AIR QUALITY MODULE
Kaizen: Continuous Improvement

Unit Length: 6 to 7 class periods

Lesson One:

Introduction: Air Pollution – Major Air Pollutants and their Effects

Background: Air pollution is an issue of concern in the United States and the world today. The effects of air pollution include health risks, long-term environmental damage and climate change. The six common air pollutants as cited by the EPA are carbon monoxide, lead, nitrogen dioxide, particulate matter, ozone, and sulfur dioxide.

The following activities are adapted from *EPA unit Air Pollution: What's the Solution? From http://www.k12science.org/curriculum/airproj/teachers*

Website Sources:

- http://www.epa.gov/air/urbanair/6poll.html
- http://www.airnow.gov
- http://www.epa.gov/air/urbanair/6poll.html
- http://www.ciese.org/curriculum/airproj/3dchart/map.html
- http://www.hazecam.net
- http://www.whatsasthma.com
- http://www.airnow.gov/index.cfm?action=airnow.national
- (http://lungaction.org/reports/stateoftheair2007.html
- See materials list

Subject Area: Science, Social Studies, Health

Kentucky Connections:

- Learner Goals: #2, 5, 6
- Academic Expectations: 2.1, 2.2, 2.3.1, 1.16, 2.19,
- Core Content: SC-HS-4.6.9; SC-HS-4.7.2; PL-HS-1.1.6; SS-HS-5.3.6; SS-HS-4.4.2

Materials:

- One 8 oz pray bottle
- 8 ounces of white vinegar
- student gathered leaves
- One box of white chalk
- Two small size bowls
- Scotch tape

- Global Warming by the Numbers *(Environmental Defense, 2007)* (http://www.edf.org/article.cfm?contentID=5816)
- Air Quality – student worksheet (http://www.ciese.org/curriculum/airproj/docs/suspectsworksheet.pdf)
- Internet Access
- Sources of Major Air Pollutants – table (http://www.ciese.org/curriculum/airproj/docs/major_air_pollutants.pdf)
- Sources of Air Pollutants - student worksheet (http://www.ciese.org/curriculum/airproj/docs/sourcesworksheet.pdf)
- Effects on Vegetation Part 3 – student worksheet (http://www.ciese.org/curriculum/airproj/docs/effects_vegetation.pdf)
- Effects on Visibility – student worksheet (http://www.ciese.org/curriculum/airproj/docs/effects_visibility.pdf)
- Effects on Property – student worksheet (http://www.ciese.org/curriculum/airproj/docs/effects_property.pdf)
- Effects on Health – student worksheet (http://www.ciese.org/curriculum/airproj/docs/effects_health.pdf)
- Effects of Common Air Pollutants – poster (http://www.epa.gov/airnow//health-prof/EPA_poster-final_lo-res.pdf)

Length of Lesson: Two class periods

Vocabulary Words:

- Carbon monoxide (CO) – A colorless, odorless, poisonous gas produced by incomplete fossil fuel combustion
- Lead (Pb) – A heavy metal that is hazardous to health if breathed or swallowed. Its use in gasoline, paints, and plumbing compounds has been sharply restricted or eliminated by federal laws and regulations
- Nitrogen dioxide (NO_2)- The result of nitric oxide combining with oxygen in the atmosphere; major component of photochemical smog. –
- Particulate matter - Fine liquid or solid particles such as dust, smoke, mist, fumes, or smog, found in air or emissions
- Ozone - oxygen in the form of molecules with three atoms, created by exposure of oxygen to electrical discharge or ultraviolet radiation
- Sulfur dioxide (SO2)- A pungent, colorless, gas formed primarily by the combustion of fossil fuels; becomes a pollutant when present in large amounts.
- Global warming –An increase in the near surface temperature of the Earth. Global warming has occurred in the distant past as the result of natural influences, but the term is most often used to refer to the warming predicted to occur as a result of increased emissions of greenhouse gases. Scientists generally agree that the Earth's surface has warmed by about 1 degree Fahrenheit in the past 140 years. The Intergovernmental Panel on Climate Change (IPCC) recently concluded that increased concentrations of greenhouse gases are causing an increase in the Earth's surface temperature and that increased concentrations of sulfate aerosols have led to relative cooling in some regions, generally over and downwind of heavily industrialized areas.

- Air quality criteria - The levels of pollution and lengths of exposure above which adverse health and welfare effects may occur

Essential Question: How does air pollution impact the air quality and health of my community?

Guiding Questions/Outcomes:

- Students will be able to identify the sources of major air pollutants.
- Students will be able to describe the air quality in their area.
- Students will be able to explain effects of air pollutants.

