Chemistry and Environmental Sciences

To Burn or Not to Burn

Objective: Students learn how a locally proposed power plant may impact the environment of their community.

National Science Education Standards:

As a result of activities in grades 9-12, students should develop

- Abilities necessary to do scientific inquiry
- Understandings about science and technology

As a result of activities in grades 9-12, students should develop understanding of

- Personal and community health
- Environmental quality
- Science and technology in local, national, and global challenges

Materials: Hand out, paper, calculator, map of Waterloo Iowa, and this website: *http://epa.gov/air/airpollutants.html* . The activity should take two or more class period to complete.

To Burn or Not to Burn Name:

Background: Elk Run Energy Associates, LLC (Elk Run Energy) is proposing to construct a modern, 750-megawatt coal-fired electric generating station in Black Hawk County. This plant will incorporate advanced emission control technology and be one of the cleanest coal-fired plants in the U.S.

Engage: Brainstorm a list of positive and negative impacts this project could have on Black Hawk County. Consider things like the economy, the environment and people.

Explore: You will use established emission factors to determine if the plant will exceed the Environmental Protection Agency standards. Before we decide this however, we must calculate the types and amounts of potential pollutants the plant may emit. This list shows the pollutants considered harmful for human health as established by the Clean Air Act of 1990: Carbon Monoxide, Lead, Nitrogen Dioxide, Ozone, Sulfur Dioxide, and Particulate Matter. They are collectively referred to as the NAAQS.

Open the website *http://epa.gov/air/airpollutants.html*

1. On a separate sheet of paper list the health concerns for each of the pollutants.

2. It has been estimated that the plant will produce 750 MW of power each day. To do this, the plant will need to burn coal at the rate of 2900 tons/day. At this rate however, the efficiency of converting that to electricity is only about 33%. How much coal will need to be consumed to produce all 750 MW?

3. If one rail car holds 100 tons of coal, how many rail cars will be needed daily to supply the plant with a sufficient amount of coal?

4. Calculate the amount of emissions per day for each of the pollutants listed in the EPA report from question #1 using the emission factors below. The emissions can be found by multiplying the activity rate in tons per day, times the emissions factor. Assume that there is no control to reduce the emissions. The basic formula for calculating emissions is: $E = A \times EF \times (1-ER/100)$

where:

- E = emissions;
- A = activity rate;
- EF = emission factor
- and ER = overall emission reduction efficiency, %

The following activity rates are per ton of coal.

SO_2 – 52.5 lb/ton NO_2 – 7.4 lb/ton CO – 0.5 lb/ton

PM (Particulate Matter) - 100lb/ton

Explain: Many citizens have expressed health concerns regarding the emissions from this plant. The company claims that it will be one of the cleanest power plants in the U.S. The chart below indicates the EPA's air quality standards that must be met by the power plant.

National Ambient Air Quality Standards

Pollutant	**Primary Stds.**	**Averaging Times**	**Secondary Stds.**
Carbon Monoxide	9 ppm ($10\ mg/m^3$)	8-hour(1)	None
	35 ppm ($40\ mg/m^3$)	1-hour(1)	None
Lead	$1.5\ \mu g/m^3$	Quarterly Average	Same as Primary
Nitrogen Dioxide	0.053 ppm ($100\ \mu g/m^3$)	Annual (Arithmetic Mean)	Same as Primary
Particulate Matter (PM_{10})	Revoked(2)	Annual(2) (Arith. Mean)	
	$150\ \mu g/m^3$	24-hour(3)	
Particulate Matter ($PM_{2.5}$)	$15.0\ \mu g/m^3$	Annual(4) (Arith. Mean)	Same as Primary
	$35\ \mu g/m^3$	24-hour(5)	
Ozone	0.08 ppm	8-hour(6)	Same as Primary
	0.12 ppm	1-hour(7) (Applies only in limited areas)	Same as Primary
Sulfur Oxides	0.03 ppm	Annual (Arith. Mean)	-------
	0.14 ppm	24-hour(1)	-------
	-------	3-hour(1)	0.5 ppm ($1300\ \mu g/m^3$)

5. What is a ppm? How large is a cubic meter (m3)? What is a µg?

6. When you look at your results from the calculations above, what do you notice regarding the expected emissions?

7. What must be missing? What is needed for the proposed plant to comply with the guidelines set forth by the EPA?

Elaborate: On your map, plot the location of the proposed plant.

8. Which direction is north? Place a compass rose on the bottom corner of your map.

9. Where do you live? Plot the location of your home on the map.

10. Generally speaking, what wind direction is most prevalent in the Midwest?

11. What wind direction would guide the smoke plume from the plant towards your home?

12. Is there a reason for citizens to be concerned?

13. What kinds of things would you want to ask the representatives from the power company?

Evaluate: There should be six major pollutants listed and the health concerns for each. The teacher should evaluate the responses to the calculations. The map should be labeled correctly and responses to the questions should reflect the answers from the stated problems.

