DEQ in the Classroom:

When a Car Coughs…

Taking a Close Look at Vehicle Exhaust

IDAHO DEPARTMENT OF ENVIRONMENTAL QUALITY

1410 North Hilton
Boise, ID 83706
208/373-0502

www.deq.idaho.gov

Grade Level:

Grades 7 - 9

Time Required:

Approximately one hour. (Assumes testing four vehicles with two adults. Time required will vary depending on number of vehicles tested, number of adults available to assist, and level of discussion.)

Objective:

To demonstrate the amount of particulate air pollution that comes from motor vehicles, to see how different types of vehicles emit different levels of pollutants, and to learn ways to keep motor vehicle pollution to a minimum.

Meets Idaho State Standards:

Grade 7: 7.M.3.5.1*, 7.M.5.1.1*, 7.M.5.2.1*, 6-9.GWH.2.5.2, 6-9.GWH.2.5.3, 6-9.GEH.2.5.2, 6-9.GEH.2.5.3, 7.S.1.2.2, 7.S.1.6.2*, 7.S.1.6.3, 7-8.H.1.1.9, 9-12.H.1.1.6

Grade 8: 8.M.3.5.1*, 8.M.5.1.1*, 8.M.5.1.2*, 8.M.5.2.1*, 6-9.GWH.2.5.2, 6-9.GWH.2.5.3, 6-9.GEH.2.5.2, 6-9.GEH.2.5.3, 8-9.PS.1.2.1, 8-9.ES.1.2.1, 8-9.ES.5.1.1, 7-8.H.1.1.9

Grade 9: 9.M.5.1.1*, 9.M.5.2.1*, 6-9.GWH.2.5.2, 6-9.GWH.2.5.3, 6-9.GEH.2.5.2, 6-9.GEH.2.5.3, 8-9.PS.1.2.1, 8-9.ES.1.2.1, 8-9.ES.5.1.1, 9-10.B.1.2.1, 9-10.B.5.1.1, 9-12.H.1.1.6

Meets standards in math (if optional Step 5 completed), geography western/eastern hemispheres, physical science, earth science, and health.

Focus:

Air quality, air pollution from motor vehicles, particulates.

Materials:

New, white men's handkerchiefs (one per car being tested, plus one extra)
Oven mitts or heavy gloves (one pair, minimum – mandatory for safety)
Permanent marker(s) (one per car being tested)
Rubber bands (sturdy) (minimum of three per car being tested)
Variety of motor vehicles (ideas: new car, old [pre-1975] car, diesel pickup truck, newer [post-1994] diesel school bus or large diesel truck, older [pre-1994] diesel bus/truck, older [pre-1994] diesel bus/truck equipped with emissions reduction technology, hybrid vehicle, vehicle fueled with alternative fuel [e.g., biodiesel, ethanol]).
Two adults (minimum – mandatory for safety)
Paper towels or rags
Watch(es) or stopwatch(es) (one per car being tested is best)
Owner's manual for each vehicle tested (optional; for optional Step 5)

Adapted from Air and Waste Management Association, *Environmental Resource Guide, Air Quality*, Grades 6 – 8.
*Meets these standards if "optional" Step 5 is completed.

Background:

In 2000, there were 225.4 million registered motor vehicles in the United States, an increase of 17.5% since 1990. As the number of motor vehicles in the U.S. and worldwide continues to grow, so does air pollution. Motor vehicles are a subset of what are called "mobile sources" of air pollution. "Mobile source" is a term used to describe a wide variety of vehicles, engines, and equipment that generate air pollution and that move, or can be moved, from place to place. Emissions from mobile sources are a leading cause of air pollution nationwide and the primary cause of air pollution in many urban areas. Driving a vehicle is the most polluting act the average citizen commits on a daily basis.

Vehicle emissions are created from the incomplete combustion of gasoline or diesel. Some of the fuel is changed to energy, and that is what makes the vehicle "go," but not all fuel is consumed. By-products of the combustion process leave the car through the exhaust pipe(s). These by-products include heat and air pollutants.

