ESA 21 Activities for AP Environmental Science: Air Pollution

Introduction

How Humans Change the Atmosphere

In addition to the natural changes that occur in the atmosphere, many of the activities we humans engage in can change the atmosphere, principally by altering the chemistry or gaseous composition of the atmosphere. Many human activities release trace amounts of gases or particulates that can result in a variety of impacts on human health and the environment.

For example, there are many technologies or devices burn wood, coal, or oil inside buildings such as woodstoves, boilers, furnaces, ovens and heaters. When these devices are used, they must be probably vented to the outside because the gases that result from combustion can have a serious impact on the ability of we humans to breathe. Carbon monoxide is one such gas that often results from combustion and it is becoming more common for carbon monoxide monitors or alarms to be installed within homes and buildings.

Carbon monoxide, or CO, is a colorless, odorless gas that results from incomplete combustion or burning of fuel. Normally, the atmosphere contains a very small amount of carbon monoxide, about 200 parts per billion (ppb), or .02 parts per million (ppm). If the concentration of carbon monoxide in the air you breathe increases slightly to 9 parts per million, you may begin to have difficulty breathing. A healthy person may be just barely affected by CO exposure of 9 ppm, but older individuals and asthmatics, whose lung function may be already compromised, are likely to feel a greater level of effect.

Carbon monoxide reduces the ability of the body's blood to absorb oxygen. It is also colorless and odorless making detection difficult. Inhaling low levels of carbon monoxide can result in fatigue and chest pain, particularly in individuals with chronic heart disease. Increased exposure to CO can result in headaches, dizziness, sleepiness, nausea, vomiting, and disorientation. At very high levels, inhalation of carbon monoxide can cause loss of consciousness and death. Every year, several hundred lives are lost in the U.S. as a result of carbon monoxide inhalation.

An increase from .02 to 9 ppm in carbon monoxide may seem like a large relative increase, but a change of this magnitude is a change of only 0.000088% in the total concentration of gases in the air you breathe. So you see, a small relative change in the composition of gases in the atmosphere can have a big impact. Also, several fuel burning or combustion devices commonly found in buildings can increase the amount of carbon monoxide by amounts much greater than 9 ppm. For example, CO levels in a room with unvented kerosene space heaters will vary between 0.5 and 50 ppm. Chimney smoke from a woodstove contains 5,000 ppm of CO. Undiluted warm car exhaust contains about 7,000 ppm of CO, and undiluted cigarette smoke about 30,000 ppm of CO. 1

Pollution Indoors

In addition to carbon monoxide, there are many other chemicals, substances, and gases which can be harmful to human health. These chemicals, substances, or gases as a group are called indoor air pollutants. Indoor pollutants are not as easily dispersed or diluted as outdoor pollutants are. As a result, concentrations can often be many times higher than outdoors. Pollutants found indoor include asbestos, biological contaminants, formaldehyde, fumes from household products, lead, nitrogen dioxide, particulates, pesticides, radon, and tobacco smoke.

Indoor pollution occurs in a wide range of indoor environments including homes, schools, factories, office buildings, and commercial workplaces. Excessive noise, dust, odors and fumes can all serve to lower worker productivity and adversely affect human health. The Occupational Safety and Health

Administration (OSHA) regulates indoor pollution within workplaces and the U.S. Environmental Protection Agency (EPA) focuses on indoor air problems within homes. Various sources of residential indoor air pollution:

1. Dirty air conditioners
2. Dirty humidifiers and/or dehumidifiers
3. Bathroom without vents or windows
4. Kitchen without vents or windows
5. Dirty refrigerator drip pans
6. Laundry room with unvented dryer
7. Unventilated attic
8. Carpet on damp basement floor
9. Bedding
10. Closet on outside wall
11. Dirty heating/air conditioning system
12. Dogs or cats
13. Water damage (around windows, the roof or the basement)

Indoor air pollution can affect human health in many ways, ranging from headaches and breathing difficulties to death. Some of these affects exhibit themselves immediately after exposure. Others occur after long periods of exposure. Each person has a different level of susceptibility to indoor air pollution. Some individuals are hardly bothered while others have acute sensitivity to the smallest levels. Many variables, in combination, determine likely health impacts from exposure. These include a person's age, existing lung function, the concentration of pollutants, and the duration of exposure.

