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AIR AND AIR QUALITY

Ву

Peggy June Anne Najarian

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTERS IN SCIENCE

Division of Science and Mathematics Education College of Natural Science

ABSTRACT

AIR AND AIR QUALITY

Ву

Peggy June Anne Najarian

Air quality and pollution are important components of the Advanced Placement Environmental Science (APES) Program. Air quality also plays an important role in student's daily It is important that they not only know the information for the APES test, but that they understand how the choices they make can put pollutants into the air they breathe. They need to understand the effects of the choices they make environmentally, economically and politically. This thesis contains a collection of demonstrations and activities that enabled my students to learn the concepts needed in order to be successful on APES The findings of this investigation are based on pretest. and post-test assessment. A significant increase in student achievement suggests that after students are actively engaged in a variety of activities, their understanding of air quality and the issues related to air quality will increase.

DEDICATION

This thesis is dedicated to my friends and family who have been incredibly supportive throughout this entire process. Rare is the friend who doesn't laugh at the person who needed to bring a laptop to the beach in order finish her Cellular and Molecular Biology questions. To Elizabeth Baker-Munro and Mary Hoyt for filling the last four summers with learning, waders, bonfires, lectures, statistics, dune trips and laughter. Thank you to my parents who always believed in my abilities without question. My most heart felt thank you and gratitude goes to my husband John, who met me the summer I began my course work, voluntarily became my proofreader, and married me anyhow.

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INTRODUCTION

RATIONALE FOR THESIS

The topic of air quality and pollution is an important component of the Advanced Placement Environmental Science (APES) Program. It makes up approximately 20% of the AP curriculum and test. My class spends three to four weeks on air and air quality. first time I taught this unit I was faced with several labs that did not work. Because of the problems with the experiments, I found it difficult to convince students that the concepts that were stressed in class were, in fact, real problems in our environment that can be tested and are associated with the air they breathe. It is important that they not only know the information for the AP test, but that they understand how the choices we make can contribute pollutants to the air we breathe. Students need to understand the effects of the choices they make environmentally, economically and politically. An example of how understanding those topics can be applied to a student's everyday life would be knowing the consequences of refueling an automobile on an ozone action day. summary, my hypothesis is: if students are actively engaged in a variety of activities (experiments,

demonstrations, computer programs) then their understanding of air quality and the issues related to air quality will increase.

REVIEW OF SCIENTIFIC LITERATURE

Air is a vital resource that affects all aerobic organisms on our planet. Models have shown that climate change due to global warming will result in an increase in wheat crop failures (EPA "Global", 1998). This failure could be attributed to an increase in temperature and even an increase in C3 weeds. If global CO2 levels continue to rise, it may become easier for these weeds to compete with certain crops. Weeds are a major cause of crop loss; as much as 60% of a potential harvest is lost in some cases. Respiratory problems from air pollution are so severe that there are days that school children in Czechoslovakia must wear masks (Bodkin and Keller, 1998). A decrease in ozone levels leads to an increase in the amount of ultraviolet (UV) B radiation that reaches the earth's surface. This increase in UV B radiation can result in damage to developing fish, shrimp, crab and other aquatic organisms (EPA *Ozone", 1999).

Many states, including Michigan, in the United States have "Ozone Action" days. When weather conditions favor

the production of tropospheric ozone, news reports on the television and radio, electronic billboards on major expressways, and web sites announce when it is an ozone action day. Citizens are asked to refrain from activities which contribute ozone forming precursors: pumping gas, cutting grass, driving excessively, or using gas grills.

Fortunately air quality standards have already been set by our government. The first version of the Clean Air Act was passed in 1963. It called for the U. S.

Department of Health to research the sources and effects of air pollution. In 1965, amendments to the act addressed national automobile emission standards for carbon monoxide and hydrocarbon. In 1970 major revisions to the Clean Air Act were made. At this point several pollutants were identified as critical and national ambient air quality standards were established (Cunningham and Saigo, 1997).

The United States Congress passed the latest version of the Clean Air Act in 1990. The goal of this latest act was to improve air quality using three strategies. The first required the Environmental Protection Agency to establish National Ambient Air Quality Standards. This was accomplished by setting maximum permissible levels for seven outdoor pollutants: lead, sulfur oxides, nitrogen

oxides, particulate matter, volatile organic compounds (VOC), ozone, and carbon monoxide. The second component was designed to prevent industries from moving to an area with high air quality, higher than the standard for particulate matter and sulfur dioxide, and degrading the air quality of that area down until it reaches the standard. This is called *prevention of significant deterioration." Finally, the Act required the EPA to establish "national emission standards for toxic air pollutants" (Miller, 2000). The success of the Clean Air Act is easy to see. Between 1970 and 1995 there was a reduction in all of the following: carbon monoxide (28%), lead (98%), VOC (25%), particulate matter with a diameter of 10 microns (25%), and sulfur dioxide (41%) (Waxman, 1999).

One undisputed phenomenon that occurs independently of the amount of pollution is the greenhouse effect.

Incoming solar radiation is generally high in energy. An example is UV radiation. When this incoming solar radiation enters the Earth's atmosphere one of two scenarios can happen. The radiation can be reflected and thus not reach the Earth's surface. If the radiation is not absorbed in the atmosphere then it can reach the Earth's surface. In this case the incoming radiation is

absorbed and re-emitted as longer wavelength, lower energy radiation, often infrared (IR) waves. The IR radiation can either escape into space or be reflected back to the Earth's surface by a variety of gases in the atmosphere. The process of trapping the IR radiation or heat energy is called the greenhouse effect.

While the greenhouse effect is an accepted occurrence, global warming is not. Global warming can be defined as the increase in the mean global temperature at or near the Earth's surface. This increase can be caused by either natural phenomena or by human activities. According to Bodkin and Keller (1998) this increase is driven by four main factors: the amount of solar radiation the Earth receives; the amount it reflects; the amount that is trapped in the atmosphere; and the evaporation and condensation of water. The controversy here lies in the fact that there are several different feedback mechanisms, positive and negative, which affect the Earth's temperature. For example, an increase in temperature will increase water vaporization. This increases the level of greenhouse gases in the atmosphere which leads to increased absorption of infrared radiation, resulting in increased temperatures. We call this global warming. This process is self-perpetuating so it is termed a

positive feedback mechanism. However, the increase in cloud cover that occurs when water evaporates will also reflect incoming solar radiation back into the atmosphere. This decreases the amount of radiation that reaches the Earth's surface and leads to global cooling. This mechanism is self-regulating so it is a negative feedback mechanism.