Vehicles emit many pollutants into the air, including carbon monoxide, carbon dioxide, hydrocarbons, nitrogen oxides, sulfur oxides, and volatile organic compounds. These pollutants then combine to form secondary pollutants such as fine particulate matter ($PM_{2.5}$ [see below and Vocabulary]) and ozone. While emissions from an individual vehicle may be minimal compared to an industrial source such as a factory, emissions from many vehicles on the road at one time can have a serious impact on air quality.

The type of air pollution captured by the handkerchiefs in this test is particulate matter (called "PM" or "particulates"). PM is the term for small particles found in the air including dust, dirt, soot, smoke, and liquid droplets. Particulates can be suspended in the air for long periods of time. Some particulates are directly emitted into the air (called "primary pollutants") while others are formed in the air through chemical reactions (called "secondary pollutants"). Vehicle emissions are a major contributor of PM. They emit some PM as primary pollutants and even more PM is created (secondary pollutants) as chemicals in vehicle exhaust interact with other chemicals in the air. Many other pollutants (see above) emitted by vehicles are not captured by the handkerchiefs.

Pollutants emitted from vehicles can lead to poor visibility (haze) and health problems such as asthma and respiratory illnesses. Under the Clean Air Act, the U.S. Environmental Protection Agency (EPA) has set protective health-based standards for ozone, PM, and other air pollutants (National Ambient Air Quality Standards, or NAAQS). Failure to meet the standards over a period of time can result in an area being designated "nonattainment" by EPA. States strive to achieve attainment with the standards to assure that public health is protected, promote economic growth, avoid the potential loss of federal highway funding, and preclude the time and cost required to develop and implement plans to re-attain attainment status. As vehicle emissions are large contributors of many of these regulated pollutants, keeping emission levels low is extremely important.

Emissions are controlled by reducing vehicle use and by driving low (or lower) emission vehicles. Many factors affect emissions from individual vehicles, including emission controls, engine design, fuel choice, and vehicle maintenance.

Vocabulary:

Alternative Fuel	A fuel that takes the place of traditional petroleum gasoline or diesel fuels.
Attainment (area)	A geographic area that has pollutant levels at or below the National Ambient Air Quality Standards.
Biodiesel (B20)	A mixture of diesel fuel with soybean or vegetable oil-based products. B20 (20% biodiesel and 80% petrodiesel) is the most common blend.
Carbon Dioxide (CO_2)	A colorless, odorless, incombustible gas, formed during respiration, combustion, and organic decomposition. A "criteria pollutant."
Carbon Monoxide	A colorless, odorless, and poisonous gas. Carbon monoxide forms when the carbon in fuels does not completely burn. Vehicle exhaust contributes roughly 60% of all CO emissions nationwide and up to 95% in cities.
Carpool	An arrangement where several people travel together in one vehicle.
Clean Air Zone Idaho	A statewide program aimed at reducing exposure to vehicle exhaust by discouraging the idling of vehicles and encouraging the use of alternative fuels.
Combustion	The process of burning.
Compressed Natural Gas (CNG)	Natural gas used to fuel vehicles. CNG vehicles may run exclusively on natural gas or on both natural gas and gasoline.
Criteria Pollutant	Six air pollutants for which EPA has established standards to protect the health and welfare of people, plants, and animals, as well as to prevent damage to buildings, monuments, water resources, and natural areas. The six pollutants are carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter, and sulfur dioxide.
Diesel Retrofit Technology	Equipment that can be added to diesel engines to reduce emissions.
Emission	The act or instance of discharging (emitting) something into the air, such as by an internal combustion engine (e.g., a vehicle).
Emit	To give off or discharge.
Ethanol (E10 and E85)	Alcohol, commonly derived from corn, that can be blended with traditional petroleum fuel. Common blends include E10 (10% ethanol and 90% petroleum) and E85 (85% ethanol and 15% petroleum).
Exhaust	The fumes or gases released from an engine.
Hydrocarbon	An organic compound containing only carbon and hydrogen.
Lead	A metal found naturally in the environment as well as in manufactured products. Historically, the major sources of lead emissions were motor vehicles and industrial sources. Due to the phase-out of leaded gasoline, however, airborne lead is no longer a problem in most of the U.S. A "criteria pollutant."
Mobile Source	A term used to describe a wide variety of vehicles, engines, and equipment that generate air pollution and that move, or can be moved, from place to place. Motor vehicles, such as cars, trucks, and buses, are mobile sources.
National Ambient Air Quality Standards (NAAQS)	Air quality standards that list the maximum concentration above which adverse effects on human health may occur for six air "criteria pollutants."

