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The Effect of Vehicular Emissions on Human Health

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Introduction

In 2006, the United States was responsible for 21.3% of all cars registered in the world, with a total of 135,047,000 cars. It was also responsible for 42.7% of all the trucks registered in the world, with 108,975,000 trucks registered.[1] These vehicles combine with off-road vehicles to produce millions of short tons of air pollutants a year in America alone. When asked about emissions, my students are aware that the emissions tested are some form of gas that cars put out of their exhaust. They are also aware that the catalytic converter was invented in order to reduce those emissions. But none of the students asked could tell what the specific makeups of the gases being emitted were; nor why those gases need to be monitored and reduced. In addition, when asked if "emissions" could have something to do with the interior of the car, the students unanimously stated that it could not; emissions dealt only with an exterior condition. I teach mainstream and inclusion ninth through twelfth grade high school science students in the public schools in Pittsburgh, Pa. This curriculum is designed to appeal to upper classmen repeating a course as well as under classmen just starting out, students whose study skills range from non-existent to self-sufficient, upper level honors students to inclusion student, and learning styles that range from kinesthetic to logical/analytical, while building study skills and basic knowledge of human health issues. This curriculum will focus most specifically on the pollutants emitted by the exhausts of small combustion engine vehicles and their effects on human health.

This topic can be used in several ways by the high school teacher. It is easily incorporated into a chemistry classroom, as each of the chemicals listed can be discussed using the periodic table of elements, and Lewis Dot Structures and bonding can be demonstrated. It can be used in a biology or health class, or within a medical magnet, because specific health hazards are mentioned and can be researched. It can be used in an ethics course, in that the results of technology and its negative impacts on humans can be discussed and debated. It can be used in a mathematics classroom in determining parts per million, and practicing the equations used in determining the hazard and the emissions factors. It can also be used in a government classroom through discussion of the laws and regulations relating to not only vehicular emissions but standards of air quality. It can further be used in an English classroom through research and development of an informative or persuasive paper. The lesson plans attached are useful specifically in either a science or English classroom, but can easily be adapted to other curricula. In addition, several extension lesson plans are offered.

Overview

For many years, air pollution was viewed as a visual nuisance. But as the twentieth century progressed, our understanding of air pollution evolved considerably. As a result of several highly publicized air pollution events, including the Donora, Pennsylvania fog, where 17 people died and nearly half the town's 14,000 residents became sick from a severe air pollution episode in 1948, researchers began to acknowledge that air pollution was a significant threat to public health.

On November 18, 1994, the first-ever conference on "Air Pollution: Impacts on Body Organs and Systems" was held in Washington, D.C. by the National Association of Physicians for the Environment:

> "Blood perfuses all of the body's organs and can carry toxic substances as well as beneficial substances, such as oxygen, to them. Air pollution is the source of many materials that may enter the human bloodstream through the nose, mouth, skin, and the digestive tract, containing chemicals known to be harmful, such as benzene, lead and other heavy metals, carbon monoxide, volatile nitrites, pesticides, and herbicides. These substances have been shown to produce harmful effects on the blood, bone marrow, spleen, and lymph nodes.[2] "

Air pollution can be caused by the release of small particles or noxious gases being released into the atmosphere, whether by natural or fabricated sources. These gases include carbon monoxide, sulfur dioxide, nitrogen oxide, and chemical vapors, as well as others. The gases can also lead to a chain-reaction event that includes acid rain, smog, and the greenhouse effect. If left unchecked, the chemical aspect of air pollution could become the largest contributor to premature death in the world, higher than the rate of cancer, AIDS, automobile accidents, or any other cause of unnatural or premature death.[3] Most people make the assumption that the greatest single cause of air pollution is the big factories that dot our landscape, especially in our big cities; however, the greatest single contributor to the pollution problem facing not only the United States but also the entire world is automobile emissions [4] which come mainly from cars and other types of automobiles, as well as off-road vehicles.

Transportation caused over half of the carbon monoxide, over a third of the nitrogen oxides, and almost a quarter of the hydrocarbons in ouratmosphere in 2006.[5] With the number of vehicles on the road and the number of vehicle miles traveled escalating rapidly, we are on the fast road to uncontrollable air pollution. These "mobile sources" include cars, motorcycles, and light trucks, heavy trucks and buses, nonroad recreational vehicles (such as dirt bikes and snowmobiles), farm and construction machines, lawn and garden equipment, marine engines, aircraft, and locomotives.[6] Table 1 below lists six different air pollutants monitored by the EPA, and reiterates the excessive amounts for which transportation is responsible, as well as separating highway and local driving habits.

Table 1: Transportation's Percent Share of Air Pollutants; Highway vs. Non-Highway

	Transportation's share of U.S. Emissions in %	Percent of Total National Emissions, Highway Vehicles	Percent of Total National Emissions, Off-Highway Vehicles
CO	77.6	54.1	23.93
NOx	58.3	6.6	4.02
VOCs	35.5	3.85	2.32

NH3	8.1	0.32	0.01
PM10	2.67	0.18	0.3
PM2.5	9	0.13	0.28
SO2	4.5	0.19	0.43

Table information can be found in Transportation Energy Data Book7.

Emissions from passenger vehicles are increasing in Canada and the U.S. despite attempts to make engines more fuel efficient and despite the addition of antipollution devices. Several reasons are; vehicle use has increased, cars are getting bigger as pick-up trucks, vans and sports vehicles, which burn more fossil fuel per mile, are often replacing smaller, lighter passenger cars, recreational vehicles using combustion engines are not regulated for air pollution, and vehicular modes of transport have increased across the country. Exhaust from all combustion engines combine to produce local adverse effects on the health of car users and all innocent bystanders. Table 2 below lists four pollutants monitored by the EPA, and separates them by type of fuel used, and local vs. long-distance driving. Cities have become islands of toxic chemicals from the unrestrained use of vehicles burning fossil fuels, with millions of short tons of pollution created by vehicle exhaust.