Within residential buildings, a variety of technologies are used to control indoor pollution. These include measurement & monitoring devices such as carbon monoxide and radon detectors, ventilation improvements, and home air cleaning equipment and systems. Because there are many more indoor pollutants within workplaces, particularly shops and factories, there are a large number of commercial scale indoor air technologies. These include filters, humidifiers and dehumidifiers, dust collection systems, fume extractors, and ventilation systems.

Local Pollution

Changes in atmospheric chemistry that result in impacts on human health or the environment can often occur outside as well. These changes are typically known as air pollution, of which there are two principal kinds, pollution that is released from a single, identifiable source, known as a point source and pollution that comes from a large number of dispersed sources, known as non-point or area sources of pollution.

Point sources of air pollution include toxic trace compounds emitted from specific industries. This type of pollution, known as local air toxics, presents an air quality problem in the vicinity of these industries. These pollutants include heavy metals such as beryllium, cadmium, and mercury, organic compounds such as aldehydes and furans and radioactive particles and gases. Occasionally, large-scale toxic emissions from industrial facilities, such as the industrial accident in 1984 in Bhopal, India, pose severely deleterious effects on human health. Other localized air quality concerns include noxiousodors from industrial facilities, landfills, and sewage treatment facilities.

A number of processes & technologies are used to control local air pollutants and odors. Of particular importance is detection equipment and systems as many of these compounds are highly toxic to humans. Processes include distillation, extraction, incineration, control, biofiltration, and removal. Technologies include toxic gas analyzers, monitors and detectors, hood fans, exhaust systems, chemicals and scrubbers.

References

1 Source: Alaska Science Forum, 1/2883, What Do Carbon Monoxide Levels Mean?, #588, by Tom Gosink.

Procedure

In your lab notebook, complete the following. You can title this Activity ESA 21: Air Pollutants in your notebook. Leave room for a purpose…and add it when you can summarize the point of the entire activity and Q1-15.

Calculating Your Emissions

To figure out your emissions and how you compare against the national average, go to:

http://airhead.cnt.org/Calculator/

Click on the "Calculate your Emissions" button at the bottom of the page and answer the following questions:

1. Which of the four emission sources - auto, air, electricity, or natural gas - results in the most emissions?
2. What is your total aggregate emissions in pounds?
3. What is the relative share or percentage of each of the four sources? (To calculate this, divide the #of pounds for each source by the total). Record your answers for auto, air, electricity, and gas.
4. How do you stack up against the national average, more or less? Are you surprised? Why or why not?

Air Quality Where You Live

In this exercise, you'll take a look at air quality near where you live. To begin with go to

http://www.epa.gov/airnow/

Click on the "Air Quality Index" link, and answer the following questions.

5. What is the Air Quality Index?
6. What scale does the AQI use? (you may have to look around the website)
7. At what point does air become unhealthy to breathe?
8. At what point does air become hazardous?

Type in your zip code in the area on the upper right, "Local Air Quality Conditions and Forecast".

9. What are the current conditions:
    a. For particulates?
    b. For ozone?
10. What are human health effects from particulates and ozone?
11. Where do ozone and particulates come from?
12. What are ways to reduce ozone and particulates?

Radiation Exposure

Radon

The largest source of radiation for many people comes from radon gas exposure. Radon-222 is a natural daughter product in the decay chain of uranium, which is found in rocks throughout the world. It is unique from the other daughter products in two ways: it is a gas at room temperature, and it is inert. When the other daughter products are produced, they are solids, which means that they stay put in the rock matrix. However, when radon is produced, it slowly starts to migrate through cracks in the rocks up to the Earth's surface. Once it reaches the surface, it mixes in the atmosphere, which we breathe.

If your home happens to be sitting on the ground above the location where the radon exits the earth, then it is possible for it to move through cracks in your foundation and enter your home. Over time, the concentration of radon in the home can build up, as radon is both non-reactive and heavy, which keeps it nearer the surface of the planet. It is estimated that about 1 in every 15 homes in the U.S. has elevated levels of radon. It is also possible for this same thing to happen in offices and schools. Since most people in the U.S. spend the majority of their time during the day either in their house or in a school or office building, this can have some serious consequences. The only way to know for sure how bad the situation is in your home or building is to test for the presence of radon decay. This can be done with very inexpensive kits (some less than $10) that require very little time or knowledge to operate.