Nitrogen Dioxide (NO_2)	A brownish, highly reactive gas present in all urban atmospheres. Nitrogen dioxide is a "criteria pollutant" that can irritate the lungs, cause bronchitis and pneumonia, and lower resistance to respiratory infections. Nitrogen oxides contribute to formation of both ozone and acid rain. Automobiles are a major emission source of nitrogen oxides.
Nonattainment (area)	Not meeting the National Ambient Air Quality Standards; a geographic area that has pollutant levels above these standards.
Ozone (O_3)	A gas that forms in the atmosphere when three atoms of oxygen are combined. It is not emitted directly into the air, but is created at ground level by a chemical reaction between oxides of nitrogen and volatile organic compounds in the presence of sunlight. Ozone close to the earth's surface is an air pollutant and is a key ingredient of smog. Ozone more than about 10 miles into the atmosphere protects the earth from the sun's harmful ultraviolet rays. A "criteria pollutant."
Particulate Matter (PM)	Small particles in the air including dust, dirt, soot, smoke, and liquid droplets. Particulate matter is a "criteria pollutant" that comes in a wide range of sizes (see $PM_{2.5}$ and PM_{10}).
$PM_{2.5}$	Particulate matter (PM or particles) in the air less than 2.5 micrometers in diameter. Often referred to as "fine" particulate matter. Not visible to the naked eye; can only be seen with an electron microscope.
PM_{10}	Particulate matter (PM or particles) in the air less than or equal to 10 micrometers in diameter. PM between 2.5 and 10 micrometers in diameter is referred to as "coarse" particulate matter. Not visible to the naked eye.
Pollutant	Any substance introduced into the environment that adversely affects the usefulness of a resource or the health of humans, animals, or ecosystems.
Pollution	The act or process of polluting or the state of being polluted, especially the contamination of soil, water, or air by the discharge of harmful substances.
Primary Pollutant	A pollutant emitted directly from a source. For example, nitrogen oxides are emitted in vehicle exhaust.
Secondary Pollutant	A pollutant that forms when two other pollutants react or combine. For example, ammonia emitted from dairies may combine with nitrogen oxides emitted from cars to form ammonium nitrate, which is a type of fine particulate matter ($PM_{2.5}$).
Sulfur Dioxide (SO_2)	A colorless, reactive gas produced during burning of sulfur-containing fuels such as coal and oil, during metal smelting, and by other industrial processes. A "criteria pollutant."
Volatile Organic Compounds (VOCs)	Organic compounds in the air that combine with other pollutants to form ozone and $PM_{2.5}$. They are common in household and industrial products, such as paints and varnishes, solvents, and fuels.

Procedure:

Ahead of time: Arrange to test several vehicles/types of vehicles (see Materials, Page 1). It is best to have a variety of types of vehicles available, but even if this is not possible, differences can usually be seen among a variety of similar (not identical) vehicles. Park all of the vehicles to be tested near the class site. Obtain the keys for all vehicles.

NOTE: Only conduct the test outdoors—never in an enclosed building. Be sure the emergency brake is set on each vehicle before beginning the test.

Step 1. Use a series of questions (below) to lead into the test.

Question 1. What does the term "pollution" mean?
Using their answers, reach a consensus that it means something that hurts the environment or makes it dirty.

Question 2. Why do people care about air pollution?
Hurts the environment, is unhealthy, blocks views, stinks, can cause economic issues if air quality doesn't meet national standards (see http://www.deq.idaho.gov/air/data_reports/monitoring/overview.cfm), etc.

Question 3. What types of things create air pollution?
Look for answers such as factories (industry), people, cars, fires/smoke, dirt roads, agriculture, etc. (Fires, dirt roads, and agriculture all contribute particulate matter to the air.) Continue soliciting answers until you get a variety of answers including cars/vehicles.

Question 4. Do all cars pollute, or only those where you can see black "smoke" coming out the tailpipe?
With very few exceptions, all cars produced commercially today produce polluting exhaust, but some pollute much less than others. Some experimental cars (e.g., hydrogen fuel cell), or cars produced in very small quantities (e.g., electric), have the potential to not produce polluting emissions.