Acid rain is another concern. Natural rainwater is not neutral. Carbon dioxide dissolves in water to produce carbonic acid. This changes water with a pH of 7 to an acidic solution with a pH of 5.5.

$$CO_2$$
 (g) + H_2O (1) \rightarrow H_2CO_3 (aq)

When we discuss acid rain we are not talking about the natural process that is shown above, we are actually discussing two other gases. These gases are more soluble in water than carbon dioxide and are being released into the atmosphere due to anthropogenic processes. The gases in question are sulfur oxides (SO_x) and nitrogen oxides (NO_x) . Because these gases are more soluble in water, they form stronger acids than carbonic acid. It takes a smaller concentration of these acids to change the pH of rainwater (Bunce, 1991).

The following are the net chemical reactions for the formation of some of the components of acid rain.

SO₂ (g) + H₂O (1)
$$\rightarrow$$
 H₂SO₃ (aq)
SO₃ (g) + H₂O (1) \rightarrow H₂SO₄ (aq)
NO (g) + H₂O (1) \rightarrow HNO₂ (aq)
NO₂ (q) + H₂O (1) \rightarrow HNO₃ (aq)

Acid rain impacts our environment on several levels. Acid rain is an enemy of marble statues where the acidic compounds in the rain react with the calcium carbonate to form a soluble calcium salt, carbon dioxide and water. Acid rain affects plants in a variety of ways. It lowers the pH of soil and releases heavy metals, which can be toxic to plants, into the soil. It has damaged the needles of red spruce and Fraser fir trees on the top of Mount Mitchell in North Carolina as shown by Dr. Bruck in The Search for Clean Air (1994). In aquatic ecosystems, a decrease in pH can lead to disruptions in the life cycle of aquatic vertebrates and invertebrates; gills can be damaged and bones can become weakened due to decalcification. The leaching of toxic metals is also a problem (Cunningham and Saigo, 1997).

Particulate matter (PM) is defined as small particles of solid or liquid substances that are released into the atmosphere and remain suspended for a period of time.

There are different subcategories for particulate matter,

which include very fine to large. Particle size can range from 0.001 - 100 microns (μm) in diameter. Fine particulate matter is considered to be about 10 μm and ultrafine particulate matter is inhalable and is \leq 2.5 μm in diameter (Miller, 2000). The particulate matter that causes the most lung damage ranges from 0.1 to 10 μm in diameter (Bodkin and Keller, 1998). For a point of reference: fly ash from incinerators ranges from 1-100 μm , pollen ranges from 10-100 μm , and tobacco smoke from 0.01-0.1 μm (Miller, 2000).

In Bangkok, Thailand particulate matter and lead increased from 1983 to 1992. Since 1988 and every year thereafter, the levels have exceeded Thailand's air quality standards. In heavily traveled streets air quality is so low that traffic police must wear air masks. The increase in lead levels can be attributed to leaded gasoline. In a study performed between 1989 - 1990, the average lead levels in blood was $18.5~\mu g/dL$ for 82 infants living in Bangkok. This number is twice the number reported for infants by the U.S. Centers for Disease Control (World Resource Institute, 1996).

REVIEW OF PEDAGOGICAL LITERATURE

In this study I did not implement new teaching strategies because AP classes focus on content rather than teaching strategy or pedagogy. Instead I chose to emphasize activity-based teaching. The following two sources support this decision.

One source compared the differences between a group of Japanese students and two groups of American students. One of the American groups was from Schaumburg, Illinois and the second from North Carolina. Staver and Small (1990) found that students who had several years of activity-based science tested very well compared to Japanese students. Instances where elementary education is not activity based resulted in lower scores. The implementation of an activity-based program will potentially become a solution. Their conclusions were as follows:

"Activity-based, materials-oriented science that is conceptually rich, emphasizes discovery and inquiry through science process skill, relates science and technology to individual needs, discusses the connections between societal issues and science and technology, and provides career awareness experiences, would seem to provide the best foundation who for all students during their early school years" (Staver and Small, 1990).

While Staver and Small refer to early education, these ideas and methods can be easily applied to older students as well.

Constructivism is an approach to teaching that first identifies students' prior knowledge. Conceptual change occurs when students reconstruct core concepts from intellectual structures through interactions between themselves and their environment (Bybee and Trowbrigde, 1990).

A radical constructivist by the name of von Glaserfield (1995 as cited in Staver 1998) believes that when we obtain knowledge, we do not obtain it by passively using our senses or by any other form of communication. He believes that active social interactions are necessary in order to build one's knowledge base. To paraphrase, students must be actively engaged in order to learn. The old style of teacher/lecture and student/note taker is no longer enough.

DEMOGRAPHICS

The ninth through twelfth grade high school students studied are from a school located in Oakland County, which is in the Detroit metropolitan area. It is one of three high schools in the district. There are approximately

1245 students in attendance. Ninety-eight percent of the 1998-1999 graduating seniors will be attending a two or four year degree program. In 1998, students took 280 AP tests with 76% scoring a three or higher. A score of three is considered passing a five is the highest possible score. The 1999 AP test scores are not available at the time of this writing. During the 1997-1998 school year 235 students took the ACT and obtained an average of 24.0. One hundred thirteen students took the SAT and scored an average of 1158. There were five National Merit Semifinalists and nine National Merit Commended Students. There were two National Achievement Semi-finalists and two National Achievement Commended students.

The student body is considered multicultural. The students represent a variety of ethnic, religious, and cultural backgrounds including, but not limited to, Caucasian, Jewish, African-American, Caledian, Albanian, and Asian. In terms of economic status the community is considered upper middle class.

While students from grades nine through twelve attend this high school, only 21 of the 22 twelfth graders in the APES class participated in this study.

IMPLEMENTATION OF UNIT

My primary goal was to engage students in meaningful laboratory experiments that work. By "work" I mean that the laboratory experiments' results teach students the concept the experiment was designed to teach them. Last year, 1998, the vast majority of our experiments were either too simple or simply did not produce the expected This problem was well known to the students data. involved in this study. The prior year's students were happy to share this problem with the students in this study. The experiments from the last year's air unit were so unsuccessful that I found myself desperately seeking activities to fill class because the ones we tried just were not working. My second goal was to have a lab, demonstration, computer program, or guest speaker, for each major concept in this unit. I wanted to spend the shortest amount of time possible delivering material in a lecture format.

My school district seems to recognize lecture as an old style that needs to be changed. My school also will have a new type of hourly schedule next year (block scheduling). In a 90 minute class students will need to be engaged in some form of activity for each and every

class period. I know that I could prepare a 90 minute lecture but I do not believe I could deliver it and I know my students, as good as they are, could not sit through it.