Skills Used:

- Data interpretation
- Synthesis of information
- Observation

Activity: Introduction: Air Pollutants and Effects
Day 1

- Teacher will present the "Global Warming by the Numbers" statistics (including America's #1 rank as top global warming polluter in the world; 20% increase of America's carbon dioxide emissions from the burning of fossil fuels since 1990; and 80% decrease in U.S. global warming pollution required by 2050 to prevent the worse consequences of global warming; and 0 number of federal bills passed to cap America's global warming pollution) and lead a class discussion of those statistics.
- Students will use the Internet (http://www.epa.gov/air/urbanair/6poll.html; http://www.airnow.gov) and the Sources of Major Air Pollutants table to complete the Air Quality student worksheet. This worksheet allows students to identify the common sources of air pollutants, introduces effects of air pollution, and allows students to identify current air quality in their area.
- Students will use the Internet (http://www.epa.gov/air/urbanair/6poll.html; http://www.ciese.org/curriculum/airproj/3dchart/map.html) to complete the Sources of Air Pollutants student worksheet. The worksheet allows students to identify the major air pollutants in general and in their state. Students will need to refer back to these results in the next activity (effects of air pollution).
- To prepare for the next day, students should gather 3 fresh, green leaves from the same tree or plant to be used in an experiment in the next day of the lesson and set up for the experiment. Students will:
    - Tape one leaf (control) to a piece of white paper, label it as the control, and place it in a dry, safe, location.
    - Spray one leaf all over using a spray bottle containing 100 ml of white vinegar, label it as leaf 2, and place it next to the control leaf.
    - Spray one leaf all over with the vinegar six times throughout the day (teacher will need to help in this step), label it as leaf 3, and place it next to the other leaves.
- The teacher should also place one piece of chalk in a bowl of white vinegar and another piece of chalk in a bowl of tap water to prepare for the Effects on Property activity the next day to demonstrate the effect of acid rain on statues.

Day 2

- Students will complete the Vegetation experiment they set up the previous day by making observations of the effect of the vinegar solution overnight. These are similar to the effect acid rain has on vegetation.
- Students will examine the effects of air pollution on visibility in major U.S. cities. Students will use the Internet (http://www.hazecam.net) site Haze Cam Pollution Visibility Camera Network to complete the Effects on Visibility and Effects on Property student worksheets.
- Students will use the "What's Asthma All About?" video (http://www.whatsasthma.com), the Effects of Common Air Pollutants poster, Air Now website (http://www.airnow.gov), current air quality map (http://www.airnow.gov/index.cfm?action=airnow.national), and the American Lung Association website (http://lungaction.org/reports/stateoftheair2007.html) to complete the Effects on Health student worksheet.
- To conclude, students will finish part B on the Sources of Pollutants worksheet that requires them to apply what they learned about acid rain, visibility, and health concerns in today's lesson.
- *Note to teacher: parts of these activities can be used in any classroom; however, other parts are more geared to a science, health, or social studies class. For instance, while it would be beneficial for all students to complete the Vegetation experiment, it is most applicable in a science classroom, and teachers of other subject areas may opt to omit that portion of the lesson.*

Assessment:

- Formative assessment will be the student worksheets.

Global Warming by the Numbers

Challenge is Clear for the New Congress

Posted: 16-Jan-2007; Updated: 30-Aug-2007

As the 110th Congress begins to debate global warming policy, our list of ten startling global warming facts underscores what's at stake and why 2007 must be a year for effective national action.

1 Rank of 2006 as **hottest year on record** in the continental United States.

1 Rank of America as **top global warming polluter in the world**.

20% Percent **increase of America's carbon dioxide emissions** from the burning of fossil fuels since 1990.

15% Percent **increase of America's carbon dioxide emissions forecasted** by 2020 if we do not cap pollution.

80% Percent **decrease in U.S. global warming pollution required** by 2050 to prevent the worst consequences of global warming.

78 Number of days by which the **US fire season has increased** over the past 20 years - tied closely to increased temperatures and earlier snowmelt.

200 million Number of people around the world **who could be displaced** by more intense droughts, sea level rise and flooding by 2080.

358 Number of U.S. mayors (representing 55 million Americans) **who have signed the U.S. Mayors Climate Protection Agreement** pledging to meet or beat the Kyoto protocol goals in their communities.

0 Number of **federal bills passed** to cap America's global warming pollution.

LESSON TWO
This activity was taken from
http://www.k12science.org/curriculum/airproj/pm_investigation.html

Introduction: What is particulate matter?

Background: Particulate matter is found in all air. Particulate matter is any fine liquid or solid particles such as dust, smoke, mist, fumes, or smog, found in air or emissions. Investigations can be formed to determine ways to control the particulate matter in our air.

Website Sources:
- http://www.k12science.org/curriculum/airproj/pm_sources.html

Subject Area: Science

Kentucky Connections:
- Learner Goals: #1, #2, #3, #5, #6
- Academic Expectations: 1.2, 2.1, 2.2, 2.6, 2.31, 3.3, 5.1, 5.3, 6.3
- Core Content: SC-HS-4.7.1; SC-HS-4.7.2; SC-HS-4.7.3; SC-HS 4.7.5

Materials Needed:
- Clear wide packing tape
- Ruler
- Index cards—colored and white, 1 per student
- Hole puncher
- String
- Scotch tape
- Hand lens or dissecting microscope
- Internet access
  - -Weather Underground
  - -Student Worksheet

***Try to plan this for a time when heavy rain showers are not expected. Students should place these cards in locations where rain cannot easily wash away particulate matter.