Table 2: Amount of Air Pollutants; Highway vs. Non Highway, Petrol vs. Diesel Vehicles

Type of air pollutant by vehicle emission	Amount produced by transportation (in millions of short tons)	Amount of pollutant produced by highway travel	Amount of pollutant produced by non-highway travel	Amount of total emissions pollutant produced by petrol vehicles	Amount of total emissions pollutant produced by diesel vehicles
CO	74.03	53.80%	23.80%	98%	1.60%
NOx	10.62	36.20%	22.10%	55.90%	44.10%
VOCs	6.17	22.10%	13.30%	5.90%	4.10%
PM-10	0.48	1%	1.60%	48.60%	51.40%
PM-2.5	0.41	2.80%	6.10%	36.70%	63.30%

Table information can be found in Transportation Energy Data Book.[8]

Emissions causing air pollution are associated with the full life-cycle of cars, buses, motorcycles, off-road vehicles, and trucks. This includes air pollution emitted during the refining and distribution of vehicle fuel, vehicle operation, refueling, and disposal, in the piecemeal manufacturing process, in the construction of the car itself within the factory, and within the vehicle itself from the carpeting, air conditioning system, leaks from the exhaust, and the fabrics and plastics used within the car. Therefore, motor vehicles cause both primary pollution, emitted directly into the atmosphere, and secondary pollution, resulting from chemical reactions between pollutants in the atmosphere. There are numerous ways that vehicles are linked to air pollution. The use of CFCs (chlorofluorocarbons) in car air-conditioning systems has contributed to the destruction of the earth's ozone layer, as cars leak about 1 pound of coolant a year. Tires, brakes, clutch linings are all made of, and leak into the air; lead, asbestos, and cadmium, all of which are toxic to humans and animals. Old oil from car engines that is dumped on the ground instead of being properly disposed of contaminates the environment. Just 1 quart of oil can contaminate 250,000 gallons of drinking water.[9] The amount of oil improperly dumped every 2.5 weeks in the U.S. equals the total amount lost in the Valdez spill,[10] with 250 million gallons a year of oil improperly discarded, and each year, 176 million gallons enter the storm

sewers. The tars and other organic compounds released in the smoke from automobiles also pollute the atmosphere, and, when they land on the ground, pollute the soil and can potentially enter the groundwater and drinking supply.

Not all pollution produced by cars is the same; there are two types of pollution discharged by petrol vehicles. These include; evaporative emissions, which occurs when vapors of fuel are released into the atmosphere, without being burnt, and exhaust emissions, including dangerous gases such as carbon monoxide, oxides of nitrogen, hydrocarbons and particulates.[11] The major pollutants are particulate matter, hydrocarbons, nitrogen oxides, carbon monoxide, sulfur dioxide, hazardous air pollutants, and greenhouse gases, all of which are extremely dangerous for humans. Others associated with the full life cycle include polychlorinated biphenyls, a.k.a. PCBs, which is a mix of about 70 chemicals, including C, H, and Cl. PCBs were manufactured in the U.S. from 1929-1979 for inks, hydraulic fluids, adhesives, graphites, and lubricants, so was used in many places within the manufacture of a car. As an example of the danger of these chemicals to humans, in 1968 and again in 1979, people in the orient used rice oil that was contaminated by PCBs, and widespread liver and kidney damage ensued. It was banned in 1979 but large amounts had been dumped improperly and still are found in old electrical equipment.

Rationale

Tailpipe Emissions

Tailpipe emissions are what most people think of when they think of vehicle air pollution; the products of burning fuel in the vehicle's engine, emitted from the vehicle's exhaust system. The major pollutants emitted include hydrocarbons, nitrogen oxides, carbon monoxide, carbon dioxide, particulates, sulphur dioxide and ozone (O_3).

Regular Gasoline

Your car runs by burning petrol or diesel, both of which are a complex blend of lots of different chemicals collectively called hydrocarbons. Gasoline (gas) or petroleum spirit (petrol) is a petroleum-derived liquid mixture consisting mostly of aliphatic hydrocarbons, with between 5 and 12 carbon atoms per molecule. Hydrocarbons are volatile organic compounds that include benzene, toluene, ethyl benzene, and xylenes. They consist of a mixture of n-paraffins, naphthenes, olefins and aromatics. Naphthenes, olefins and aromatics increase the octane rating of the gasoline whereas the n-paraffins have the opposite effect. Gasoline may also contain significant quantities of ethanol and some may contain small quantities of additives such as methyl tert-butyl ether as anti-knock agents to increase the octane rating, and may further be enhanced with iso-octane or the aromatic hydrocarbons toluene and benzene to increase its octane rating. Petrol is primarily used as fuel in internal combustion engines, which includes automobiles, motorcycles, buses, and off-road vehicles, and burns incompletely to produce carbon dioxide and water, as well as other pollutants.

In the 1980s, there was a move towards "lean burn" petrol engine technology — increasing the amount of air with the fuel in the engine so that more of the fuel is completely burned up. This reduces the amount of the some of the pollutants but tends to encourage the oxygen and nitrogen in the air to combine to produce Nitrogen Oxides (NOx). Some of the hydrocarbons in the gasoline do not get burned in your engine and pass

through the exhaust unchanged. There are two in particular, called Benzene and 1:3 Butadiene that can be harmful. Even with the "lean burn" technology, not all the fuel burns up completely, so some Carbon Monoxide (CO) is also produced. Gasoline can also contain some other organic compounds such as organic ethers (deliberately added), plus small levels of contaminants, in particular sulfur compounds such as disulfides and thiophenes. Some contaminants, in particular thiols and hydrogen sulfide, must be removed because they cause corrosion in engines.

The mixture known as gasoline, when used in high compression internal combustion engines, has a tendency to auto ignite (detonation) causing a damaging "engine knocking" (also called "pinging" or "pinging") noise. The discovery that lead additives modified this behavior led to the widespread adoption of addition of lead to the petrol in the 1920s and therefore more powerful higher compression engines. The most popular additive was tetra-ethyl lead. This practice began to wane in the 1980s. Most countries are phasing out leaded fuel; different additives have replaced the lead compounds. The most popular additives include aromatic hydrocarbons, ethers and alcohol (usually ethanol or methanol). Oxygenate blending adds oxygen to the fuel in oxygen-bearing compounds such as MTBE, ETBE and ethanol, and so reduces the amount of carbon monoxide and unburned fuel in the exhaust gas, thus reducing smog. In many areas throughout the U.S. oxygenate blending is mandated by EPA regulations to reduce smog and other airborne pollutants. The resulting fuel is often known as reformulated gasoline (RFG) or oxygenated gasoline.