Question 5. Can we see pollution from a typical, newer car (e.g., not just from old cars with obvious "smoke")?
We'll find out!

Question 6. What happens when a vehicle burns fuel?
Discuss vehicles' contribution to air pollution (also see Background, Page 2).
Vehicle emissions are created from the incomplete combustion of gasoline or diesel. Some of the fuel is changed to energy and that is what makes the vehicle "go," but not all fuel is consumed. By-products of the combustion process leave the car through the exhaust pipe(s). These by-products include heat and air pollutants.

Question 7. Why is air pollution from vehicles a big issue?
Emissions from mobile sources (mainly motor vehicles) are a leading cause of air pollution nationwide and are the primary cause of air pollution in many urban areas. The number of motor vehicles on the road is rising; therefore, so is the amount of air pollution. While emissions from an individual vehicle may seem small, emissions from many vehicles on the road at one time can have a serious impact on air quality. Pollutants emitted from vehicles can lead to poor visibility (haze) and health problems such as asthma and respiratory illnesses. Air pollutants also can damage buildings and affect the quality of water resources.

Step 2. Explain to students that they are going to trap pollutants as the pollutants leave vehicles through tail pipes (trap vehicle exhaust). Divide students into groups—one group per vehicle being tested. Provide one handkerchief, several rubber bands (in case they break), one pair of gloves/oven mitts, and one set of instructions and photos (Pages 11 and 12) to each group.

Keep one extra handkerchief for a "control" to compare to at the end.

Step 3. Perform test. Follow instructions on Page 11 (also see photos on Page 12). Have each group test one vehicle. Have at least two adults present as each vehicle is tested—one to start/run the engine (remain in the driver's seat for the duration of the test) and one at the side/rear of the car to supervise the test. If only two adults are available, test only one car at a time and allow remaining groups to observe each group as they test. (You can start testing a second car while waiting for the tailpipe on the previous car to cool down.)

Done with test. Return to classroom.

Step 4. Have the students compare handkerchiefs, then line handkerchiefs up on a table, from the "cleanest" handkerchief to the "dirtiest" handkerchief. Include the clean (control) handkerchief for comparison. Take a digital photo or make a drawing to record the range of "dirtiness." See photo, page 12.

Step 5. *Optional.* **Look up the average gas mileage** (miles per gallon) of each vehicle tested at www.fueleconomy.gov and/or in the owner's manual(s) and create a graph (each student, in groups, or as a class) that shows what you found. Compare the graph(s) to the "line-up" of handkerchiefs from Step 6. Is there a correlation between gas mileage and emissions (dirtiness of handkerchiefs)?

Step 6. Discuss the results of Steps 4 and (optional) 5. Which vehicles had the dirtiest emissions? The cleanest ones? Do you see differences in colors or consistency of emissions on handkerchiefs from different vehicles as well as differences in amount? Were any or all of the handkerchiefs damp or were they all dry? Why? What conclusions can be made from the results? Will this affect your future driving decisions? If so, how? Discuss with students that the pollution they see on the handkerchiefs is particulate matter only. Invisible pollutants are also emitted by vehicles.

Step 7. Wrap up with "Additional Questions for Discussion," page 7.

Additional Questions for Discussion:

1. How can we reduce (limit) air pollution from motor vehicles?

Answers may include:

- *Limit driving: carpool, walk, combine errands, take the bus, ride a bike*
- *Turn off engines while waiting for more than 30 seconds (e.g., don't idle in drive-through)*
- *Keep vehicles well-maintained (get better gas mileage, so produce fewer emissions per mile driven)*
- *Purchase and use low-emission vehicles (e.g., hybrids)*
- *Use alternative fuels (e.g., biodiesel [B20], ethanol [E85], and compressed natural gas [CNG])*
- *Choose to drive the most fuel-efficient vehicle you own*
- *"Trip chain" – combine multiple errands in one trip*
- *Retrofit existing diesel engines (e.g., school buses, trucks) with emissions reduction technology*
- *Use an electric or non-motorized lawn mower and trimmer instead of gasoline-powered equipment*
- *Avoid fueling vehicles during the heat of the day; fuel in the evening instead (helps keep ozone from forming)*