Length of Lesson: One to two class periods

Vocabulary Words:
- Particulate Matter (PM) - Fine liquid or solid particles such as dust, smoke, mist, fumes, or smog, found in air or emissions

Essential Question: What does Particulate Matter (PM) have to do with air pollution?

Guiding Questions/Outcomes
- Students will be able to list sources of PM? **
- Students will be able to describe variables affect PM? **

- Students will make particulate air monitoring cards and gather samples.
- Students will be able to describe variables that influenced the amount of particles gathered on their cards.
- A more extensive background lesson for Particulate Matter can be found at http://www.k12science.org/curriculum/airproj/pm_sources.html

Skills Used:

Observing
Analyzing
Gathering data
Summarizing

Activity:

- The text and student assignments have been copied below:

Particulate Matter Investigation

What does Particulate Matter have to do with air pollution?

In this activity, you will create your own particulates monitoring cards to collect particulates around the area.

1. Obtain a Student Worksheet from your teacher. Find the outdoor location in which you would like to hang your monitoring card. Measure the length of string necessary to suspend the card.
2. Back in the classroom, measure and cut a length of string.
3. Obtain one colored and one white index card.
4. Cut out a large square in the middle of the colored index card. (Refer to Student Worksheet for diagram).
5. Whole punch the center of the card and attach the length of string.
6. On the front of the card, write your name, location, and dates of exposure.
7. Cut strips of clear wide packing tape and place them on the card, so that the sticky side of the tape will show from the front of the card. Try not to touch the exposed sticky area.
8. Place your card in the location you identified earlier. Make sure that the card is hanging freely.
9. Each day the card is exposed, obtain and record the average wind speed and direction for the day.
10. After four days, collect the cards and return them to the classroom for analysis.
11. Place a white index card behind the colored one to help see any particulates that may have been trapped by the tape.
12. Use a hand lens or microscope to evaluate the particulates that are present, determining the approximate size and amount on the card.
13. Sketch your results on the Student Worksheet and answer the questions.

STUDENT WORKSHEET

Air Pollution: What's the Solution?

Student Worksheet :
Particulate Matter Investigation

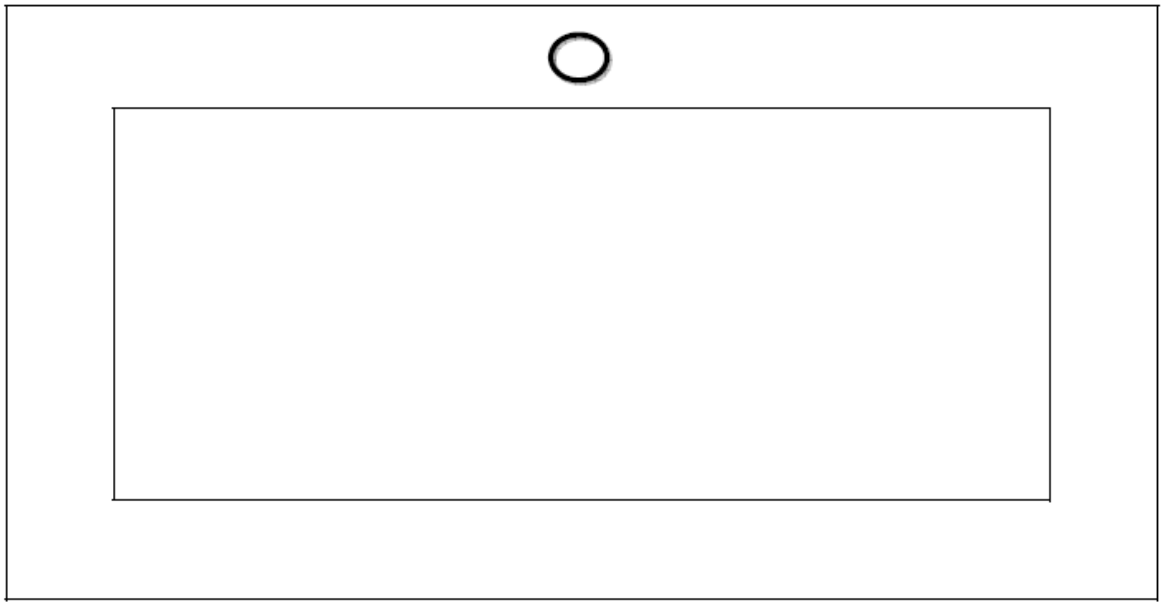
Name: _____ Group: _____

1. Describe the location you chose for your monitoring card.

2. Weather Observations – Daily Averages

Wind Observations	Day 1	Day 2	Day 3
Wind Speed			
Wind Direction			
Rain?			

3. Sketch the Results:



4. What percentage of the exposed area had particulates on it?

5. Do you think you were able to see all the particulates trapped by the tape? Explain

6. Describe the types of particulates observed on the cards. Were any of the particulates obvious to you, like a grain of sand?