The Air and Air Quality Unit discuss here was taught at the end of the school year. Topics that were taught prior to this unit include: population, resources, biogeochemical cycles, water and water pollution, energy, waste, diversity, productivity, succession, and environmental economics. Environmental impact planning was the last topic taught after the air unit. The study lasted from March 29 until April 27, 1999. Students were on spring break from April 1 until April 11, 1999. Due to unfavorable weather conditions both the ozone testing lab and sunscreen lab were postponed until the week of May 24, 1999. Table 1 provides a basic outline of this unit including the main idea, order, and time spent for each Appendix A contains copies of the pre-test, posttest/unit test and the final exam questions on air. Appendix B contains copies of student handouts for the activities listed, when appropriate.

BASIC OUTLINE OF THE AIR AND AIR QUALITY UNIT

Table One: Basic Outline of the Air and Air Quality Unit

		ne of the All and All Q	
MAIN IDEA	TIME	ACTIVITY	TIME
7	TABLE	4 D	(minutes)
Assessment	Week 1	*Pre - test	20
Atmosphane	Week 1	1) Convertion Current	10
Atmosphere and Climate	week 1	1) Convection Current	10
	Week 1	Demonstration	30
Atmosphere and Climate	week I	*2) Microclimates Lab	30
Atmosphere	Week 1	*3) Greenhouse Effect	50
and Climate	WEEV T	Lab	
Air	Week 2	Video: Search for	55
Pollution	neek 2	Clean Air	
Air	Week 2	*4) Thermal Inversion	15
Pollution	neer 2	Demonstration	
Air	Week 2	*5) Plant Indicator	5 set-up
Pollution	MCCK Z	Demonstration	5 discussion
Air	Week 2	*6) Effects of Acid	45
Pollution	ncch 2	Rain on <i>Daphnia</i>	
Air	Week 3	*7) Particulate	55
Pollution		Matter Lab	
Indoor	Week 3	Guest Speaker-William	35
Air	-	Spencer Radon Testing	
Pollution			
Indoor	Week 3	*Guest Speaker-James	25
Air		Ratliff construction	
Pollution		manager for school	
Indoor	Week 3	*8) Indoor Air	45
Air		Quality Analysis	
Pollution			
Ozone	Week 2	Ozone Tracking	110
		Computer Program	
Ozone	May 24	*9) Sunscreen Lab	50
Ozone	May 25	*10) Ozone Testing	10 set - up
		Lab	40 analysis
Assessment	Week 4	Unit Test	55
Assessment	May 18	Final Exam	55
L			

^{*} denotes new or improved items to this unit

CHANGES TO CURRICULUM

I have not used a pre-test (Appendix A) as a regular part of my teaching in the past. I began to use it to determine the students' prior knowledge and possible misconceptions. As expected, they could not answer several of the questions. The advantage of the pre-test is that I was able to find the misconceptions before the unit was taught, not during it. This allowed me to address them immediately and continue to reinforce the correct information throughout the unit.

I normally have a formal lecture for each unit, for example on biogeochemical cycles, water, or succession, that may be delivered over two to three class periods.

Lectures are normally delivered in 20-30 minute time intervals at the beginning of the class period. The remainder of the time is devoted to laboratory experiments or some other activity. There are generally one to two laboratory experiments per topic. In this unit I tried to employ many different sources of information other than myself and the textbook. This unit utilized everything from guest experts to demonstrations, videos, and laboratory experiments. I did find the need for some lecture; their book Environmental Science: Earth As a Living Planet (Bodkin and Keller, 1998) just does not go

into enough detail on the chemistry of acid rain.

Students also had trouble with the ozone-depleting chemical reactions that take place in the polar stratospheric clouds.

The radon expert who spoke to the class is a former teacher at our high school. He spoke to my class last year and was very thorough, so I told my students that this year his talk would not only be on the test, but the material he covered would be their only lecture on radon. I would only answer questions if necessary. They were to use the speaker as their main source of information. I did see a change in the students' behavior compared to last year's students. They were more alert, showed, a genuine interest in the topic and asked the speaker some very good questions.

The Spatially Plotted Ozone Tracking System or SPOTS computer program was also a wonderful tool to use in the classroom. By the time the students started the program they had already read and answered questions about ozone depletion. This program provided them with real data taken from an ozone episode in the metropolitan Detroit area. Students tracked the ozone levels and temperatures over a three day ozone episode. What they learned was that higher temperatures and higher traffic volumes contribute

to ozone production; that wind patterns can influence the magnitude of an ozone episode; and that places that produce the ozone are not necessarily the areas that are effected by the increased ozone levels. Last year I lectured this material and used the program for reinforcement. This year I really relied on this program to teach the students these concepts. My role was as a facilitator, a role that is not an easy one to play.

I also decided to have students prepare formal lab reports. This was by no means innovative, but was necessary, because students need to develop good technical writing skills. Ideally, formal lab reports should be done with every experiment. Unfortunately, with the number of laboratory experiments we perform, the pace our class must keep and the number of AP classes my students take, we do not have time for many formal laboratory reports. During this unit students were expected to prepare one for the greenhouse effect lab. Again, I do not consider this innovative, but it is not a normal practice due to time constraints.

DESCRIPTION OF EACH DEMONSTRATION AND LABORATORY EXPERIMENT AND THEIR EVALUATION

1) Convection Current Demonstration—The convection current demonstration was used to show students how air currents move throughout the Earth's atmosphere. It primarily showed students that hot air rises and cool air sinks. This was an important concept to understand before we shifted our discussion to thermal inversion layers. We also used this demonstration to explain why each biome is located where it is on Earth.

The convection demonstration was the only demonstration that worked last year. I made a convection box using an old shoebox, two glass cylinders, aluminum foil, brown paper towel and a candle. This year we had brand new convection boxes and real smoke paper. The smoke paper did not produce an adequate amount of smoke, so I decided to switch to the paper towel. The commercial convection box did not show the convection currents like the homemade version, but did show the movement of the smoke well enough for the student to see the currents. I believe the homemade model will be used in future demonstrations.

2) Microclimate Lab-The microclimate lab was a very simple lab. Students were to test relative humidity in a

variety of areas on the school grounds. Students used sling psychrometers to find the relative humidity, both inside and outside of the school. Test sites included the pool, our classroom, the middle of the teacher parking lot, a shaded grass area next to the building, under a tree on the grass island in front of the school and an open grass area. Class data were collected and analyzed.