Diesel Fuel

Residues of diesel fuel are found in every building in the United States at this time.[12] Diesel fuel in general is any fuel used in diesel engines and home "oil" furnaces. The most common is a specific fractional distillate of petroleum fuel oil. In the past, diesel fuel contained high quantities of sulfur, which are harmful for the environment because they prevent the use of catalytic diesel particulate filters to control diesel particulate matter emissions. The U.S. annual consumption of diesel fuel in 2006 was about 50 billion gallons.[13] In the United States, more stringent emission standards have been adopted with the transition to a standard for defining diesel fuel with substantially lowered sulfur contents, (ULSD,) starting in 2006 and becoming mandatory on June 1, 2010. As of 2007, almost every diesel fuel available in America and Europe is the ULSD type. However, the process for lowering sulfur also reduces the lubricity of the fuel, meaning that additives must be put into the fuel to help lubricate engines, most of which are harmful as well.

Specific Health Hazards of Hazardous Air Pollutants

Hazardous air pollutants are chemical compounds which are emitted by cars, trucks, refineries, gas pumps, and related sources, and have been linked to birth defects, cancer, and other serious illnesses. There are currently 188 hazardous air pollutants that are regulated. The major pollutants emitted through the exhaust system include hydrocarbons, nitrogen oxides, carbon monoxide, carbon dioxide, particulates, and sulphur dioxide, all of which fall into the category of hazardous air pollutants (HAPs.) There are currently 188 hazardous air pollutants that are regulated. This group of chemicals is also commonly referred to as toxic air pollutants, or simply air toxics. Other pollutants from vehicle exhaust, although intuitively can be considered as hazardous air pollutants, are called criteria pollutants. The 1990 Amendments to the Clean Air Act require that EPA significantly reduce emissions to the air of this particular set of chemicals. Many different types of sources can release air toxics, including on-road and off-road mobile sources such as cars, trucks, and construction equipment, as well as snow mobiles, ATVs, and school buses.

Those Most at Risk

Due to engine exhaust, illnesses are becoming worse. People who suffer from serious illnesses, including asthma, chronic obstructive pulmonary disease (COPD), cardiovascular disease, diabetes, and lung cancer suffer more often and more severely. Tens of millions of Americans suffer from these illnesses. Children, the elderly, those with compromised immune systems, and those with specific genetic traits are at special risk.[14] Recent health literature indicating that residents near major roads face elevated rates of several adverse health outcomes has prompted legal dispute over the responsibility of transportation agencies to use roadway air dispersion models to characterize the impacts of new and expanded roadways, bus terminals, truck stops, and other sources. In a typical urban area (i.e., at the "community scale"), toxic air pollutants are of particular concern because people and sources of emissions are concentrated in the same geographic area.

According to the 2000 census,[15] approximately 226 million out of 281 million Americans live in metropolitan areas. Since most Americans live in these areas, this proximity leads to the potential for large numbers of people to be exposed to numerous air pollutants (some at potentially high concentrations). Everyone in a traffic jam is exposed to hazardous mixtures through tailpipe and evaporative emissions, when hydrocarbon pollutants escape into the air through fuel evaporation - evaporation causes significant hydrocarbon pollution from cars on hot days when ozone levels are highest. Benzene, acetaldehyde, acrolein, and 1, 3-butadiene are examples of toxic air pollutants associated with motor vehicle emissions.[16] The negative effects of automotive emissions are maximized when sitting in traffic surrounded by cars, their engines idling. The Environmental Protection Agency estimates that the air toxics emitted from cars and trucks account for half of all cancers caused by air pollution.[17]

Within these communities, there may be additional exposure considerations of concern, including populations with special sensitivities (e.g., children and the elderly) or environmental justice communities. Sources of urban emissions tend to be relatively small in size but large in number (e.g., gas stations or mobile sources), and they typically emit chemicals at ground level where people are more likely to be exposed to them. Studies have shown that school children are exposed to an extremely high amount of air pollution, due to walking or standing by roadsides, sitting on idling buses, and riding buses to school. In addition, it has been realized that many of the air intakes for the school are situated near where the school buses idle, sucking the toxic gases right into the school's circulation system.[18]

The 1990 Amendments to the Clean Air Act require that EPA significantly reduce emissions to the air of this particular set of chemicals that are known or suspected to cause serious health problems, such as cancer or birth defects. Many different types of sources can release air toxics, with on-road and off-road mobile sources such as cars, trucks, and construction equipment, as well as snow mobiles, ATVs, and school buses responsible for the largest percent. The two types of pollutants, (i.e., HAPs and criteria pollutants,) are regulated under different sections of the CAA.

Hydrocarbons

Hydrocarbons (HCs) are made up of unburned or partially burned fuel, and are a major contributor to urban smog, as well as being toxic. HCs are pollutants that react with nitrogen oxides in the presence of sunlight to form ground level ozone, a primary ingredient in smog, the formation of which can lead to risk of damage to the human respiratory system. Though beneficial in the upper atmosphere, at the ground level this gas irritates the respiratory system, causing coughing, choking, and reduced lung capacity. In addition, some kinds of HCs are also indirect greenhouse gases, and can cause liver damage and even cancer. Many of these HCs are considered hazardous substances and are regulated in the United States by Occupational Safety and Health Administration [19]. The Material Safety Data Sheet for unleaded gasoline shows at least fifteen

hazardous HCs occurring in various amounts. HCs are volatile organic compounds (VOCs) that include benzene, toluene, naphthalene, trimethylbenzene, MTBE and about ten others. [20] While these compounds can cause dizziness, headaches, and loss of consciousness, the EPA and the U.S. Department of Health and Human Services, from overwhelming human evidence and supporting animal studies, have specifically identified benzene as a carcinogen, with leukemia [21] specifically named.