7. Would you be able to hypothesize about the origin of any of the particulates? For example, if you found a red piece of clay on your card that was hanging near the baseball field that uses red clay on the infield.

8. Do you think the wind conditions had an effect on your results? Explain.

Assessment: Formative assessment of students' participation and formative assessment of the students' worksheet.

Extensions: Repeat the procedure every month or six weeks and discuss changes observed.

LESSON 3

Introduction: This lesson is designed to provide students with information about the "Killer Fog" in England in 1952 while challenging them to examine the purpose, audience, and authorship of the article/s.

Background: Approximately a half century ago, a toxic mix of dense fog and sooty black coal smoke killed thousands of Londoners in four days. It remains the deadliest environmental episode in recorded history. The so-called killer fog is not an especially well-remembered event, even though it changed the way the world looks at pollution.

Website Sources:

- http://www.npr.org/templates/story/story.php?storyId=873954&sc=emaf

Subject Areas: English, Social Studies

Kentucky Connection:

- Learner Goals: #1, #5, #6
- Academic Expectations: 1.2, 1.4, 1.16, 2.2, 5.3, 6.2
- Core Content: SS-HS-5.1.1; SS-HS-5.3.3; RD-11-10.0.4; RD-11-2.0.6; RD-11-3.0.2; RD-11-3.0.9; RD-11-3.0.7; RD-11-3.0.8; RD-11-5.0.4

Materials Needed:

- Internet access
- Real Media/Media player

Length of Lesson: One class period

Vocabulary Words:

- Catastrophe - An event producing a subversion of the order or system of things; a final event, usually of a calamitous or disastrous nature; hence, sudden calamity; great misfortune.
- Writing terms:
  - Purpose – Purpose is the reason why something is written. Examples include expressive, cognitive, informative, poetic, phatic and metalinguistic
  - Audience – the group of people that a writing was intentionally written to be read
  - Authorship – The quality or state of being an author; function or dignity of an author

Essential Questions: How were different articles written and what information did they offer relating to historic evidences of air pollution?

Guiding Questions/Outcomes:

- Students will be able to describe the Killer Fog of 1952?

- Students will be able to identify and list other historical examples of air pollution?
- Students will be able to identify the purposes of the different articles?
- Students will be able to explain how an author or sponsor impacts the content of the article?

Skills Used:

Observing
Analyzing
Summarizing
Inferring

Activity:

This lesson allows students to research the "Killer Fog" that hit London, England in 1952 and more recent examples of polluted air. It has students read the articles and examine the purpose, audience and authorship of the article.

Students can answer the following questions for any article or article link:

1. What is the title of the piece?
2. Who is the author?
3. What group, if any, sponsors the site?
4. Who is the audience for the site?
5. What made you determine that this was the audience?
6. What is the purpose of the article?
7. What is the tone of the article?
8. What connections can you see between the group sponsoring the site and the purpose of the article?

Students can read the main article at
http://www.npr.org/templates/story/story.php?storyId=873954&sc=emaf

They can also click on the links to the right of the page. These include historical articles from the Environmental Protection Agency, a timeline from the Environmental Institute of Houston, a scientific article from *Environmental Health Perspectives* and personal stories of the 1952 fog from the BBC.
Students could read some or all of these articles. The NPR site also contains audio and video clips. These require Real Media.

Assessment: Summative assessment through student participation and recall.

Extensions:

- Students can research and orally report to the class other incidents of environmental catastrophes especially in the United States.

LESSON FOUR

Introduction: Wind Barb and Pollutants
This lesson was adapted from http://www.ciese.org/curriculum/airproj/enrichtransport.html.

Background: Pollutants are transported from one location to another by wind (moving air). Learning to read a wind barb can provide valuable information on air quality.

Subject Area: Science

Kentucky Connections:
- Learner Goals: #1, #2, #6
- Academic Expectations: 1.5, 1.6, 1.7, 1.8, 1.9, 1.10, 2.2, 2.5, 2.8, 6.2
- Core Content: SC-HS-1.2.1, SC-HS-2.3.1

Materials:
- Computer with internet access
- Copies of student worksheet

Length of Lesson: One to two class periods

Vocabulary Words:
- Wind barb – a convenient way to represent both wind speed and wind direction in a compact graphical form
- Ozone (O3) - Found in two layers of the atmosphere, the stratosphere and the troposphere. In the stratosphere (the atmospheric layer 7 to 10 miles or more above the earth's surface) ozone is a natural form of oxygen that provides a protective layer shielding the earth from ultraviolet radiation. In the troposphere (the layer extending up 7 to 10 miles from the earth's surface), ozone is a chemical oxidant and major component of photochemical smog. It can seriously impair the respiratory system and is one of the most wide- spread of all the criteria pollutants for which the Clean Air Act required EPA to set standards. Ozone in the troposphere is produced through complex chemical reactions of nitrogen oxides, which are among the primary pollutants emitted by combustion sources; hydrocarbons, released into the atmosphere through the combustion, handling and processing of petroleum products; and sunlight.
- Nitrogen Oxide (NOx) - The result of photochemical reactions of nitric oxide in ambient air; major component of photochemical smog. Product of combustion from transportation and stationary sources and a major contributor to the formation of ozone in the troposphere and to acid deposition
- Volatile Organic Compound (VOC) - Any organic compound that participates in atmospheric photochemical reactions except those designated by EPA as having negligible photochemical reactivity
- Particulate matter - Fine liquid or solid particles such as dust, smoke, mist, fumes, or smog, found in air or emissions.
- Knot - A nautical measure of speed, approximately 1.5 miles per hour