2. How can you, as teenagers (and soon-to-be drivers), make a difference?

Answers may include:

All of the above, plus specifically…

- *Make good choices regarding when you drive, what you drive (if you have a choice), and what fuel you use*
- *Consider environmental factors as you buy your first car*
- *Keep using alternative transportation (e.g., carpool, bike, walk, bus) even after you get your driver's license; having a driver's license doesn't mean you have to use it every day!*
- *Teach your friends that <u>everyone</u> does not have to drive his or her <u>own</u> car to school <u>each</u> day. Instead, take turns riding with each other—make it cool to carpool at your school!*

Expansion and Follow-Up Ideas:

- Have students conduct an educational campaign at their school or in their city to reduce vehicle miles driven. Write letters to the editor, make posters, etc.

- Develop a campaign at the local high school to make carpooling cool!

- Track the levels of pollutants in your area on DEQ's Web site (http://www.deq.idaho.gov/air/aqindex.cfm); create graphs, charts, etc. of the data.

- Have students research air quality issues in your area and compile an oral or written report.

- Have students develop a plan of what they (as individuals) or their school or community should do during episodes of poor air quality. (See http://www.deq.idaho.gov/air/data_reports/monitoring/aqi.cfm, http://www.deq.idaho.gov/air/aqindex.cfm, and http://www.deq.idaho.gov/air/prog_issues.cfm to get you started.)

- Visit an auto dealership that sells low-emission vehicles and/or vehicles that use alternative fuels or visit a gas station that sells alternative fuels to learn more about these technologies.

- Have students pick one type of alternative fuel (CNG, ethanol, biodiesel, hydrogen fuel cells, etc) or one type of low-emission vehicle (e.g., hybrid) and prepare a report on it. How is the fuel generated? Is it renewable? How does it affect the economy? Is that type of fuel available in my community? Are low-emission vehicles available in my community? How much do they cost compared to traditional vehicles? How does the technology work?

- Research the issue of vehicle emissions testing in general and in Idaho and prepare a written or oral report. Why are vehicles subject to vehicles emissions testing? How does the process work? Is this testing required in Idaho? Should it be (in your opinion)? If it is required, is it required in the entire state? On all vehicles? (Get started at http://www.deq.idaho.gov/air/prog_issues/pollutants/vehicles.cfm)

- Contact DEQ to learn about diesel retrofit technologies, which are available to reduce emissions from school buses (and other vehicles). Your school district may be able to apply for a grant for retrofit technologies for its buses[1].

- Encourage your school or school district to join the Clean Air Zone Idaho program (if it hasn't already). See http://www.deq.idaho.gov/air/educ_tools/clean_air_zone_idaho/index.cfm for more information.

[1] For information on retrofit grants, call Mike Edwards at DEQ at (208) 373-0502.

Additional Resources:

Air Quality Brochures, Fact Sheets, and More for Citizens and Communities
http://www.deq.idaho.gov/air/assist_citizen_comm/publications.cfm

Air Quality Educational Tools (includes information for students and teachers, activities, and more)
http://www.deq.idaho.gov/air/educ_tools.cfm

Air Quality: How it is Measured http://www.deq.idaho.gov/air/data_reports/monitoring/overview.cfm

Air Quality Index (check your air quality) http://www.deq.idaho.gov/air/aqindex.cfm

Air Quality in the Treasure Valley http://www.deq.idaho.gov/air/data_reports/monitoring/bro.cfm

Air Quality Reports, Portneuf Valley
http://www.deq.idaho.gov/air/data_reports/reports/portneuf_valley/index.cfm

Clean Air Idaho http://air.idaho.gov/

Clean Air Zone Idaho http://www.deq.idaho.gov/air/educ_tools/clean_air_zone_idaho/index.cfm

Fuel Economy www.fueleconomy.gov

Local Environmental Information http://www.deq.idaho.gov/about/office_locations.cfm

Vehicle Emissions http://www.deq.idaho.gov/air/prog_issues/pollutants/vehicles.cfm

Visibility and Haze http://www.deq.idaho.gov/air/prog_issues/pollutants/haze_overview.cfm