Benzenes

Death may occur in humans and animals after brief oral or inhalation exposures to high levels of benzene; however, the main effects of these types of exposures are drowsiness, dizziness, and headaches. Leukemia (cancer of the tissues that form the white blood cells) and subsequent death from cancer have occurred in some workers exposed to benzene for periods of less than 5 and up to 30 years. Long-term exposures to benzene may affect normal blood production, possibly resulting in severe anemia and internal bleeding. In addition, human and animal studies indicate that benzene is harmful to the immune system, increasing the chance for infections and perhaps lowering the body's defense against tumors. Benzene can be measured in the blood and the breath. The body changes benzene to phenol, which can be measured in the urine. Exposure to benzene has also been linked with genetic changes in humans and animals.[22] Animal studies indicate that benzene has adverse effects on unborn animals, including low birth weight, delayed bone formation, and bone marrow damage. Some of these effects occur at benzene levels as low as 10 parts of benzene per million (ppm) parts of air.

The Environmental Protection Agency (EPA) set the maximum permissible level in drinking water at 5 parts of benzene per billion parts of water (ppb), which is higher than the level in air to shown effects. Because benzene can cause leukemia, EPA established an ultimate goal of 0 ppb for benzene in drinking water and in ambient water such as rivers and lakes.[23] The EPA realizes that this goal may be unattainable and has estimated how much benzene in ambient water would be associated with one additional cancer case for every 100,000 persons (6.6 ppb benzene), one case for every 1 million persons (0.66 ppb benzene), and one case for every 10 million persons (0.066 ppb benzene). The National Institute for Occupational Safety and Health (NIOSH) has recommended an occupational exposure limit in air of 0.1 ppm. [24] The Occupational Safety and Health Administration's (OSHA) legally enforceable limit is an average of 1.0 ppm over the standard 8-hour workday, 40-hour workweek.[25]

Nitrogen Oxides

Nitrogen oxides are generated when nitrogen in the air reacts with oxygen under the high temperature and pressure conditions inside the engine. Oxides of Nitrogen (NOx) react in the atmosphere to form Nitrogen Dioxide (NO_2) which can have adverse effects on health, particularly among people with respiratory illness. NOx are pollutants that cause lung irritation and weaken the body's defenses against respiratory infections such as pneumonia and influenza, can cause shortness of breath and chest pains and increase a person's susceptibility to asthma. High levels of exposure have been linked with increased hospital admissions due to respiratory problems, while long term exposure may affect lung function, chronic lung disease, and increase the response to allergens in sensitive people. NOx also contribute to smog formation, the formation of particulate matter, acid rain, can damage vegetation and contributes to ground level ozone formation. Nitrogen oxides also upset the chemical balance of nutrients in the water, which can cause problems with the animals and plants that are dependent upon the water, leading to reduction of the fish and shellfish population.[26]

Carbon Oxides

Carbon monoxide (CO) is an odorless, colorless, and poisonous gas and is formed by the combustion of fossil fuels such as gasoline and is emitted primarily from cars and trucks. It is a product of incomplete combustion and at low concentrations CO may pose a health risk and is especially dangerous to the elderly, people with cardiovascular disease or other circulation disorders, anemic individuals, young infants, and pregnant women.[27] CO reduces the blood's oxygen carrying capacity, and, when inhaled, blocks the transport of oxygen to the brain, heart, and other vital organs in the body. Extreme levels of exposure, such as might occur due to blockages in tailpipes, can be fatal. Fetuses, newborn children, and people with chronic illnesses are especially susceptible to the effects of CO. In addition, carbon monoxide is directly linked to visual impairment, reduced work capacity and mental dexterity, poor learning ability, nausea, headaches, dizziness, and even death.[28]

Motor vehicles also emit pollutants, such as carbon dioxide, that contribute to global climate change, and are within the category of greenhouse gases. One gallon of gasoline creates 18 pounds of CO_2. The U.S. alone produces 22 billion tons a year of CO_2.[29] The transportation sector currently accounts for over a quarter of all U.S. greenhouse gas emissions.

Acrolein

Acrolein is a colorless or yellow liquid with a disagreeable odor. It dissolves in water very easily and quickly changes to a vapor when heated and also burns easily. Small amounts of acrolein can be formed and can enter the air when trees, tobacco, other plants, gasoline, and oil are burned. Breathing large amounts can damage lungs and can cause death. Animal studies show that breathing acrolein causes irritation to the nasal cavity, lowered breathing rate, and damage to the lining of the lungs. Animals that swallowed acrolein suffered stomach irritation, vomiting, stomach ulcers and bleeding. In animal studies, ingestion of very large amounts of acrolein during pregnancy caused reduced birth weights and skeletal deformities in newborns, while the levels causing these effects were often fatal to the mother. The EPA has stated that the potential carcinogenicity of acrolein cannot be determined based on an inadequate database.[30]

Particulate Matter

Particulates are tiny solid particles which can bind to and clog the respiratory tract. Particulate matter (PM) consists of particles of soot and metals that give smog its murky color. PM, also found in off-road vehicle emissions, is detrimental when found in both fine ($PM_{2.5}$) and coarse (PM_{10}) forms as it accumulates in the respiratory system, and can lead to decreased lung function, respiratory disease and even death.[31] $PM_{2.5}$ consists of particles less than one-tenth the diameter of a human hair and poses the most serious threat to human health, particularly among those with existing respiratory disorders, as they can penetrate deep into lungs. Particles have been associated with increased hospital admissions due to respiratory problems and hastening the deaths of those suffering from respiratory illnesses. Very little particulate emission is from petrol engines, though, with much more coming from diesels, disproportionately from the larger diesels in trucks and buses, and an exponential amount from ATVs and snowmobiles. Of the pollutants emitted by off-road vehicles, particulates are of special concern because their small size makes them easily respirable and thus deliverable directly into the lungs, causing any number of the aforementioned maladies.[32]

In addition to direct emissions of fine particles, automobiles release nitrogen oxides, hydrocarbons, and sulfur dioxide, which generate additional fine particles as secondary pollution. The National Environmental