There were two problems with the microclimate lab. I include them here to show how unexpected events can take place and how I chose to deal with them. The first was that 14 of my normally diligent students lied to their parents and told them that I would not be in school that day or told them that "we weren't really doing anything important." They had their parents excuse them from my class and the students went to a local restaurant for an extended lunch. This left eight students with poor attitudes who wanted the hour off. I had made prior arrangements with the pool custodian to open the pool towards the end of the hour. While I was giving the introduction to the lab, the pool custodian came to my room and said that we need to get to the pool immediately because she was just told she had to have the pool locked up and she was to be off the clock in the next ten minutes. Even though we had performed relative humidity

tests several times this year, the attitude of the class was not conducive to strict laboratory protocol. Once each site was tested, we compiled group data so that the entire class could benefit from the results. Results were not as consistent as they should have been considering all eight students collected data at the same time in the same location. We took the median for our data points to correct for outlying values. Fortunately, the point of the lab-the fact microclimates exist within a climate-was observed. Students were able to apply what they learned here in the ozone testing lab, the greenhouse effect lab, and the indoor air quality analysis.

3) Greenhouse Effect Lab-In the lab on the greenhouse effect (Appendix B) students were asked to compare the difference in the rise in temperature between two systems. The first system contained a cup with moist soil. The second system was identical to the first except plastic wrap was used to cover the top of the cup. Students recorded the rise in temperature at one minute intervals over 15 minutes. The soil was checked for moistness and adjusted if necessary. The cups were then covered with plastic wrap and the experiment was repeated. Students were then asked to prepare a formal laboratory report for this experiment. This included a graphical analysis of

their data and an analysis of the experiment as related to the concept of global warming.

The greenhouse effect lab worked incredibly well. Students saw a higher increase in temperature when the plastic wrap was in place than when the plastic wrap was absent. Although the lab was a success, one change needs to be made to the procedure. Students recorded temperature changes when plastic was absent. As expected all lab groups experienced an increase in temperature. They did not wait for the temperature to cool to the original temperature before adding the plastic wrap. meant that the temperature at which they started trial #2 was higher than trial #1. This can be misleading. correct this, students can run two trials at once or they can cool the original set-up to the starting temperature by adding water and removing it from the sun. A very interesting aspect of this lab was that we had one group perform their experiment on the grass while the other groups were on the concrete sidewalk in front of the school. The students had already learned that vegetation will help regulate the temperature and humidity in an area. We saw much higher temperatures with the cement groups than we saw with the grass group. We also related this to the reason the temperature in Detroit is usually

- 1-2 °C warmer that the suburbs. This was a nice way to show that the urban microclimate is different than the suburban microclimate
- 4) Thermal Inversion Demonstration-Two possible thermal inversion layer demonstrations were considered. The first involved smoke and the second involved water. The latter demonstration required water, a hot plate, a small ice bath, two glass plates, four equal sized jars and food coloring. In this demonstration, water was heated to almost boiling. Two of the four jars were placed in an ice bath; water was then added to the rim of the colder jars. Hot water was then used to fill the remaining jars. Food coloring was then placed in the jars containing the hot water. Using a glass plate, the jar of cold water was placed on top of the jar with hot water. With the glass plate in place, students were asked to predict what happens when the glass plate is removed. expected the warm water rose and the cold water sank to towards the bottom jar. The mixing was easily seen because of the food coloring. Next, the jar with the hot water was placed on top of the jar with the cold water. Again with the glass plate in place, students are asked to predict what will happen. The glass plate was removed and the hot water stayed above the cold water. This

demonstration can be altered using much of the same equipment. The water can be replaced with smoke from a burning cigarette, smoke paper or brown paper towel. The inversion layer is more difficult to produce when smoke is used; a greater temperature differential is required.

Students were asked to explain why the hot water remains on top of the cold water. I then asked them to relate this demonstration to the convection current demonstration and the case study in their chapter on air pollution that deals with the 1952 London Smog incident (Bodkin and Keller, 1998).

The thermal inversion demonstration worked very well.

I used the hot and cold water demonstration first.

Students could easily see the inversion layer. We discussed the results and then I asked students if they thought they needed me to repeat the demonstration with smoke and we all agreed that one demonstration was sufficient. While students were able to apply this demonstration to the concentration of air pollutants during the London Smog incident, in the future I think I will use the water demonstration to show how lakes become stratified and save the smoke for thermal inversion layers.

5) Pollution Indicator Demonstration-Another aspect of this course was that biological organisms could act as pollution indicators. An algal bloom is an indication of excess nitrogen or phosphorus in a lake or river ecosystem. Lichens can be indicators of air pollution, as can canaries. Canaries were once used in coal mines. Canaries will not sing if the air quality is "bad" (Miller, 1997). I decided to use wax begonia plants as indicators of sulfur dioxide damage. A wire frame was placed into the pot of each wax begonia plant. Approximately 10 mL of sodium sulfite crystals was placed into a small beaker. Approximately 20 mL of 0.1 M hydrochloric acid was added to the sodium sulfite. A large plastic baggie was placed over the wire and secured with a rubber band. The control set-up should contain the same items, omitting the sodium sulfite and the hydrochloric acid. As a precautionary measure, I placed the plants in a fume hood. After three days, the plant leaves were examined for damage. Damage due to sulfur dioxide exposure can be identified by yellow, tan or ivory papery blotches on the leaf between the veins. Veins usually stay green. Damage is normally done to the entire leaf (Wolff, 1984.)

The plant indicator demonstration was a success.

Students could easily see the yellow papery blotches on the leaf of the begonia and thus the effect of the sulfur dioxide on the begonia.

6) Effects of Acid Rain on Daphnia: The acid rain lab (Appendix B) was designed to show how an aquatic invertebrate would respond to a range of pH levels. While the lab does work with either Daphnia or brine shrimp, I chose to use Daphnia because it is readily available from the science center in our district. In this lab ten Daphnia were placed in a petri dish containing one of eight different pH solutions. Each group of students was assigned a different pH solution. Students recorded the number of Daphnia living at time intervals of 0, 10, 20, 30 minutes and 24 hours. Each group ran two simultaneous trials. Class data were collected and analyzed.

When I developed and tested the lab, it produced results that would teach students that pH changes will affect the survivorship of both Daphnia and brine shrimp. I thought this lab would also be successful in the classroom. I made and tested each solution. I triple checked each pH level. I picked up the Daphnia the day of the lab from the science center. Students observed them under the microscopes. Daphnia behaved as expected.