Essential Questions: How are pollutants such as ozone, NOx, VOCs and particulate matter transported or moved away from their sources?

Guiding Questions/Outcomes:

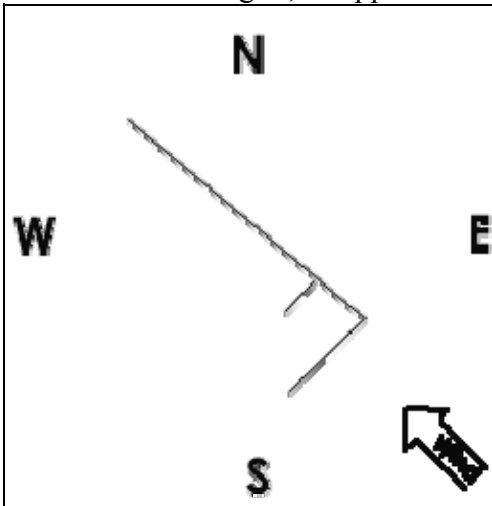
1. Students will be able to interpret a wind barb.
2. Students will be able to access near real time wind data and pollutant animations to track the transport and ultimate destination of pollutants.

Skills Used:

- Observing
- Calculating
- Predicting

Activity:

1. Review the wind information below. Remember that the wind barb points in the direction where the wind is blowing to, as opposed to where the wind is blowing from.



Example of Wind Barb

Calm	
5 knots	
10 knots	
15 knots	
20 knots	
50 knots	
65 knots	

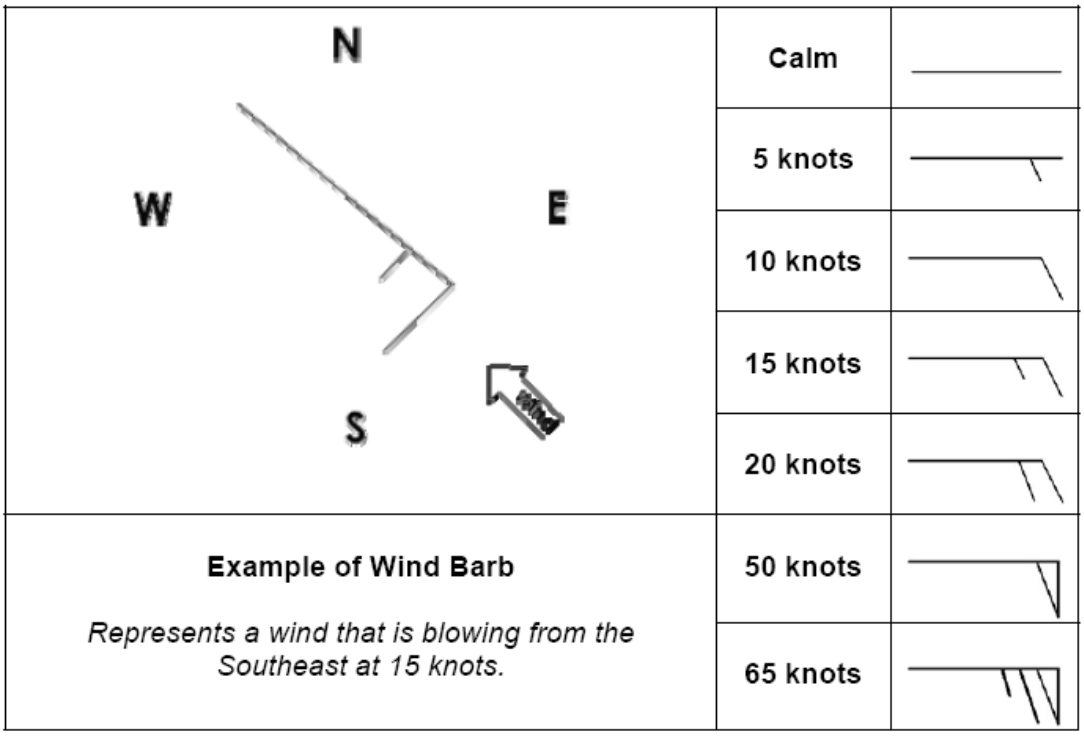
1. NOTE: The Example Wind Barb above represents a wind that is blowing from the Southeast at 15 knots. Wind speed is often reported in the units of "knots". A "Knot" is a nautical mile per hour.
    - 1 Knot = 1.15 Miles Per Hour (MPH)
    - 1 Knot = 1.9 Kilometers Per Hour (KM/HR)
    - Each short barb represents 5 knots, each long barb 10 knots. A long barb and a short barb is 15 knots, simply by adding the value of each barb together (10 knots + 5 knots = 15 knots.
2. On your Student Worksheet, analyze the wind barbs and determine which way the wind is blowing and how hard the wind is blowing.

