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LESSON:

Particles: Size Makes All the Difference

Summary: Students plot the different sizes of airborne liquid and solid particles on log paper and examine how the size of a particle affects how it gets into the body through the respiratory system. Then they read an article about what happens to ultrafine particles when they get into the body.

EHP Article: "Particles in Practice: How Ultrafines Disseminate in the Body"
EHP Student Edition, February 2006, p. A758
http://ehp.niehs.nih.gov/docs/2005/113-11/ss.html

Objectives: By the end of this lesson, students should be able to:

1. draw a log graph;
2. compare the size of different airborne particles; and
3. explain how particle size affects what particles get into the body through the respiratory system.

Class Time: 30 minutes

Grade Level: 9–12

Subjects Addressed: Environmental Health, Biology, Health

Prepping the Lesson (10 minutes)

INSTRUCTIONS:

1. Download the entire February 2006 *EHP Student Edition* at http://ehp.niehs.nih.gov/science-ed/ or download just the article "Particles in Practice: How Ultrafines Disseminate in the Body" at http://ehp.niehs.nih.gov/docs/2005/113-11/ss.html.
2. Read the article and review the Background Information and Student Instructions.
3. Make copies of the Student Instructions and the article.

MATERIALS (per student):

- 1 copy of *EHP Student Edition*, February 2006, or 1 copy of "Particles in Practice: How Ultrafines Disseminate in the Body"
- 1 copy of the Student Instructions

VOCABULARY:

- Aerosol
- Alveoli
- Cytoplasm
- Endocytosis
- Endothelial cells
- Epithelial cells
- Inhalable
- Macrophages
- Metal fumes
- Mitochondria
- Nucleus
- Phagocytosis
- Respirable
- Ultrafine particles

BACKGROUND INFORMATION:

There are numerous sources and sizes of airborne particles. For example, pollen can be as small as 10 micrometers (µm), clay particles in soil as small as 0.02 µm, tobacco smoke as small as 0.01 µm, and smog (primarily resulting from automobile combustion) as small as 0.001 µm. Refer to the table in the Student Instructions for more examples.

The respiratory system has defense mechanisms to help prevent airborne particles from getting into the lungs and causing harm. When you inhale, the air is drawn in through the nose or mouth into the upper respiratory system, which consists of the nasal passages, trachea, and conducting airways (bronchi and bronchioles). The air becomes moist and makes numerous twists and turns through the nasal passages and branching airways. Particles 100 µm or larger are not typically drawn into the body by inhalation because of their size. Particles in the size of range of 10 to 100 µm are unable to make the turns and impact on the nasal hairs, nasal mucosa, or mucus-covered ciliated epithelium in the bronchi and bronchioles. Soluble particles simply dissolve, while insoluble particles are transported up the conducting airways by the ciliated epithelium and swallowed or expectorated. Smaller particles less than 10 µm in size are generally able to travel into the pulmonary part of the lungs (the respiratory bronchioles, alveolar ducts, and alveolar sacs), where gas exchange, or respiration, occurs. Thus, particles that reach this part of the lungs are called respirable particles and, if deposited, are typically removed by particle-eating cells called macrophages. These macrophages transport the insoluble particles either to the lymph system or to the ciliated epithelium in the bronchioles.

The article "Particles in Practice: How Ultrafines Disseminate in the Body" raises questions about how ultrafine particles smaller than 100 nanometers (or 0.1 µm) are able to be absorbed into the body and distributed in the cells. They do not appear to be encapsulated by macrophages and seem to be entering cells and transported throughout the body by other, yet unknown, mechanisms. This has significant implications for the potential health effects caused by particles in this size range.

REFERENCE:

Johnson D, Vincent J. Sampling and sizing of airborne particles. In: DeNardi SR, ed. 2003. The Occupational Environment: Its Evaluation, Control, and Management. Fairfax, VA: American Industrial Hygiene Association.

RESOURCES:

Environmental Health Perspectives, Environews by Topic page, http://ehp.niehs.nih.gov/topic. Choose Air Pollution, Particulate Matter

Canadian Lung Association, The Respiratory System, http://www.lung.ca/children/grades7_12/respiratory/respiratory_system.html

Canadian Centre for Occupational Health and Safety:

- What are the effects of dust on lungs? http://www.ccohs.ca/oshanswers/chemicals/lungs_dust.html#_1_2
- How do particulates enter the respiratory system? http://www.ccohs.ca/oshanswers/chemicals/how_do.html

Freitas R, Jr. Nanomedicine [online book]:

- Navigational bronchography, http://www.nanomedicine.com/NMI/8.2.2.htm
- Clearance of inhaled particles, http://www.nanomedicine.com/NMIIA/15.4.3.3.2.htm

Pima County, Arizona, Department of Environmental Quality:

- Animation on particulates (click on "Lung Attack"), http://www.airinfonow.org/html/activities.html
- Health effects of particulates and other air pollutants, http://www.airinfonow.org/html/health.html

Implementing the Lesson

INSTRUCTIONS:

1. Lead a brief discussion about what types of particles are found in the air and where they come from (refer to the Background Information and Student Instructions).
2. Hand out the Student Instructions and the article "Particles in Practice: How Ultrafines Disseminate in the Body."
3. Review the examples on the student handout of the Particle Size Distribution Graph in Micrometers (µm) to ensure that students understand how to plot on the log scale. Review the concept of logs as needed.
4. In groups or as individuals, ask students to complete the graph and the questions on the Student Instructions, and to read the article.
5. Conclude with a class discussion about how particle size affects where particles are deposited in the lungs.