Students then took fresh Daphnia and placed them into their assigned pH solution. Daphnia at every pH except 6 and 7 died within 10 minutes. In the trial run Daphnia and brine shrimp lasted at least 20 minutes when exposed to pH 3 and higher. During our experiment most died instantly at pH 1-5. There are two differences between the original trial and the trial with my students. First, the Daphnia were used the same day they were transported. This was not the case with the trial run. Second, in the original trial I used sulfuric acid, which is a diprotic I had some difficulties getting the proper pH levels, but eventually did reach them. It is because of this that I decided to use hydrochloric acid, which is monoprotic. Students did see the Daphnia die at the lower pH levels, but it was too dramatic to be realistic. attempted to explain that their Daphnia were dying too quickly. Unfortunately, they decided that this was another one of those labs that just did not produce the expected results.

7) Particulate Matter Lab-According to Laura DeGuire at the Michigan Department of Environmental Quality, particulate matter (PM) is the next pollutant about which we will be hearing a lot about especially the fine particulate matter, PM-2.5. PM-2.5 particulate matter that

is 2.5 µm in diameter. A colleague at an AP conference recommended this lab to me. I modified it to meet the needs of my class. I needed to get special permission from my principal to do this lab because she was worried about the possible fumes that could be given off while the cars were running. Students were not allowed to sit in or near cars. Even though the particulate matter was being collected in the socks and students were not near the cars, the parking lot attendants, the students and myself were required to wear masks.

In this lab (Appendix B) students placed a clean white or light colored sock onto the exhaust pipe of their car.

The cars were allowed to run for 15 minutes. The socks were removed and returned to the classroom. Socks were labeled with make, model and year and put out for display.

Afterwards students prepared dry mount slides and observed their particulate matter under low power. Next students observed four prepared slides under low power: normal lung tissue, lung with coal dust, lung with anthracosis and lung with emphysema. Students were asked to infer the relationship between the particulate matter and the prepared slides.

The particulate matter lab worked very well.

Students were able see the carbon that was given off and

their particulate matter under a microscope. I realize that it looked like a black speck, but it was a nice prelude to the lung tissue slides they observed. These slides showed what happens when particulate matter is trapped in human lungs. The socks are effective when collecting the larger particulate matter. In addition, they also picked up the odor of the VOCs. This showed that their cars do in fact emit VOCs, which help contribute to the formation of photochemical smog.

8) Indoor Air Quality Analysis-Our school is currently undergoing a renovation. Several areas throughout the building were under construction during the school year. We now occupy new windowless science labs. The air quality has been of concern for both students and faculty. This was a sensitive experiment that required special permission. Both the principal and the equipment available to us restricted our testing. I was able to speak with two individuals from the Office of Radiation, Chemical and Biological Safety for Michigan State University. They were Sarah Buehler, industrial hygienist, and Robert Ceru, assistant director and chemical safety officer. When a complaint is made, the first tests that are performed by an industrial hygienist determine comfort

level air quality. Aspects tested include air flow, air temperature, relative humidity, and carbon dioxide level. On the day of our lab the construction manager came in and spoke with students about the steps that had been taken in the newly renovated sections of the school, including our classroom, to ensure air quality. He discussed the new air exchange rate and compared it to the older sections of the building. He also spoke about where the air originated and the heating and cooling systems. Students tested all aspects of comfort level air quality in our building except air flow. We did not test air flow because we did not have the proper equipment. collected class data and compared our findings to the accepted standards. We then discussed limitations to our study and whether our indoor air quality was acceptable. We also discussed whether it was acceptable throughout the day in each location and how the results at each location were affected by daily fluctuations in carbon dioxide, temperature and relative humidity.

The indoor air quality analysis (Appendix B) was a success in terms of awareness. The class drew several conclusions. First, carbon dioxide levels could be easily skewed; the test result depended upon where you stood in the room. If the middle of the cafeteria were tested

during a lunch hour the CO₂ levels would be higher than if the test was performed in the doorway. Several areas of our school had a relative humidity that was high and could promote bacterial growth. The advantage was that the high humidity also reduces the survival of viruses. Our study showed that overall we had adequate indoor air quality in terms of comfort level, but we could still have other problems because of pollutants we were unable to test *i.e.* VOCs.

9) Sunscreen Lab-The sunscreen lab protocol (Appendix B) was taken from the Chemistry in the Community 2nd and 3rd edition written by the American Chemical Society (1998).

Last year the results to this experiment were difficult to decipher. After several trials the lab was modified to reduce a few significant errors. While the protocol was similar to that described in the ChemCom curriculum, my goals and objectives were not. My students were asked to relate how sunscreens, both PABA (para-aminobenzoic acid) and zinc oxide, act like the ozone layer. They were then asked to relate the application of sunscreen to the thinning of the stratospheric ozone layer.

The purpose of this lab was for students to make connections between ozone layer and sunscreen use. Most student groups found that as the sun protection factor or

SPF of a sunscreen increased, the amount of sunlight that reached the photosensitive paper decreased. Many groups found variations between two different brands with the same SPF. Answers on their lab reports indicate that they understood that para-amino benzoic acid (PABA) and zinc oxide in sunscreen act like ozone and prevent the UV radiation from reaching their skin. One problem with the lab is that some students did not apply even amounts of sunscreen to the acetate sheets before exposure. This is amended with more explicit lab procedure directions.

testing lab (Appendix B) was to show students that ozone is produced during the day in the troposphere. Students collected their ozone test strips in the morning and hung them in their assigned location. Locations included underneath the handicap ramp next to the stop sign in the parking lot (where a car may idle), next to three different copy machines, behind refrigerators, behind computers in classrooms and the CAD computer lab. Samples were not placed in direct sunlight. At the end of the day, students collected their test strips labeled them, sprayed them with enough water to get them moist and placed their test strip on the board. As a class we assigned Schoenbein numbers. The assignment of these

numbers was subjective, so students asked if numbers could be assigned as a group in order to help reduce error and be consistent. Results showed that the greatest concentration of ozone was found underneath the handicap ramp in the teachers' parking lot and behind the teachers' copy machine the next greatest concentration.

One important concept that I have not mentioned, which I stressed with students throughout the unit was experimental error. I know that I was successful teaching them experimental error when we discussed the results of the ozone testing lab. After collecting their test strip, students asked to assign the Schoenbein number as a group in order to reduce error. This way the experimental data was assigned the same Schoenbein number by the entire class. We sent a student to find the relative humidity so we could figure out the ozone concentration in parts per billion. When the student returned, several members of the class mentioned that each test strip was in a different area and may have a different humidity was different due to its microclimate. This lab not only showed students that ozone is produced during the day both inside and outside of the building, it got them thinking about experimental error and they related it to microclimates.