Technology Centre (NETCEN) recently suggested that one bus can produce as many particulates as 128 typical cars.[33] Diesel combustion exhaust is an important source of atmospheric soot and fine particles, which is a type of air pollution implicated in human heart and lung damage. Diesel exhaust also contains nanoparticles which have been found to damage the cardiovascular system in a mouse model.[34] Particulates that are released into the air via car exhaust can have an impact upon the precipitation that an area gets. Research has found that it can cause an area to get less rain, which can have a significant impact upon the water sources in your area.[35]

Sulphur Oxides

Sulphur oxide (SOx) is the general term for oxides of sulphur, mostly sulfur dioxide and some sulfur trioxide, from coal or unrefined oil. Sulfur dioxide (SO_2) is created both by power plants and motor vehicles, which create this pollutant by burning sulfur-containing fuels, especially diesel. In the state of Pennsylvania, the source of the HAP with the highest contribution to cancer risk was diesel emissions.[36] Sulfur dioxide can react in the atmosphere to form fine particles and poses the largest health risk to young children and asthmatics. According to the CDC, exposure to SOx can create a number of health problems, including sweating, papillary constriction, muscle cramps, excessive salivation, dizziness, labored breathing, nausea, vomiting, convulsions, and unconsciousness, as well as possibly being absorbed by the skin and creating severe diarrhea. In addition, the CDC warns that the substance may cause effects on the nervous system, resulting in respiratory depression. It is a cholinesterase inhibitor, and exposure may result in death. It is also quite deleterious for the environment.

PAHs

Polycyclic aromatic hydrocarbons, (PAHs,) are a group of chemicals that are formed during the incomplete burning of coal, oil and gas, garbage, or other organic substances. PAHs can be man-made or occur naturally. There are more than 100 different PAH compounds. PAHs attach to dust and other particles in the air or in soil or sediment as solids and originate from vehicle exhausts, asphalt roads, coal, coal tar, wildfires, agricultural burning and hazardous waste sites. They can also be found in substances such as crude oil, coal, coal tar pitch, creosote, road and roofing tar. Most PAHs do not dissolve easily in water, but some PAHs evaporate into the air. PAHs generally do not burn easily and they will last in the environment for months to years. Background levels of PAHs in the air are reported to be 0.02-1.2 milligrams per cubic meter (mg/m3) in rural areas and 0.15-19.3 mg/m3 in urban areas.[37]

PAHs are changed into chemicals that can attach to substances within the body. They enter the body quickly and easily by all routes of exposure, and enter easily through the lungs. The rate at which PAHs enter your body is increased when they are present in oily mixtures and then tend to be stored in the kidneys, liver, and fat, with smaller amounts in the spleen, adrenal glands and ovaries. The U.S. Department of Health and Human Services has determined that PAHs may be carcinogens;[38] reports in humans show that individuals exposed by breathing or skin contact for long periods of time to mixtures of other compounds with PAHs develop cancer. Mice fed high levels of benzopyrene during pregnancy had difficulty reproducing and so did their offspring. The offspring from pregnant mice fed benzopyrene also showed other harmful effects, such as birth defects and decreased body weight.

Studies in animals have also shown that PAHs can cause harmful effects on skin, body fluids, and the body's system for fighting disease after both short- and long-term exposure. The presence of PAHs can be measured in body tissues or blood after exposure, and PAHs or their breakdown products can also be measured in urine.

Although these tests can tell that you have been exposed to PAHs, it is not yet possible to use these tests to predict the severity of any health effects that might occur or to determine the extent of your exposure to the PAHs.[39]

MMT, MTB, Phosphorous, and ETBE

Methylcyclopentadienyl manganese tricarbonyl (MMT) has been used for many years to boost octane and helps old cars designed for leaded fuel run on unleaded fuel without need for additives to prevent valve problems, but a large Canadian study concluded that MMT impairs the effectiveness of automobile emission controls and increases pollution from motor vehicles.[40] U.S. Federal sources state that MMT is suspected to be a powerful neurotoxin and respiratory toxin.[41] MTBE use is being phased out in some states due to issues with contamination of ground and water. Many of the non-aliphatic hydrocarbons naturally present in gasoline (especially aromatic ones like benzene), as well as many anti-knocking additives, are carcinogenic. Because of this, any large-scale or ongoing leaks of gasoline pose a threat to the public's health and the environment, should the gasoline reach a public supply of drinking water. Although phosphorus is no longer used in gasoline, it (and zinc, another low-level catalyst contaminant) was until recently widely used in engine oil antiwear additives such as ZDDP. ZDDP is a skin, eye, and respiratory irritant, and has shown in animal studies to be responsible for low sperm count.[42] ETBE is also associated with harmful effects for humans,[43] and has been shown to create liver and kidney problems, as well as narcotic effects in mice, and is considered harmful to marine invertebrates.

Political Intrigue

Many different nations have regulatory policies where air pollution is concerned. Automobile companies are expected to make vehicles that follow these emissions laws, and many auto manufacturers have come up with vehicles that emit less in the way of harmful gases. New regulations are being developed to control marine emissions, farm equipment, and gas-powered personal equipment such as lawnmowers and other landscaping equipment, but there are no true restrictions on any off-road vehicles.

In the mid-20th century, Congress recognized the potential for air pollution to cause health problems and responded by enacting the Clean Air Act (CAA) specifically designed to target smog and air pollution. Before1970, there were no rules on air pollution, and then the EPA was formed, and began setting limits on how much of a pollutant may be in the air anywhere in the United States, allowing each individual state to set more stringent standards if needed. In 1971, national ambient air quality standards were introduced for 6 major air pollutants: particles, hydrocarbons, photochemical oxidants, sulfur oxides, carbon monoxide, and nitrogen oxides. By 1973, there were air, water, and wildlife regulations. Unfortunately, air pollutants created in one state often create problems in other states, which then have little control over their resultant air quality.

Air quality index averages over the country have improved significantly since the Clean Air Act was passed in 1970. Yet, those are averages over large areas. It is now known that almost half of all Americans - over 130 million people - still live in areas that violate federal health standards for air pollution,[44] and we now understand that even modest amounts of air pollution at levels lower than current federal health standards can have significant and detrimental impacts on public health.[45] In some larger metro areas, air pollution routinely reaches unhealthy levels nearly twice a week, and in 52 larger metropolitan areas (for which data was available), air quality was unhealthy at least once a month during the period 2000 to 2002.[46] In short, while significant progress has been made in reducing air pollution nationwide, many regions have, and

millions of people still live, with poor air quality that poses a significant threat to public health.