What Can Citizens Do to Prevent (Air) Pollution
http://www.deq.idaho.gov/multimedia_assistance/p2/citizens_overview.cfm#air

DEQ Regional Offices, Air Quality Contacts:

Boise Regional Office
Dave Luft
1445 N. Orchard
Boise, ID 83706
ph: (208) 373-0201
fx: (208) 373-0287

Coeur d'Alene Regional Office
Mark Boyle
2110 Ironwood Pkwy.
Coeur d'Alene, ID 83814
ph: (208) 769-1422
fx: (208) 769-1404

Idaho Falls Regional Office
Aaron Swift
900 N. Skyline, Suite B
Idaho Falls, ID 83402
ph: (208) 528-2650
fx: (208) 528-2695

Lewiston Regional Office
Clayton Steele
1118 "F" Street
Lewiston, ID 83501
ph: (208) 799-4370
fx: (208) 799-3451
toll free: (877) 541-3304

Pocatello Regional Office
Melissa Gibbs
444 Hospital Way, #300
Pocatello, ID 83201
ph: (208) 236-6160
fx: (208) 236-6168

Twin Falls Regional Office
Steve VanZandt
1363 Fillmore St.
Twin Falls, ID 83301
ph: (208) 736-2190
fx: (208) 736-2194

DEQ State Office Contact:

Joanna Pierce
Pollution Prevention Coordinator
1410 N. Hilton
Boise, ID 83706
ph: (208) 373-0146
fx: (208) 373-0342
joanna.pierce@deq.idaho.gov

Measuring Vehicle Exhaust—Instructions

Safety First!

- **Have at least two adults present as each vehicle is tested—one to start/run the engine (and remain in the driver's seat for the duration of the test) and one at the side/rear of the car to supervise the test.**
- **Do <u>not</u> conduct the test in a building or garage.**
- **Be sure the emergency brake is engaged on each car before beginning.**
- **Have the car radio turned OFF so the driver can clearly hear those outside the vehicle.**
- **Be sure each vehicle (tailpipe) is cool before trying to place the handkerchief on the tailpipe.**
- **Always wear gloves/oven mitts when removing handkerchiefs from the tailpipes.**
- **Stand away from the vehicle during the test.**
- **Do not touch the tailpipe until the vehicle has cooled for five minutes or more. (Even then wear gloves/oven mitts!)**

Step 1. Lay your handkerchief flat (not folded) and, using a permanent marker, **write the following on the outer edge of your handkerchief:**

- ✓ Manufacturer of car (e.g., Subaru)
- ✓ Model of car (e.g., Forester)
- ✓ Year manufactured (e.g., 2001)
- ✓ Engine type (e.g., unleaded gasoline)
- ✓ Group name or names of group members (e.g., Jeff, Lisa, Josh, and Haley's group)

Write "Control" on the outer edge of the control (extra) handkerchief.

Step 2. Using a paper towel or rag, **wipe off the end/outside of the tailpipe** to prevent dirt that has collected on the tailpipe from transferring to the handkerchief.

Step 3. Using two or more rubber bands, **tightly secure the handkerchief over the end of the tailpipe** of your group's car. Place the handkerchief so the tailpipe is approximately in the middle. See photo.

Step 4. All students and all but one adult **move at least eight feet away from the vehicle**.

Step 5. Remaining adult **start the vehicle**. See photo.

Step 6. Let the vehicle run for five minutes. One adult remain in the vehicle the entire time. Second adult stand to the side/rear of the vehicle to watch the tailpipe as the vehicle is running to ensure no problems occur and to ensure students stay a safe distance back.

Step 7. Turn the engine off.

Step 8. Wait five minutes for tailpipe to cool (OK to test another vehicle during this time).

Step 9. Using oven mitts or heavy gloves, carefully **remove the handkerchief from the tailpipe**. While the tailpipe will have cooled somewhat, it may still be hot. Be careful. See photo.

Step 10. Repeat for next vehicle.

Step 11. Return to classroom after testing all vehicles.

A. Placing handkerchief on tailpipe.

C. Removing handkerchief from tailpipe.

B. Adult starting car engine and remaining in car.

D. Line-up of handkerchiefs after the test.