- Wind not only moves air, but also particles and objects that may be in the air. You may have experienced this before if you have dropped a piece of paper outside on a windy day and chased after it as the wind picks up the paper and carries it along.
- What about the particles you cannot see? Winds can transport particles like NOx, VOCs, ground level ozone and particulates great distances from where they were produced.

3. Pollutants such as ground level ozone and particulate matter are usually swept along by winds that blow around 3,000 ft above the surface (sea level). Access the 3,000 ft wind data at http://adds.aviationweather.noaa.gov/data/winds/ruc00hr_900_wind.gif and answer the questions on the Student Worksheet, either found at http://www.k12science.org/curriculum/airproj/docs/transportworksheet.pdf or printed below.

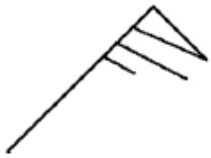
Air Pollution: What's the Solution? **Student Worksheet: Transport**

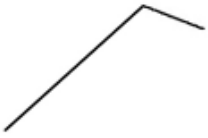
Name:_____ **Group:_____**



For the following images, answer the following questions:

1. Which direction is the wind blowing?
2. How hard is the wind blowing?

		
_____ at _____knots _____ mph _____kmh	_____ at _____knots _____ mph _____kmh	_____ at _____knots _____ mph _____kmh

		
_____ at _____knots _____ mph _____kmh	_____ at _____knots _____ mph _____kmh	_____ at _____knots _____ mph _____kmh

What about the particles you cannot see? Winds can transport particles like particulates, NOx, VOCs, and ground-level ozone great distances from where they were produced. Pollutants such as ground-level ozone are usually swept along by winds that blow around 3,000 ft above the surface (sea level.)

Access the 3,000 ft wind data and answer the following questions:

1. If there was an Ozone Alert Day issued in Chicago, IL and some of the ground-level ozone was transported at the 3,000 ft level, in which direction would the zone move and at what speed?
2. Locate Atlanta, GA on the map. If a large amount of particulates were released, in which direction would the particulates move, and at what speed?
3. Locate St. Louis, MO on the map. If the winds continued to blow at the same speed and direction, which state would the winds blow over next?
4. Locate Los Angeles, CA on the map. If a forest fire was burning, which direction would the wind blow the fire, smoke and particulates?

Assessment: Formative assessment based on student performance on worksheets

Extension:

Locate where you live on the map. Which direction and at what speed is the current wind blowing? Over which state would any particulate pollution released where you live blow over first?

Lesson Five

Introduction: This activity is from http://www.k12science.org/curriculum/airproj/whataqi.html. The lesson and the student worksheet have been copied below.

Background: The AQI (Air Quality Index) can be determined by using gathered data and set formulas. Students will learn how to determine the AQI of a given location.

Website Sources:

- http://www.k12science.org/curriculum/airproj/whataqi.html

Subject Areas: Mathematics, Science

Kentucky Connections:

- Learner Goals: #1, #2, #6
- Academic Expectations: 1.5, 1.6, 1.7, 1.8, 1.9, 1.16, 2.3, 2.4, 2.5, 2.8, 2.11, 6.2
- Core Content: MA-HS-1.3.1; MA-HS-2.2.1; SC-HS-4.7.1; SC-HS-4.7.2; SC-HS-4.7.3; SC-HS-4.7.5

Materials Needed:

- AQI formulas
- Breakpoints Table
- AQI student worksheet: "What's Your AQI?"

Length of Lesson: One class period

Vocabulary:

- Air Quality Index (AQI) – Index by which the amount of pollutants in the air is measured
- particulate matter - Fine liquid or solid particles such as dust, smoke, mist, fumes, or smog, found in air or emissions
- pollution - Generally, the presence of a substance in the environment that because of its chemical composition or quantity prevents the functioning of natural processes and produces undesirable environmental and health effects. Under the Clean Water Act, for example, the term has been defined as the man-made or man-induced alteration of the physical, biological, chemical, and radiological integrity of water and other media
- ppm – parts per million
- breakpoint - A breakpoint is a location referred to by meteorologists when issuing watches, warnings, or advisories, for specific areas
- ozone - Found in two layers of the atmosphere, the stratosphere and the troposphere. In the stratosphere (the atmospheric layer 7 to 10 miles or more above the earth's surface) ozone is a natural form of oxygen that provides a protective layer shielding the earth from ultraviolet radiation. In the troposphere (the layer extending up 7 to 10 miles from the earth's surface), ozone is a chemical oxidant and major component of photochemical smog. It can seriously impair the respiratory system and is one of the most wide- spread of all the criteria pollutants for which the Clean Air Act required EPA to set standards.