EVALUATION

PRE-TESTS

Students were given a pre-test (Appendix A) before the air quality unit began. The pre-test contained 16 questions and was worth a total of 25 points. Students were asked about global warming, acid rain, air pollution in general, indoor air pollution, and ozone depletion. Criteria were established (Appendix A). Table 2 shows that 67% of the students were able to define global warming. Thirty-eight percent of the students could identify at least one cause of global warming. For example, student #9 identified car exhaust as a factor responsible for the increase of carbon dioxide in the atmosphere. Twenty-four percent of the students related greenhouse gases to global warming; student #9 stated that carbon dioxide traps heat in the atmosphere. Unfortunately, 64% of the students identified the cause of global warming, either partially or in full, to be ozone depletion.

Table 2: Pre-Test Questions on Global Warming

	Able to define global warming	warming	effect/gases to global warming	Believed ozone depletion caused global warming
1	X	X	X	
2	X			X
3	X	X		
4				
5	X			X
6	Х			X
7	X			
8			X	
9	Х	Х	X	
10	Х	Х	X	X
11		Х		X
12	Х			Х
13	Х			Х
14	Х	Х		
15				X
16		Х	Х	X
17		Х		
18				Х
19	Х			X
20	Х			X
21	Х			X
Percent	67%	38%	24%	62%

Information in Table 3 focuses on student responses to questions regarding ozone depletion and chlorofluorocarbon (CFC) use. Forty-eight percent of the students knew about the hole in the ozone layer. Fifty-seven could identify at least one general cause of ozone depletion. Most students were able to name CFCs as the cause. Only 10% were able to tell the difference between "good" and "bad" ozone. Student #1 identified low

atmospheric ozone as being chemically reactive and potentially hazardous to one's health. Twenty-four percent understood the how CFCs affect the ozone layer. Student #2 knew the ozone layer was broken up by CFCs.

Table 3: Pre-Test Questions on Ozone and CFCs

Student	Understood ozone layer hole	Identified at lease one cause of hole	Understood *good" versus *bad"	Understood effects of an increase in CFC
1	X	V	ozone	
		X	X	V
2	X	X		X
3	Х	Х		Х
4				
5	Х	Х		Х
6		X		
7	X			
8	X	X		X
9	X	X		X
10	Х	X		
11		X		
12				
13				
14	Х	Х		
15	Х	Х	X	
16		Х		
17				
18				
19				
20				
21		Х	······································	Х
Percent	48%	57%	10%	24%

Table 4 shows data for student responses regarding different air pollutants. Twenty percent of the students were able to name three or more air pollutants. Twenty percent of the students could identify the cause of acid rain. Student #1 and #15 knew that a reaction took place between the sulfur oxides and water. Twenty-five percent of the students knew that radon entered a house through the ground.

Table 4: Pre-Test Questions on Air Pollutants (excluding CFC)

Student	Identify 3 or more major air pollutants	Cause of Acid Rain	How Radon Enter Homes	Problem with Radon in Homes	Under- stood PM	Effect of PM on Air Quality
1		X				
2	X		X			
3						
4						
5						
6	X				Х	Х
7			Х			
8		X				
9	X		Х	Х	X	
10		X	X	X		
11						
12						
13				X		
14						
15	X	X				
16						
17						
18			Х	X		
19						
20						X
21						
Percent	19%	19%	24%	19%	10%	10%

Several were more specific and identified cracks in the basement as an entry point. Fewer could identify problems associated with radon exposure, primarily lung cancer. Of the students surveyed, 10% understood the concept of particulate matter and 10% knew the effects of particulate matter on air quality. Student #6 identified particulate matter as small particles or dust in the air and stated that their presence decreases the air quality.

Two students or 10% were able to name a factor that influenced indoor air quality.

EVALUATION OF CHANGES TO CURRICULUM

I did not conduct formal student interviews before teaching this unit. I found the pre-test to be a sufficiently valuable tool in providing me with information. Through informal discussion I did learn of a major misconception that did not come up in the pre-test. An overwhelmingly large number of students believed that the greenhouse effect and global warming were interchangeable terms. Knowledge of this enabled me to address why the misconception was in fact a misconception at the beginning of the unit and I was able to reinforce the correct information throughout the unit.

Last year was the first year APES was taught nationwide. I taught this course with an experienced AP Biology teacher. The purpose of team teaching the class was to teach me how to plan and implement an AP course. This year I taught this course alone. I found myself almost a month behind schedule and seriously pressed for This was a major disadvantage for those students who had opted to take the AP test because we were still learning content material the week before the AP test. It was a major benefit in terms of weather, as we moved into spring. For the most part, the warm sunny weather really added to the labs that were conducted outside. I did have back up protocols for some of the labs if the weather was not favorable. It rained the night before we were to test for ozone. Since students learned that rain washed many of the ozone precursors out of the atmosphere they understood why the lab was postponed.

Student interest was also higher when laboratory experiments were conducted outside. The nicer the weather the higher their motivation to work. The one lab that students understood but did not enjoy was the one that tested the effects of acid rain on Daphnia. Several were upset because we were "killing poor defenseless creatures again."

ANALYSIS OF PRE-TESTS, POST-TESTS AND FINAL EXAM

To determine whether or not the labs and activities in this unit did in fact enable students to increase their scores between the pre-and post-test (Table 5) I used the Student's t test. The Student's t test showed that there was a statistically significant difference between the pre- and post-test scores. This suggests that students learned a lot during the teaching of this unit.

In order to perform the Student's t test the following information is needed for both sets of data.

The pre- and post-test are groups 1 and 2 respectively.

Student's t test, t

$$t = X_2 - X_1 = 12.8$$

where

 X_1 is the pre-test mean X_2 is the post-test mean s_{Dx} is the standard difference of the mean degrees of freedom = 19

The Student's t test result for the difference between the pre-test and post-test is 12.8. This suggests that the implementation of this unit played a role in the differences in the mean pre- and post-test scores at the 0.001 level.

Table 5: Pre-test, Post-test and Final Exam Scores

Student	Pre-test (%)	Post-test (%)	Final Exam (%)
1	40	97	80
2	36	84	60
3	24	101	60
4	0	79	80
5	32	83	80
6	16	83	70
7	24	61	60
8	20	80	30
9	52	80	70
10	36	80	60
11	8	81	30
12	16	69	40
13	24	63	50
14	20	61	60
15	32	76	-
16	24	76	60
17	8	60	20
18	28	77	40
19	8	57	40
20	24	47	40
21	12	77	30

Figure 1 shows the scores for the pre-test, post-test, and final exam questions (Appendix A) on air. Achievement increased between the pre-test and post-test. The post-test, which was also the unit test, contained 40 multiple-choice questions and six essay questions that were graded positively. Positive grading is the style that is used on the AP test. In this type of grading, students are given points for correct answers to essay questions. They are not marked down for negative responses unless they directly contradict themselves. Essentially students start with zero points and attempt to earn points through

correct answers to questions. If a student gives more detail in an answer, she/he may earn more points than a person who correctly answered the question, but did not elaborate. This type of grading rewards well thought detailed answers. Total possible points are based upon the highest scores earned. If the highest score was far above the other students, the total possible points is either the second highest score or a number between the first and second highest scores. In this case the total possible points was a number between the first and the second highest score. The final exam was given two days before the AP test and contained 110 multiple-choice questions. Ten of these were based upon our air unit.

