that drains from the landfill. This is *leachate*, or precipitation that has flowed through waste. You might also call it "garbage juice"! Record your observations, using Question 2 as a guide.

__5. Using the second bottle bottom and materials of your choice (obtain your instructor's approval), design and build a modern landfill model that 1) protects human health and the environment (for example, leachate could be collected for treatment at a wastewater treatment plant), and 2) takes up less space for the same amount of waste disposed. Repeat steps 2–4 using your new model.

More Things to Try

What if the red cereal pieces were a pesticide that might contribute hazardous constituents to your leachate? How could you test the material to see if it gave off enough hazardous leachate to be considered for alternate disposal? Ask your instructor for information on batch leaching tests.

Questions

1. Using your data from steps 2 and 3, calculate the density of the old-style landfill.
2. Observe the liquid as it moves through the old-style landfill, including: a. Does it reach all of the cereal pieces before exiting?; b. What color is the leachate after exiting?; c. Does the leachate contain solids after exiting?
3. How does the old-style landfill illustrate why the Resource Conservation and Recovery Act (RCRA) was passed, regulating waste disposal methods and facilities?
4. Describe your modern landfill design and why you selected its particular features. How does your design help to protect human health and the environment? How does its density compare to that of the old-style model?
5. How did the characteristics of the cereal "waste" affect the leachate? How does this relate to real world landfills where leachate is collected?
6. What if the yellow and blue cereal pieces were recyclable materials such as newspaper and aluminum cans? How would recycling (keeping this waste out of the landfill) affect the landfill and its leachate?

Information from the World Wide Web *(accessed Dec 2006)*

Bottle Biology—Decomposition Column. *http://www.bottlebiology.org/investigations/decomp_main.html*

Clean Sweep U.S.A. *http://www.kab.org/kids/defaultx.htm*

Delaware Solid Waste Authority: Educational Resources & Web Links. *http://www.dswa.com/education_teachers.html*

Garbage Juice: Waste Management and Leachate Generation W

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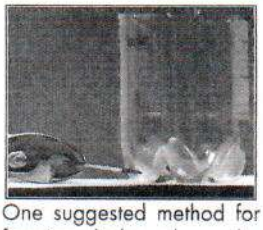
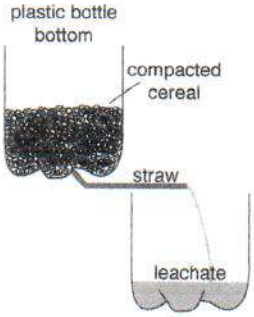
This Activity uses multi-colored breakfast cereal and liquid to model the concepts of leachate and leaching from municipal solid waste disposed of in a landfill. Students create a modern landfill model with the same materials.

Background

In 2003, the U.S. produced over 200 million tons of municipal solid waste (MSW) *(1)*. In 1976, the Resource Conservation and Recovery Act established federal guidelines for hazardous waste management and landfill construction and operation. Historically, waste in landfills was only minimally compacted. Waste in modern landfills is compacted in several stages. Modern landfills are also lined to collect liquid, or leachate, that infiltrates the landfill, usually from precipitation. Collected leachate is then treated, often at a wastewater treatment plant. Hazardous waste (as defined by the U.S. government) is not allowed to be disposed of in MSW landfills *(2)*. Another experiment for university-level students is a good example of how landfill leachate is tested for metal concentrations *(3)*.



One suggested method for forming holes along the bottle's outside bottom edge.



A possible model (step 5) of a modern landfill.

Integrating the Activity into Your Curriculum

This Activity is offered in conjunction with the American Chemical Society's 2007 Chemists Celebrate Earth Day theme "Recycling—Chemistry Can!" It can easily be integrated into a discussion of waste composition and quantity. After this Activity, students may re-evaluate how much trash they throw away and how they dispose of it. Municipalities often collect household hazardous waste (e.g., oil-based paint, pesticides) to keep them out of MSW landfills *(4)*. This Activity would coordinate well with a field trip to a hazardous household waste collection center or landfill.

About the Activity

Use recycled bottles for this Activity! Choose clear, plastic bottles with diameters similar to the width of your chosen compacting tool; 16–32 oz. bottles work well. To prepare a bottle bottom, use a marker to make several marks around the circumference of the bottle, ~10 cm from the bottom. Use a utility knife to make a small slit at one of the marks. Then, insert a scissors and cut around the bottle at the marks to create a bottle bottom ~10 cm tall. Each group will need two bottle bottoms. Poke four or five drainage holes in one bottle bottom, along the bottom outside edge. Do not poke holes in the second bottle bottom. Form the initial holes with a thick needle (such as one used to sew canvas), or a heated nail tip held with pliers. The holes can then be enlarged with the needle, nail, or other tool (see ref *5* for other tool suggestions.) Provide extra materials for the students to use in their own designs, such as straws, clay, cardboard pieces, and general craft items. This issue of *JCE Online*[W] includes a separate procedure that simulates a "batch leaching" procedure sometimes used to determine whether a waste is hazardous or not.

Answers to Questions

1. Density = [mass of cereal (step 2)] / [volume of cereal (step 3)].
2. Liquid follows the path of least resistance through the heterogeneous cereal. The leachate will not have any bright specific color, as all the colors leach. Solids typically appear in the leachate.
3. The old-style landfill allows liquid to pass through the waste into the ground and aquifers, leading to possible contamination. Improved landfills do not allow the leachate to infiltrate the ground.
4. Student designs should collect leachate. This prevents leachate from entering the ground and removes it from the landfill (otherwise it would fill up like a bathtub, which there are laws against!). The authors designed a bottle with only one hole and a straw in the hole leading to a separate leachate collection container. Designs should further compact the waste. Students might add the cereal in batches, compacting it after each batch. This results in a greater density, which reduces the land area needed for an equal amount of waste.
5. The cereal colors leach into the liquid. Soluble waste constituents could end up in leachate.
6. The newspaper and cans would not contribute to the leachate. Recycling reduces the volume needed for disposal.

References and Additional Related Activities *(URLs accessed Dec 2006)*

1. Municipal Solid Waste: Basic Facts. *http://www.epa.gov/epaoswer/non-hw/muncpl/facts.htm*
2. RCRA Orientation Manual 2006; Resource Conservation and Recovery Act. *http://www.epa.gov/epaoswer/general/orientat/*
3. Dunnivant, F. M., Analytical Problems Associated with the Analysis of Metals in a Simulated Hazardous Waste, *J. Chem. Educ.* **2002**, *79*, 718–720.
4. Household Hazardous Waste. *http://www.epa.gov/epaoswer/non-hw/household/hhw.htm*
5. Bottle Biology: Tool Box. *http://www.bottlebiology.org/toolbox/index.html*

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