NOTES and HELPFUL HINTS:

- This lesson could be done as homework.
- This lesson could be extended to address cell structure, immune responses, and/or the respiratory system. The Resources section has some websites that may be helpful to students.

Aligning with Standards

SKILLS USED OR DEVELOPED:
- Classification
- Communication (oral, written—including summarization)
- Comprehension (reading)
- Graphing
- Graph reading
- Tables and figures (reading)
- Unit conversion

SPECIFIC CONTENT ADDRESSED:
- Types of airborne particles and their sizes
- Respiratory system
- Graphing using a log scale
- Inhalable and respirable particle sizes
- Environmental health
- Immune system

NATIONAL SCIENCE EDUCATION CONTENT STANDARDS MET:

Unifying Concepts and Processes Standard
- Systems, order, and organization
- Evidence, models, and explanation
- Change, constancy, and measurement
- Form and function

Science As Inquiry Standard
- Understanding about scientific inquiry

Physical Science Standard
- Structure and properties of matter

Life Science Standard
- The cell

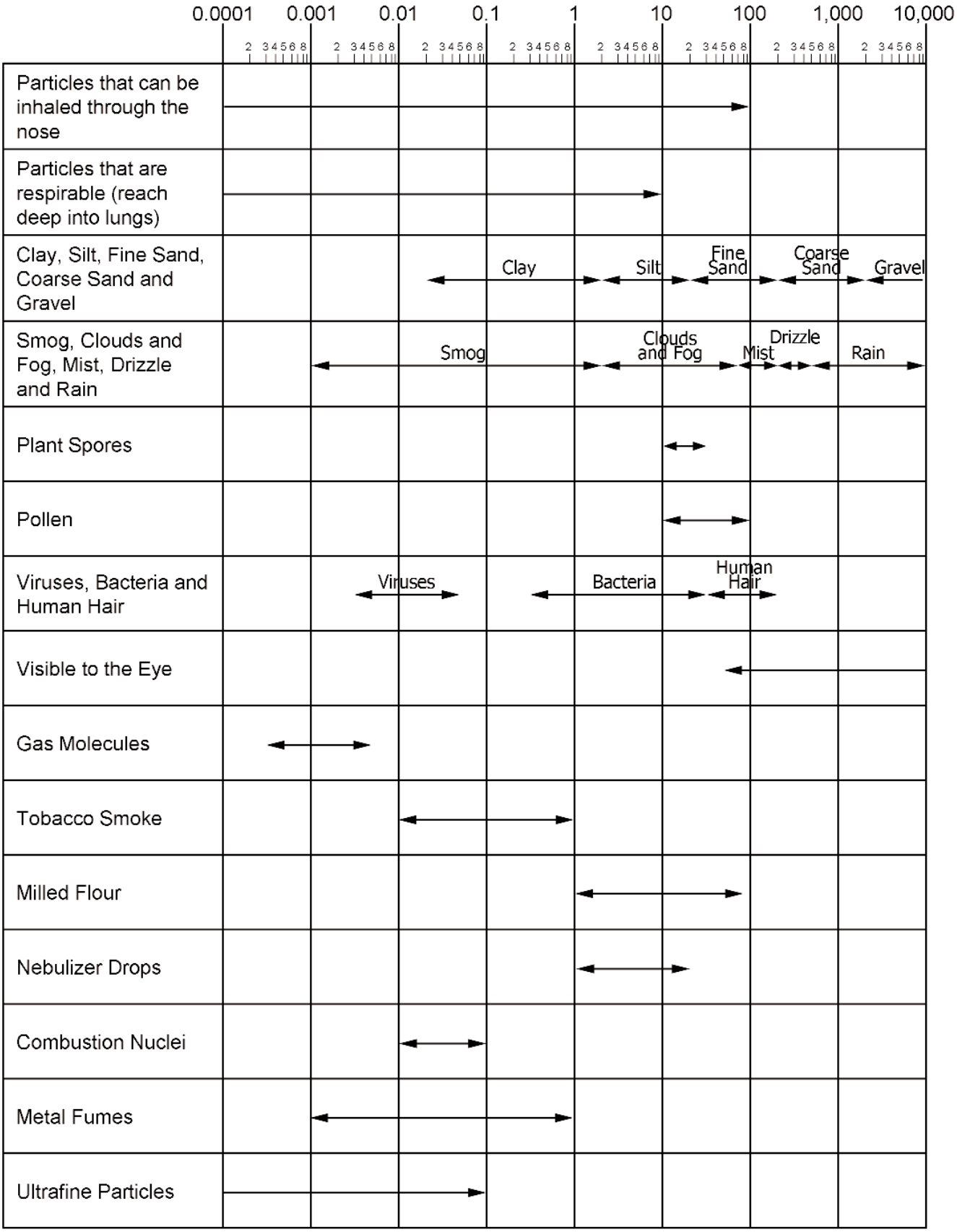
Science in Personal and Social Perspectives Standard
- Personal and community health
- Environmental quality
- Natural and human-induced hazards