Ozone in the troposphere is produced through complex chemical reactions of nitrogen oxides, which are among the primary pollutants emitted by combustion sources; hydrocarbons, released into the atmosphere through the combustion, handling and processing of petroleum products; and sunlight

- ozone concentration – the amount of ozone concentrated in a given area

Essential Questions: How do you calculate the AQI values of different air pollutants?

Guiding Questions/Outcomes:

- Students will be able to convert ozone ppm readings into an AQI value.
- Students should understand how the Air Quality impacts people who live in an area.

Skills Used:

- Observing data from a chart
- Categorizing
- Analyzing
- Summarizing
- Inferring

Activity:

What's Your AQI?

Procedure

1. Obtain copies of the AQI Equation (.PDF) and Breakpoints Table (.PDF).
2. Review the following examples to learn how to convert ozone ppm readings into an AQI value:
   A. **8-hour Ozone example**
   Suppose you have an 8-hour ozone concentration of 0.0874125 ppm. First you round off the concentration to 0.087 ppm. Then look in the Breakpoints Table (.PDF) under the 8-hour ozone for the range of concentrations that contain this concentration (0.085 - 0.104 ppm). This range in the table for the 8-hour ozone corresponds to index values of 101 to 150. Now you have all the numbers needed to use the AQI equation:

$$I_P = \frac{I_{Hi} - I_{Lo}}{BP_{HI} - BP_{Lo}} (C_P - BP_{Lo}) + I_{Lo}$$

Where I_P = the index for pollutant $_P$
C_P = the rounded concentration of pollutant $_P$
BP_{Hi} = the breakpoint that is greater than or equal to C_P
BP_{Lo} = the breakpoint that is less than or equal to C_P
I_{Hi} = the AQI value corresponding to BP_{Hi}
I_{Lo} = the AQI value corresponding to BP_{Lo}

$$\frac{(150 - 101)}{(0.104 - 0.085)}(0.087 - 0.085) + 101 = \frac{49}{0.019}\ 0.002 + 101 = 106.157 = 106$$

So, an 8-hour concentration of 0.0874125 ppm corresponds to an AQI value of **106**.

B. **Multiple Pollutants example**
Suppose you have an 8-hour ozone value of 0.077 ppm, a $PM_{2.5}$ value of 54.4µg/m^3, and a CO value of 8.4 ppm. You apply the equation 3 times:

- For Ozone (O_3): O_3: $\frac{(100 - 51)}{(0.084 - 0.065)}(0.077 - 0.065) + 51 = 82$

- For Particulate Matter ($PM_{2.5}$): $PM_{2.5}$: $\frac{(150 - 101)}{(65.4 - 40.5)}(54.4 - 40.5) + 101 = 128$

- For Carbon Monoxide (CO): CO: $\frac{(100 - 51)}{(9.4 - 4.5)}(8.4 - 4.5) + 51 = 90$

The AQI is 128 with $PM_{2.5}$ as the responsible pollutant.

STUDENT WORKSHEET

Air Pollution: What's the Solution?

Student Worksheet : *What's Your AQI?*

Name: _____ **Group:** _____

What's Your AQI?

A. 8-HOUR OZONE EXAMPLE

Suppose you have an 8-hour ozone concentration of 0.0875125 ppm. First you round off the concentration to 0.087 ppm. Then look in the Breakpoints Table under the 8-hour ozone for the range of concentrations that contain this concentration (0.085 – 0.104 ppm). This range in the table for the 8-hour ozone corresponds to index values of 101 to 150. Now you have all the numbers needed to use the AQI equation:

$$I_P = \frac{I_{Hi} - I_{Lo}}{BP_{HI} - BP_{Lo}} (C_P - BP_{Lo}) + I_{Lo}$$

Where I_P = the index for pollutant $_P$
C_P = the rounded concentration of pollutant $_P$
BP_{Hi} = the breakpoint that is greater than or equal to C_P
BP_{Lo} = the breakpoint that is less than or equal to C_P
I_{Hi} = the AQI value corresponding to BP_{Hi}
I_{Lo} = the AQI value corresponding to BP_{Lo}

$$\frac{(150 - 101)}{(0.104 - 0.085)} (0.087 - 0.085) + 101 = \frac{49}{0.019} 0.002 + 101 = 106.157 = 106$$

--> Therefore, an 8-hour concentration of 0.0875125 ppm corresponds to:

an AQI value: of **106**.

B. MULTIPLE POLLUTANTS EXAMPLE

Suppose you have an 8-hour ozone value of 0.077 ppm, a $PM_{2.5}$ value of 54.4µg/m^3, and a CO value of 8.4 ppm. You apply the equation 3 times:

For Ozone (O_3):	O_3: $\frac{(100-51)}{(0.084-0.065)}(0.077-0.065)+51=82$
For Particulate Matter ($PM_{2.5}$):	$PM_{2.5}$: $\frac{(150-101)}{(65.4-40.5)}(54.4-40.5)+101=128$
For Carbon Monoxide (CO):	CO: $\frac{(100-51)}{(9.4-4.5)}(8.4-4.5)+51=90$

The AQI is 128 with $PM_{2.5}$ as the responsible pollutant.