Fossil fuel combustion, particularly as it occurs in motor vehicles, has been identified as the LARGEST contributor to air pollution in the WORLD.[47] The EPA responded by establishing emission standards to regulate the amount of pollutants entering the air from vehicles, power plants, aircraft, and other industries. In 1977 use of MMT was banned in the U.S. by the CAA until the Ethyl Corporation could prove that the additive would not lead to failure of new car emissions-control systems. As a result of this ruling, the Ethyl Corporation began a legal battle with the EPA, presenting evidence that MMT was harmless to automobile emissions-control systems. In 1995 the US Court of Appeals ruled that the EPA had exceeded its authority, and MMT became a legal fuel additive in the US. This is a prime example of the improvements that are still needed to be added to the CAA.

In 1990, a significant set of strengthening amendments to the CAA aimed specifically at reducing air pollution from cars and heavy duty vehicles was approved, since it was increasingly evident that underestimating transportation as a major source of air pollution had been a significant factor in the failure of many air pollution control plans. To help states and metropolitan areas cut pollution from cars, buses and trucks, in addition to meeting the goals of the CAA, Congress established the Congestion Mitigation and Air Quality Improvement program (CMAQ) when it passed the Intermodal Surface Transportation Efficiency Act (ISTEA) in 1991. Under that program, states have spent over $11 billion in federal funds over the last 11 years to provide greater mobility and improve air quality in non-attainment and maintenance areas. Of that, more than $5 billion has been used for public transit projects. The CMAQ program provides a dedicated source of federal funds to help states meet the air quality standards set under the Clean Air Act. In February 2001, the U.S. Supreme Court also upheld the right of the EPA to use health-based air quality standards. Since that time, the CAA, as amended, has provided the primary authority that EPA uses to develop programs for protecting people and the environment from the harmful effects of air pollution across the U.S.

In the U.S., where lead had been blended with gasoline (primarily to boost octane levels) since the early 1920s, standards to phase out leaded gasoline were first implemented in 1973. In 1995, leaded fuel accounted for only 0.6% of total gasoline sales and less than 2,000 short tons of lead per year. From January 1, 1996, the CAA completely banned the sale of leaded fuel for use in on-road vehicles. Possession and use of leaded gasoline in a regular on-road vehicle now carries a maximum $10,000 fine in the U.S. However, fuel containing lead may continue to be sold for off-road uses,[48] including aircraft, racing cars, farm equipment, and marine engines.

Recently, the Sierra Club of Nevada sued the Nevada Department of Transportation and the Federal Highway Administration over its their failure to assess the impact of the expansion of US-95 in Las Vegas on neighborhood air quality.[49] The Sierra Club asserted that a supplemental Environmental Impact Statement should be issued to address emissions of hazardous air pollutants and particulate matter from new motor vehicle traffic. They asserted that modeling tools were available, including the EPA's MOBILE6.2 model, the CALINE3 dispersion model, and other relevant models. The Department of Transportation won in the U.S. District Court under Judge Philip Pro, who ruled that the transportation agencies had acted in a manner that was not "arbitrary and capricious," despite the agencies' technical arguments regarding the lack of available modeling tools being contradicted by a number of peer-reviewed studies published in scientific journals. On appeal to the 9th Federal Circuit Court, the court stayed new construction on the highway pending the court's final decision. The Sierra Club and the defendants settled out of court, setting up a research program on the air quality impacts of US-95 on nearby schools.

Emissions regulations vary considerably from jurisdiction to jurisdiction, as do what engines are regulated. In the United States, there are several states which only test vehicles in certain cities within the state, and, at that, require only certain vehicles within a certain time frame of manufacture. In California, where there have been emissions tests for some time, the residents of the state argue that the tests should not be required, and are a waste of time. Currently, there are no statutes being proposed to unite all states in agreement on vehicular emissions. Diesel engine regulations are similarly varied, with some jurisdictions focusing on NOx (nitric oxide and nitrogen dioxide) emissions and others focusing on particulate (soot) emissions. This can cause problems for the engine manufacturers as it may not be economical to design an engine to meet two sets of regulations. There are currently no regulations whatsoever on off-road vehicles or school buses.

Catalytic Converters

The catalytic converter is a device which converts various emissions into less harmful ones using, generally, a combination of platinum, palladium and rhodium as catalysts. They make for a significant, and easily applied, method for reducing tailpipe emissions. In order to remove sulfur using a catalytic converter, gases are passed over a special chemical called a catalyst, which speeds up a reaction, and converts harmful sulfur dioxide to sulfur trioxide, by binding with another oxygen atom. The sulfur trioxide can then be combined with water to form sulfuric acid, which can be collected and sold.

Due to the negative effects caused by catalyst poisoning, which occurs when the catalytic converter is exposed to exhaust containing substances that coat the working surfaces, encapsulating the catalyst so that it cannot contact and treat the exhaust, some positive results have developed. One example is 'leaded' fuel (a fuel with lead content.) When burnt, there will be a residue of lead which can damage the catalytic converter. With the discovery of the environmental and health damage caused by the lead, and the incompatibility of lead with catalytic converters, it became necessary to force unleaded gasoline to be used. Since 1975, virtually all newly sold U.S. automobiles are equipped with catalytic converters and can only be run on unleaded gasoline. The virtual elimination of lead has been one of the most successful reductions in air pollution. Other common catalyst poisons include manganese primarily from MMT, silicon, and phosphorus. Currently, there is a push to replace these chemicals with a less harmful compound. Yet, the effect of catalytic converters is offset by the dramatic increase in the fleet of cars. This year alone there is an overcapacity for production of 18 millions cars worldwide; next year the overcapacity will be 20 million, which may encourage more people to buy cars. So cities will be increasingly congested,[50] which, in turn, raises the exposure to each of the harmful emissions.