Assessing the Lesson

Step 2: Plot the ranges of particle size on the Particle Size Distribution Graph in Micrometers (μm).

See completed graph on next page.

Particle Size Distribution Graph in Micrometers (µm)



Step 3: What types of particles are visible to the eye (>50 µm)?

Fine sand, coarse sand, gravel, clouds/fog, mist, drizzle rain, pollen, human hair, milled flour

Step 4: What types of particles are capable of being inhaled into the nose or mouth (<100 µm)?

Clay, silt, fine sand, smog, clouds/fog, mist, plant spores, pollen, human hair, viruses, bacteria, gas molecules, tobacco smoke, milled flour, nebulizer drops, combustion nuclei, metal fumes, ultrafine particles

Step 5: What types of particles are respirable, or capable of getting into the deep part of the lungs (<10 µm)?

Clay, silt, smog, clouds/fog, viruses, bacteria, gas molecules, tobacco smoke, milled flour, nebulizer drops, combustion nuclei, metal fumes, ultrafine particles

Step 7: Why are health scientists concerned about what happens to ultrafine particles?

Ultrafine particles seem to have the unexplained ability to rapidly penetrate cells throughout the body and impair many cellular functions.

Authors and Reviewers

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Student Instructions: Particles: Size Makes All the Difference

Step 1: There are many different sizes and types of particles that can get into the air. Table 1 shows a variety of airborne particles and their sizes in micrometers (μm). Many of these particles are small enough to be inhaled through the nose into the lungs and cause health problems. The body has defensive mechanisms that protect the body from breathing in larger particles. Important size cutoff points provided by the defensive mechanisms in the body are also noted in Table 1.

Step 2: In order to get a better picture of the different particle sizes, it is helpful to plot the different size ranges for each type of particle on a graph. Because the particle size range for all of the particles is so large (0.00001 to 10,000 μm), the particle size ranges need to be plotted on log paper. Log paper automatically converts the particle sizes to logs and compresses the width of the graph to better show the sizes.

Plot the ranges of each particle or other parameter on the Particle Size Distribution Graph in Micrometers (μm) in the appropriate row. When two or more types of particles are listed in one row, the lines should not overlap and can be plotted in the same row. The first three rows of particles have been completed as a guide. Show the ranges on your graph as follows:

Range has maximum size with no minimum (<0.0001 μm) 

Range has minimum and maximum size 

Range has minimum size with no maximum (>10,000 μm) 

As an alternative, you may use vertical lines to mark the end of the ranges rather than arrows.

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Table 1: Approximate Size Ranges of Different Airborne Particles*

Particle Type	Minimum Size (µm)	Maximum Size (µm)
Particles that can be inhaled	<100	100
Particles that are respirable (can reach the deep part of the lungs)	<10	10
Clay	0.02	2
Silt	2	20
Fine Sand	20	200
Coarse Sand	200	2,000
Gravel	2,000	>2,000
Smog	0.001	2
Clouds/Fog	2	70
Mist	70	200
Drizzle	200	500
Rain	500	10,000
Plant Spores	10	30
Pollen	10	100
Viruses	0.003	0.05
Bacteria	0.3	30
Human Hair	30	120
Visible to the Eye	50	>50
Gas Molecules	0.0003	0.005
Tobacco Smoke	0.01	1
Milled Flour	1	80
Nebulizer Drops	1	20
Combustion Nuclei	0.01	0.1
Metal Fumes	0.001	1
Ultrafine Particles	<0.1	0.1

***Source:** Johnson D, Vincent J. Sampling and sizing of airborne particles. In: DeNardi SR, ed. 2003. The Occupational Environment: Its Evaluation, Control, and Management. Fairfax, VA: American Industrial Hygiene Association.

Step 3: What types of particles are visible to the eye (>50 μm)?

Step 4: What types of particles are capable of being inhaled into the nose or mouth (<100 μm)?

Step 5: What types of particles are respirable, or capable of getting into the deep part of the lungs (<10 μm)?

Step 6: Read the article "Particles in Practice: How Ultrafines Disseminate in the Body."

Step 7: Why are health scientists concerned about what happens to ultrafine particles?

Particle Size Distribution Graph in Micrometers (µm)