The average American receives about 360 mrems of radiation each year. In this activity, we are going to try to estimate what your yearly exposure is from the various sources. In order to increase the accuracy of this estimate, we will need to know a few details about where and how you live. It should be stressed that this is only an estimate of your exposure, and should not be relied upon as a full accounting of what your actual exposure is. There may be unusual factors in your case, which will cause the estimate to differ radically from what it actually is. If you are concerned about your exposure actually is, you should consider purchasing a dosimetry badge or consulting with a health physicist.

Since radon gas is the largest factor for most people, we will start the investigation there. There are two ways to estimate your exposure from radon gas. One way would be to assume that you live in the average home in your area, and use the home radon zone map (at http://www.epa.gov/radon/zonemap.html) developed by the EPA, which list the average value for homes in your county. This map is based upon actual measurements that the EPA has made in homes across the U.S. A second way to estimate your exposure is measure the concentration of radon in your home using a home test kit. These kits are relatively inexpensive (about $10) and provide a much more accurate means for determining the concentration in your home than using the EPA maps. Your instructor will let you know which method to use for this activity. Either of these methods will give you an estimate for the concentration of radon in your home. Using this and an estimate for the amount of time that you spend indoors will allow us to estimate your radon exposure levels.

There are a few other facts about your home that we will need in order to finish our your exposure due to your location. First, we will need to know the elevation of your community above sea level. As one goes higher in the atmosphere, there is less protection from the atmosphere from radiation coming from outer space. Therefore, if you live at 5000 feet above sea level, you will receive more radiation than if you live at 4000 feet above sea level. Consultation with a decent map should give you this value. We will also need to know in what region of the U.S. your home is located. Different regions have different rocks underlying them, which results in differing amounts of terrestrial radiation. Areas overlying a large amount of sediment (Gulf Coast and Atlantic Coast) receive only about 23 mrems of radiation; areas with igneous rock very near the surface (Colorado Plateau) receive about 90 mrems. Besides these two things, we need to know what the exterior of your home is (earth materials have more radioactive substances in them), how far you live from a nuclear and coal power plant (both emit radiation, with a coal plant emitting more), and whether you have a smoke detector in your home (smoke detectors use a very small amount of americium, which will give you about .008 mrems of radiation each year).

There are also some activities and lifestyles contribute to your radiation exposure. Some of them, such as jet travel, we have mentioned above. Most of these activities or lifestyles add very little to your overall exposure. About the only one that does add a fair amount is the use of a pacemaker, which has a plutonium-powered battery that will give you about 100 mrems of exposure each year.

The last area of information that we need for the estimate concerns medical procedures. These fall into two categories: diagnostic and treatment. Radiation is used in diagnostic procedures in order to peer into the body without opening it up. More than likely, you have had several of these in your lifetime, especially if you have ever been to a dentist. The amount of exposure you get from these can be as small as 2-3 mrems from a dental x-ray up to 1000 mrems from an abdominal CT scan. The radiation in a treatment procedure is used to kill cells, usually cancerous, that are in your body. Since this radiation is used to target specific cells and kill them, we have not included them in this estimate. If you want to know more about how much radiation the rest of your body received during one of these procedures, we suggest that you consult your physician.

Now that we have acquired all of the information required for the estimate, we will proceed to the online calculator. This calculator will sum up the contributions from all of these sources and add it to the 66 mrems of radiation that you receive from on average other sources (ex. food and water) for which we have no way of personalizing. Once you have done so, you will need to answer the questions on the following page.

Enter your current data into the online calculator.

http://esa21.kennesaw.edu/activities/exposure/radiationcalculator.htm

Then, see how your total exposure would change if you made the following changes and record in your notebook:

a. Current data ________ mrems
b. The radon concentration in your home were to double. ________ mrems
c. You lived in Denver, CO. ________ mrems
d. You lived in Death Valley, CA. ________ mrems
e. You had a chest x-ray each year ________ mrems
f. You lived 1 mile from a nuclear reactor ________ mrems
g. You doubled the amount of jet travel ________ mrems
h. You had a pacemaker installed ________ mrems

Answer the following questions in your notebook:

13. Which of these scenarios gave you the greatest exposure? Which gave you the least?
14. Compared to other things in your life, how does living near a nuclear reactor affect your total exposure?
15. After completing this exercise, are you as worried about living near a nuclear reactor? Are there other things to consider about this situation?