Complete the following problems:

1. On June 10, Wichita, Kansas reported a 1-hour ozone concentration of 0.162 ppm and an 8-hour ozone concentration of 0.141125. What would the AQI be and why?

2. On December 3, Madison, Wisconsin reported a CO value of 13.2 and an 8-hour ozone value of 0.032. What would the AQI be and why?

Calculating the Air Quality Index (AQI)

AQI Equation

$$I_P = \frac{I_{Hi} - I_{Lo}}{BP_{Hi} - BP_{Lo}} (C_P - BP_{Lo}) + I_{Lo}$$

Where: I_P = the index for pollutant P

C_P = the rounded concentration of pollutant P

BP_{Hi} = the breakpoint that is greater than or equal to C_P

BP_{Lo} = the breakpoint that is less than or equal to C_P

I_{Hi} = the AQI value corresponding to BP_{Hi}

I_{Lo} = the AQI value corresponding to BP_{Lo}

Breakpoints for the AQI

These Breakpoints							equal these AQIs...	Category
O_3 (ppm) 8-hour	O_3 (ppm) 1-hour[1]	$PM_{2.5}$ ($\mu g/m^3$)	PM_{10} ($\mu g/m^3$)	CO (ppm)	SO_2 (ppm)	NO_2 (ppm)	AQI	
0.000-0.064	-	0.0 – 15.4	0 – 54	0.0-4.4	0.000-0.034	([2])	0 – 50	Good
0.065-0.084	-	15.5 – 40.4	55 – 154	4.5-9.4	0.035-0.144	([2])	51 – 100	Moderate
0.085-0.104	0.125-0.164	40.5 – 65.4	155 – 254	9.5-12.4	0.145-0.224	([2])	101 – 150	Unhealthy for sensitive groups
0.105-0.124	0.165-0.204	65.5 – 150.4	255 – 354	12.5-15.4	0.225-0.304	([2])	151 – 200	Unhealthy
0.125-0.374	0.205-0.404	150.5–250.4	355 – 424	15.5-30.4	0.305-0.604	0.65-1.24	201 – 300	Very Unhealthy
([3])	0.405-0.504	250.5-350.4	425 – 504	30.5-40.4	0.605-0.804	1.25-1.64	301 – 400	Hazardous
([3])	0.505-0.604	350.5-500.4	505 – 604	40.5-50.4	0.805-1.004	1.65-2.04	401 – 500	Hazardous

[1] Areas are generally required to report the AQI based on 8-hour ozone values. However, there are a small number of areas where an AQI based on 1-hour ozone values would be more precautionary. In these cases, in addition to calculating the 8-hour ozone index value, the 1-hour ozone index value may be calculated and the maximum of the two values is reported.

[2] NO_2 has no short-term NAAQS and can generate a AQI only above a AQI value of 200.

[3] When 8-hour O_3 concentrations exceed 0.374ppm, AQI values of 301 or higher must be calculated with 1-hour O_3 concentrations.

Assessment: Formative assessment of the students' participation and performance. Formative assessment of the students' completion of the student worksheet

Extension: Research local sources i.e. newspaper, television reports, weather channel, etc. Determine the AQI of several locations in the United States. Interesting dates to research could be during the fire season in the fall or the very hot days of summer.

TOYOTA CONNECTIONS

- TMMK decants the water in the paint sludge and waste water sludge to reduce the weight. This is important because it reduces disposal volume, which in turn reduces transportation which ultimately affects CO2 emissions- all by re-using water.
- TMMK has replaced catalytic incinerators with high efficiency RTO's (Regenerative Thermal Oxidizer) which destroys air toxics and Volatile Organic Compounds (VOCs) (example: paint thinner) that are discharged in industrial process exhausts. The system achieves VOC destruction through the process of high temperature thermal oxidation, converting the VOC's to carbon dioxide and water vapor, recycling released energy to reduce operating costs.
- TMMK has implemented a strong energy conservation program throughout the plant. Although this does not impact emissions at the TMMK plant, it does reduce emissions from the local power plant since less energy is needed. This also helps to preserve our natural resources.
- TMMK has reduced the number of plastics paint booths from 8 to 4 by using wet on wet paint technology. Some of the benefits include reduced electrical usage and reduced water usage.
- TMMK has begun using a new lower VOC waterborne purge in plant 1 and 2 which creates a decrease in volume as well as a reduction in VOC content in the new material. The impact is as follows: and the reduction is approximately 84,000 lbs of VOC per year.
    - Plant 1: Implemented Nov-07 reducing 84,912 pounds of VOC per year
    - Plant 2: Implemented Feb-08 reduction is approximately 175,000 pounds of VOC per year.