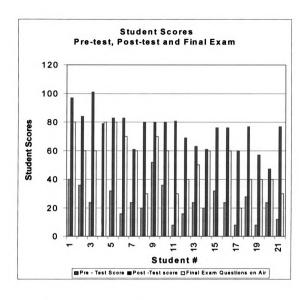


Figure 1: Student Scores: Pre-test, Post-test, and Questions from the Final Exam

DISCUSSION AND CONCLUSION

The indoor air quality analysis, the particulate matter lab and the sunscreen lab were very effective because each was relevant to students' lives. For example, they could see the possible effect of particulate matter on their lungs.

The sunscreen lab showed students that the SPF ratings on the labels of sunscreen lotion do have meaning. They do block UV rays. I asked the class if they would pay extra for sunscreen that blocked UVA, UVB and UVC. Student response was varied until student #10 reminded the class that ozone completely absorbs UVC and thus the more expensive sunscreen would be unnecessary. I think students were able to relate to this lab in terms of their personal health and as their roles as consumers.

A few students said that they had looked forward to the indoor air quality study. We all knew there were issues about poor air quality in our building. They wanted to test for related problems. While some students were disappointed that we were not able to test for the identity of the smell in B Hall, they were glad to be able to ask the construction manager about the smell and that seemed to placate them somewhat.

There was not a student in our class who did not know about the air quality problems in the Los Angeles area. I believe the SPOTS computer program showed them that we, Southeastern Michigan, in fact have Ozone Action Days for a reason. It gave meaning and sound reasoning to avoid filling the gas tank in their cars during such occasions. The fact that they saw the level of ozone increase throughout the day in the area where they live was powerful.

I would also label the microclimate lab a success because students related it to other labs, even with eight students of 22 collecting inconsistent data. Our brief class discussion of the data was enough to allow students to gain enough understanding of microclimates that the students were the ones to tie it to the ozone testing, greenhouse effect, and indoor air pollution labs. I did not need to direct the discussion in that particular direction.

Each lab included questions regarding experimental error and limitations to our experimental data. Class discussions showed that students were able to evaluate a lab and look for improvements and limitations. This is a life skill that can be applied to future lab work or any other study they may read about or conduct themselves.

My goal was to have a meaningful activity, other than lecture, to teach the students each major aspect of air quality. I feel that I accomplished this. However, I believe there was a cost. We spent so much time doing experiments that we did not have enough time for meaningful discussions. This is an enormous drawback. I knew the point to each lab and I knew where it could be related in "real life" but it was usually a few days after the experiment that the class was able to discuss it. Understanding could have been higher if we could have discussed the lab while it was fresh in their minds. This most likely will be remedied by our schools adoption of block scheduling will help allow time for post-laboratory discussions on the day of the lab.

The lab testing the effects of acid rain on Daphnia needs to be changed. Several students were upset that we were "killing things again" and I think that the same concept can be taught using radish seeds or possibly bacteria. This is reasonable since we do a lot of experimentation on plants. The bacteria would allow them to work with another form of life. I will need to develop and test this lab first.

I strongly believe that a well-rounded hands-on science curriculum is the most effective way for me to

teach my science classes. However, instead of doing several small labs each unit I would like to take what I learned here to incorporate more student-centered long-term labs into my curriculum. I think that this will give me the time I need to conduct the in depth class discussions that are needed for students to be able to internalize and apply the information they learned in the lab to the topic we are studying. I did hear some very good insightful comments from students in class discussions. I also heard some students say that they could not identify the point to each lab, they were just glad they got to go outside.

In conclusion, I believe that I have demonstrated that using a lab-based approach to teach the concepts required in the APES Curriculum will lead to student success and learning.

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APPENDIX A

Evaluation Tools

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NAME	
NAME	

(Answers are given in italics)

1. What is global warming? (1)

Answer: Increase mean global temperature

2. What is the cause of global warming? (2)

Answer: increase greenhouse gasses: water, CO2, CH4, CFC ...

If pollution only = 1 point

3. What do we mean when we say there is a hole in the

ozone layer? (2)

Answer: thinning of ozone layer (1)

$$catalyst$$
 $O_3 -----> O_2 + O$ (1)

4. What caused the hole in the ozone layer? (2)

Answer: CFC (1)
CFC mechanism (2)

5. Name the six major air pollutants and their sources. (2)

Answer: 0-3 correct (1) 4-6 correct (2)

6. What is the cause of acid rain? (1)

Answer: example SO_x or NO_x from car exhaust or factories

7. If the pH of rain water is 4, what is the hydrogen ion concentration? (1)

Answer: 10^{-4} M

8. How does radon get into our homes? (1)

Answer: could have basement crack, sump pump etc.

A-I Continued

9. Why is it a concern? (1)

Answer: causes lung cancer

conditions)

10. Name two types of smog. What causes each type? (4)

Answer: Industrial (SO_2 and correct atmospheric conditions)

Photochemical (NO_x and correct atmospheric

11. Is all ozone good? Explain. (2)

Answer: only stratospheric ozone is beneficial, tropospheric

ozone is an irritant

12. What are CFCs? (1)

Answer: chloroflurocarbons

13. How do CFCs affect the environment? (1)

Answer: involved in the breakdown of stratospheric ozone

14. What is particulate matter? (1)

Answer: suspended particles or aerosol in the air

15. How does particulate matter affect air quality? (1)

Answer: as PM $\hat{\tau}$ s air quality ψ s

16. What factors influence indoor air quality? (1)

Answer: temperature, relative humidity, carbon dioxide, VOCs, etc.