Off-Road Vehicles Which Cause Emissions

It is well-established that off-road vehicles contribute a large amount of pollution to the air. While emissions from on-road vehicles decreased 56% over the last 20 years as a result of emission control programs, there was a 42 percent increase in ATV emissions during the same time period.[51] For example, on-road vehicle emissions of nitrogen oxide were virtually unchanged during the same twenty-year span, while emissions from off-road vehicles increased 56 percent.[52] According to the EPA, if left uncontrolled, off-road vehicles will contribute 33 percent of hydrocarbon emissions, nine percent of carbon monoxide, nine percent of nitrogen oxide, and two percent of particulate emissions nationally by 2020.[53] The EPA has yet to establish emission standards for off-road vehicles and the engines on which they run. The off-road vehicle industry has been slow to adopt technological changes that could lessen the impact of its machines on air quality at the local, and even the global, level. And while the industry has been sluggish, government regulatory and enforcement agencies have been all-too complacent in allowing continued degradation.

The EPA found that ATVs emit more than 381,000 tons of hydrocarbons, 1,860,000 tons of carbon monoxide, and 11,000 tons of nitrogen oxide each year across the country.[54] The EPA went even further to research individual ATVs: they showed that a two-stroke ATV or motorcycle could emit as much pollution as more than thirty automobiles operating in the same time frame. Even more shocking is that the ATV took a distant second from two-stroke snowmobiles, which can emit as much as nearly one hundred automobiles in the same time frame.[55] These emissions have all been shown to affect human health. Despite this fact, the U.S. EPA has yet to establish emission standards for off-road vehicles.

Snowmobiles are the Biggest Polluters in Off-Road Vehicles

With 36 million registered all-terrain vehicles and 12 million registered snowmobiles in the U.S. alone, these machines are a significant source of pollutants. They run on inefficient two and four-stroke engines that emit several dangerous gasses and chemicals including carbon monoxide (CO), hydrocarbons (HC), nitrogen oxide (NOx), and particulate matter (PM),[56] yet are not monitored in any way by the EPA. While ATV sales outnumber those of other off-road vehicles, two-stroke snowmobiles are much more polluting and contribute more air pollution per vehicle than any other type of vehicle. Extensive research on snowmobile emissions has been carried out in Yellowstone National Park, and by the Southwest Research Institute, based in Texas. Research conducted in 2000 showed that average carbon monoxide levels sampled over an eight hour period inside the West Yellowstone park entrance exceeded the 9.0 parts per million (ppm) standard of the National Ambient Air Quality Standards.[57] Putting it in sharper perspective, at 25 miles per hour, on-road vehicles emit around 45 gallons/mile of carbon monoxide, while snowmobiles emit 348 gallons/mile. This is an 87 percent difference in emission rates between the two vehicles and the engines that power them.[58] Thus, the 720 snowmobiles that are currently allowed in Yellowstone National Park each day emit more carbon monoxide than 5000 on-road vehicles.[59]

In A Nutshell

Transportation is a critical component of any effort to reduce air pollution, as vehicles are still a major source of air pollution in this country. Although we have made great strides in cleaning up auto emissions, we are also driving more. In some parts of the country, the increase in driving is slowing down, or even reversing, the trend toward cleaner air.

It has been shown that exposure to benzene is related to the development of leukemia and lymphoma, and there may be several targets of toxicity, including stem, progenitor, and some stromal cells. Carbon monoxide binds to hemoglobin two hundred times more avidly than oxygen and distorts the release to the tissues of any remaining oxygen. Thus, CO poisoning isa form of suffocation and can exacerbate cardiovascular disease in humans. Some airborne chemicals, HAPs, stimulate the immune system to activate leukocytes and macrophages that can produce tissue damage, especially to the cells that line human blood vessels, accelerating the changes that eventually lead to hypertension and ischemic heart disease. In various studies, increased levels of air pollutants are accompanied by increased psychiatric emergency calls and hospital admissions, behavior changes, and a lessened sense of well-being.[60]

The central nervous system appears to be a target of gasoline toxicity following acute-duration exposures in both humans and animals. In humans, acute inhalation exposure to gasoline is characterized by eye irritation, dizziness, headaches, giddiness, euphoria, vertigo, blurred vision, nausea, numbness, drowsiness, anesthesia, and coma.[61] Children admitted to the hospital as a result of gasoline ingestion exhibited central nervous

system complications such as convulsions, coma, and lethargy.[62] Chronic intermittent exposure to high levels of gasoline is associated with neurological effects, such as cerebellar effects including postural tremor, ataxia, abnormal gait; affected speech; fatigue; headaches; memory loss; and sleep problems.[63] Behavioral and intellectual changes (effects on visual memory and perception, psychomotor disturbances, or changes in visuomotor learning ability) have been observed in individuals chronically exposed to gasoline vapors. Animals acutely exposed by inhalation to high levels of gasoline also exhibit neurotoxic effects, including restlessness, equilibrium disturbances, convulsions, and narcosis. [64]

The effects of car pollution are far reaching. Due to vehicular emissions, cardiovascular effects, nervous system effects, and respiratory problems are seen. It also contributes to the formation of ozone, which causes severe respiratory and environmental effects. Though action is being taken to reduce the effects of car pollution on the planet, more needs to be done to preserve life and health. The public must become more informed about the deleterious effects of vehicular emissions.

Objectives

The student will be able to weigh the cost of government interference against an environmental issue. The student will be able to use computers to research technology and its impact on society. The student will be able to discriminate information and record facts while forming questions to guide comprehension. The student will be able to artistically represent information as a public service. The student will be able to make comparisons between state laws and contrast with need for government guidance.

Strategies

I believe that all children can learn, but that they do so in varied ways, some of which are easier for them to use than others. My goal as a teacher is to reach students of diverse learning styles through the use of different teaching techniques. Students will gain more knowledge, retain more information, and perform far better when teaching styles match learning styles.[65] However, it is recognized that it is difficult to match a single lesson with every learning style and therefore, a portfolio of teaching styles is recommended.[66] Extraverts need activities that will require them to engage in reflective thinking and to communicate that thinking in writing rather than orally. Introverts need to have their thinking stimulated and to be able to quietly rationalize their ideas. Activities which physically engage encourage all students to be involved, while art projects foster internalization and allow the students to express themselves in unique ways. In Pittsburgh, we have adopted the "5E" program of teaching, which encourages teachers to explore several ways to present information to the students, as well as to allow them time to explore the information themselves. In this way, each student can find a way to internalize their learning.