Assessment Rubric:

CATEGORY	**4**	**3**	**2**	**1**
Calculations	All calculations are shown and the results are correct and labeled appropriately.	Some calculations are shown and the results are correct and labeled appropriately.	Some calculations are shown and the results labeled appropriately.	No calculations are shown OR results are inaccurate or mislabeled.
Participation	Used time well in lab and focused attention on the experiment.	Used time pretty well. Stayed focused on the experiment most of the time.	Did the lab but did not appear very interested. Focus was lost on several occasions.	Participation was minimal OR student was hostile about participating.
Question/Purpose	The purpose of the lab or the question to be answered during the lab is clearly identified and stated.	The purpose of the lab or the question to be answered during the lab is identified, but is stated in a somewhat unclear manner.	The purpose of the lab or the question to be answered during the lab is partially identified, and is stated in a somewhat unclear manner.	The purpose of the lab or the question to be answered during the lab is erroneous or irrelevant.
Summary	Summary describes the skills learned, the information learned and some future applications to real life situations.	Summary describes the information learned and a possible application to a real life situation.	Summary describes the information learned.	No summary is written.
Data	Professional looking and accurate representation of the data in tables and/or graphs. Graphs and tables are labeled and titled.	Accurate representation of the data in tables and/or graphs. Graphs and tables are labeled and titled.	Accurate representation of the data in written form, but no graphs or tables are presented.	Data are not shown OR are inaccurate.

Teacher Notes:

Health Effects of Lead

Exposure to lead can occur from breathing contaminated workplace air or house dust or eating lead-based paint chips or contaminated dirt. Lead is a very toxic element, causing a variety of effects at low dose levels. Brain damage, kidney damage, and gastrointestinal distress are seen from acute (short-term) exposure to high levels of lead in humans. Chronic (long-term) exposure to lead in humans results in effects on the blood, central nervous system (CNS), blood pressure, kidneys, and Vitamin D metabolism. Reproductive effects, such as decreased sperm count in men and spontaneous abortions in women, have been associated with high lead exposure. The developing fetus is at particular risk from maternal lead exposure, with low birth weight and slowed postnatal neurobehavioral development noted. Human studies are inconclusive regarding lead exposure and cancer.

Health Effects of Particulate Matter

The size of particles is directly linked to their potential for causing health problems. EPA is concerned about particles that are 10 micrometers in diameter or smaller because those are the particles that generally pass through the throat and nose and enter the lungs. Once inhaled, these particles can affect the heart and lungs and cause serious health effects. EPA groups particle pollution into two categories:

- "Inhalable coarse particles," such as those found near roadways and dusty industries, are larger than 2.5 micrometers and smaller than 10 micrometers in diameter.

- "Fine particles," such as those found in smoke and haze, are 2.5 micrometers in diameter and smaller. These particles can be directly emitted from sources such as forest fires, or they can form when gases emitted from power plants, industries and automobiles react in the air.

Health Effects of Nitrogen Dioxide

NOx reacts with ammonia, moisture, and other compounds to form nitric acid and related particles. Human health concerns include effects on breathing and the respiratory system, damage to lung tissue, and premature death. Small particles penetrate deeply into sensitive parts of the lungs and can cause or worsen respiratory disease such as emphysema and bronchitis, and aggravate existing heart disease.

Health Effects Associated with Carbon Monoxide

At low concentrations, fatigue in healthy people and chest pain in people with heart disease. At higher concentrations, impaired vision and coordination; headaches; dizziness; confusion; nausea. Can cause flu-like symptoms that clear up after leaving home. Fatal at very high concentrations. Acute effects are due to the formation of carboxyhemoglobin in the blood, which inhibits oxygen intake. At moderate concentrations, angina, impaired vision, and reduced brain function may result. At higher concentrations, CO exposure can be fatal.

Health Effects of Ozone

People with lung disease, children, older adults, and people who are active can be affected when ozone levels are unhealthy. Numerous scientific studies have linked ground-level ozone exposure to a variety of problems, including:

- lung irritation that can cause inflammation much like a sunburn;
- wheezing, coughing, pain when taking a deep breathe, and breathing difficulties during exercise or outdoor activities;
- permanent lung damage to those with repeated exposure to ozone pollution; and
- aggravated asthma, reduced lung capacity, and increased susceptibility to respiratory illnesses like pneumonia and bronchitis.

Health Effects of Sulfur Dioxides

SOx contributes to respiratory illness, particularly in children and the elderly. It may also aggravate existing heart and lung diseases. People with asthma are particularly affected by high levels of SO2.

Emissions Calculations

SOx	E = 8700tons/day x 52.5 lb/ton = 456,750 lb/day
NOx	E = 8700 ton/day x 7.4 lb/ton = 64,380 lb/day
CO	E = 8700 ton/day x 0.5 lb/ton = 4350 lb/day
PM	E = 8700 ton/day x 100lb/ton = 870,000 lb/day

Some students will need assistance with the terms and the math. Students should see that the emissions from such a large plant are going to enormous. However, the portion of the emissions equation that is missing are the technological controls that are intended to reduce the emissions to meet EPA standards. Answers to the questions should reflect this.