Lesson Plans Overview

Engage: Guided debate session on limiting daily vehicular mileage. Explore: Internet research to determine

what health issues relate to which chemical ingredients, and on the catalytic converter; who invented it, where and when, for what purpose, and what results it gives us. Explain: Guided notes with Power Point, students illustrate catalytic converter and label the parts of the converter. Elaborate: Students collaborate to create poster or brochure as a "public health service" to warn the public of the health issues that may result from the exposure to vehicle emissions. Evaluate: Cooperatively compare and contrast 3 states' vehicle emissions laws and regulations. Students will debate if government should create laws about vehicle emissions, and if so, what they should be.

Lesson Plan I:

The students are given prepared arguments and are to determine whether the argument given is a "pro" or "con" for limiting daily vehicular mileage. The students will arrange themselves on opposite sides of a conference table according to their position on the issue. The students will take turns reading their position out loud, with the pro first, and the student on the opposite side of the table with the con will respond. This continues until all students have read a prepared statement. Students are then to leave their position papers and rearrange themselves according to their feelings about the issue and will re-debate the issue, using the prepared notes as guidelines only. The teacher will then stop the debate and have the students, as a class, explain what they have learned from the debate, and ask any questions that have resulted from it, for further research and discussion later in the week.

Lesson Plan II:

Students are given a list of the chemicals found in the complete life cycle of vehicles. They are to use this list to determine no less than two impacts each vehicle has on human health. Students will create a table, using EXCEL, to graphically represent their findings. Students will research the catalytic converter to answer the 5 W's (who invented it, when, for what reason, how does it work, and what results does it give.)

Lesson Plan III:

Students are put into small groups (2 or 3 students each is best) and are assigned 3 states in the United States to research. They are to use the internet to determine what the CURRENT laws on vehicle emissions are for all vehicles in each state. They should be able to answer 5 questions for each state: What is the law? When was it enacted? What are some specific reasons in that state for the enactment of this law? How do citizens in that state comply, and demonstrate compliance? What are the arguments used in the state by its citizens for and against this law? After research, the students will cooperatively explain their findings to the teacher and the rest of the class. When all students have explained their findings, students will create a minimum of three arguments for their personal position about whether the government should have the power to create laws about emissions.

For more extensive lesson plans, extensions, on-going research on air pollutants in the Pittsburgh Public Schools, and teacher resources, contact author via email. rrossman1pghboe.net

Annotated Reading Lists

Annotated Suggested Student Reading List

Brininstool, Jason. Off -Road Vehicle Emissions and Their Effects on Human Health. Road-RIPorter Issue: Spring Equinox 2006, Volume 11 #1 http://www.wildlandscpr.org/biblio-notes/off-road-vehicle-emissions-and-their-effects-human-health

http://yosemite.epa.gov/oswer/ceppoweb.nsf/content/index.htm

(This article provides a brief overview of the effect of emissions on human health and demonstrates the need for testing on recreational vehicles quite clearly.)

Jamssem, S., T. Schettler. 2003. Health implications of snowmobile use in Yellowstone National Park. 27p. http://www.womenandenvironment.org (An overview of snowmobile effects on human health, as found by a study in Yellowstone Park, and examines the park service's decision to limit the use of these vehicles rather than phase them out entirely. Students must go to the website and type in Yellowstone as a search vehicle on the site.)

Stanford University (2008, January 4). Carbon Dioxide Emissions Linked To Human Mortality. Science Daily. Retrieved June 29, 2008, from http://www.sciencedaily.com/releases/2008/01/080103135757.htm (Discusses the effects of carbon dioxide, and the EPA's decision to not allow states to set their own emissions standards.)

US EPA. http://www.epa.gov (A thorough research tool for environmental impact analyses.)

Wargo, John, PhD., Wargo, Linda, MES, Alderman, Nancy. The Harmful Effects of Vehicle Exhaust: A Case for Policy Change. Jane Bradley. Environment and Human Health, Inc. 2006. Can be accessed or ordered at http://www.ehhi.org/diesel/exhaust_effects_06.shtml (an incredible resource for students to follow the issues in plain speak, while relating it to their own lives.)

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http://www.access.gpo.gov/su_docs/fedreg/a990719c.html (the PDF file is indexed at:

http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=1999_register&docid=99-17774 - filed as a pdf. (This website lists 33 HAPs identified as posing the greatest risk to public health in the largest number of urban areas. In addition, it identifies other air toxics and discusses the Integrated Urban Air Toxics Strategy.)

Jamssem, S., T. Schettler. 2003. Health implications of snowmobile use in Yellowstone National Park. 27p. http://www.womenandenvironment.org/Health_Imp_snow.pdf (An overview of snowmobile effects on human health, as found by a

study in Yellowstone Park, and examines the park service's decision to limit the use of these vehicles rather than phase them out entirely. Students must go to the website and type in Yellowstone as a search vehicle on the site.)

Standards

Pennsylvania Science Standards

- S1. All students explain how scientific principles of chemical, physical, and biological phenomenon have developed and relate them to real-world situations.
- S2. All students demonstrate knowledge of basic concepts and principles of physical, chemical, biological and earth sciences.
- S5. All students construct and evaluate scientific and technological systems using models to explain or predict results.
- S7. All students evaluate advantages, disadvantages and ethical implications associated with the impact of science and technology on current and future life.
- S9. All students demonstrate basic computer literacy, including word processing, software applications, and the ability to access the global information infrastructure, using current technology.
- S3.8. All students will recognize that technology and scientific knowledge influence society through the impact of their products and processes.
- S4.3.12.A - Analyze the complexity of environmental health issues.

National Standards

1. . Unifying Concepts and Processes: evidence, models, and explanation
2. . Science as Inquiry: abilities necessary to do scientific inquiry
3. . Life Science: biological evolution
4. . Life Science: behavior of organisms
5. . Science in Personal and Community Perspectives: personal and community health

Notes

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