A-II

APES A	ir 1	Unit	Test/	Post-	test
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- 1. Pick all of the appropriate sources of atmospheric carbon dioxide.
- a. volcanoesb. photosynthesis
- c. burning fossil fuels d. run off
- 2. Urban microclimates are warmer than surrounding areas by 1-2°C in winter and 0.5 - 1.0°C in the summer, on average. Which of the following contributes to this effect? Cities
- a. contain less particulate matter
- b. have more concrete
- c. have increased air flow
- d. have increased overall convection
- 3. One problem with air quality standards is:
- a. only one or two countries have adopted them
- b. those that have adopted them do not agree on the level at which pollution is harmful.
- c. they attempt to control pollution
- d. a Pollution Standard Index is used to monitor pollution emissions.
- 4. According to the text, the best way to reduce sulfurous smog is:
- a. scrubbers b. add bag house filters
- c. reduce auto emissions d. reduce the amount of sunlight
- 5. Which term includes the others?
- a. point sourceb. stationary sources
- c. fugitive sources d. area sources
- 6. Canaries in a mine, lichens near a road and begonias are all ways:
- a. to detect an increase in air quality
- b. to demonstrate the effects of convection
- c. show the atmospheric window is closing.
- d. to indicate air pollution
- 7. The naturally occurring phenomenon that happens when incoming ultraviolet radiation is absorbed by the Earth and infrared is re-emitted. Atmospheric gases trap in this heat energy and warm the Earth. We call this phenomenon:
- a. global warming b. greenhouse effect
- c. thermal inversion d. sunspots

- 8. Which feedback mechanism in the Earth-atmosphere system is incorrect?
- a. increased atmospheric CO₂ leads to an increased greenhouse effect
- b. increased glacial melting leads to decreased albedo (reflectivity)
- c. decrease in cloud albedo leads to increased atmospheric temperature
- d. decreased atmospheric H2O leads to an increased greenhouse effect
- e. increased surface temperature leads to increased evaporation
- 9. The part of the atmosphere where weather occurs is the:
- a. tropopause b. stratopause c. troposphere
- d. stratosphere e. homeosphere
- 10. The eruption of Mount Pinatubo in the Philippines in 1991 sent volcanic ash into the stratosphere. What tends to happen to the climate after a volcanic eruption? It becomes: a. warmer b. cooler c. wetter d. drier
- 11. In 1500 A.D. the CO_2 level was between 200-300 ppm. Today it is about 450 ppm. Even though there is an increase we see a yearly drop in CO_2 . The reason for this fluctuation is probably due to:
- a. combustion b. photosynthesis
- c. global warming d. the increase in particulate matter
- 12. Which is does NOT contribute to situation in Mexico City?
- a. high population b. older automobiles
- c. underdeveloped economy d. high elevation
- e. basin topography
- 13. The photochemical reactions producing ozone involve:
- a. sunlight, nitrogen oxides, hydrocarbons, triatomic oxygen
- b. sunlight, sulfur dioxides, hydrocarbons, diatomic oxygen
- c. sunlight, sulfur dioxides, hydrocarbons, atomic oxygen
- d. sunlight, nitrogen oxides, hydrocarbons, diatomic oxygen
- e. sunlight, nitrogen oxides, UV radiation, diatomic oxygen
- 14. The pH of natural rainfall is _____; the pH of acid rain is _____;
- a. 6-8; greater than 9
- b. 5-6; less than 4.5
- c. 6-8; less than 1.5
- d. 5-6; greater than 8.5
- e. 4-5; greater than 7

- 15. Tall smokestacks on power plants were designed to:
- a. allow exhaust to cool before entering the atmosphere
- b. disperse pollutants, in order to reduce harmful effects in the immediate area
- c. trap sulfur emissions
- d. intensify the chimney effect in the area of the plant and give the scrubbers enough space to react with the oxygen being released.
- e. inhibit the reactions that form sulfuric acid
- 16. Secondary pollutants differ from primary pollutants in that they are not:
- a. as dangerous as primary pollutants
- b. emitted directly into the air as are primary pollutants
- c. eliminated from the atmosphere as easily as are primary pollutants
- d. as abundant as primary pollutants
- e. natural components of the atmosphere
- 17. The Clean Air Act Amendments of 1990:
- a. focuses on pollution emitted by volcanoes
- b. mandates the reduction of SO_2 because of their effect on photochemical smog.
- c. bans the use of electrostatic precipitators and scrubbers on coal plant towers.
- d. bans CFCs by the year 2000 because their role in ozone reduction.
- 18. Which of the following are true of the London Smog situation in 1952?
- a. It is the same type of smog found in LA.
- b. It is the product of rapid air currents
- c. It involved acid deposition.
- d. It did not result in immediate deaths, but did contribute to chronic lung disease.
- 19. Asbestos is hazardous to human health because:
- a. it releases toxic fumes.
- b. if it is trapped in the lungs, it will decay and damage DNA.
- c. it is composed of small fibers, which damage skin or lung tissue.
- d. if it is trapped in the lungs, it can be carcinogenic.
- e. it is a potent toxin, damaging the neurological systems of humans and animals.

The following question refers to the Global Thermal Balance figure below:

- 20. The figure above illustrates an analogy of the Earth's thermal balance. Water pouring into the bucket is equivalent to in-coming solar radiation, and the water leaking from holes in the bucket is like outgoing thermal radiation (Earthshine). The amount of water in the bucket is equivalent to the amount of heat on Earth a higher water level is like higher temperature on Earth. In this analogy, if the holes in the cup represent the atmospheric window, you would show the effect of an increase in the emission of anthropogenic
- a. putting the bucket on the stove
- b. increasing the stream of water pouring into the bucket
- c. decreasing the stream of water pouring into the bucket
- d. punching some new holes in the bucket
- e. plugging-up some of the holes in the bucket
- 21. If the above situation were indeed happening we would experience:
- a. global warming

gasses by

- b. an increase in the total amount of water available on earth.
- c. global cooling
- d. an increase in lung cancer due to an increase in inhalable particulate matter.
- 22. According to Mr. Spencer:
- a. Michigan is radon free, but there are many other states that have dangerous levels of radon.
- b. Radon is artificially produced by fusion reactions in the earth.
- c. Detectors have changed little since they were developed.
- d. Polonium is what we are really afraid of, it is an alpha emitter and is a particulate.
- 23. What was the apparent cause of the large number of respiratory ailments reported at the Massachusetts Registry of Motor Vehicles after it opened in 1994?
- a. ozone b. radon gas
- c. global warming d. poorly designed ventilation system

- 24. Black lung disease usually results from:
- inhaling soot or fumes b. smoking
- C. high levels of radon gas d. inhaling asbestos fibers
- 25. Mechanisms by which radon gas may enter homes include:
- outgassing from carpets, particle board, and insulation
- leakage of refrigerants in air conditioners and refrigerators
- vapors emitted from common cleaning products
- d. seepage through cracks in basements or foundations
- emissions from nearby nuclear power plants
- 26. Which of the following are true of ozone?
- it is an unstable molecule
- b. it naturally occurs in the stratosphere
- c. it can be produced copy machines
- d. it breaks into O and O_2 when struck with UV light
- e. all of the above.
- 27. Montreal Protocol calls for
- a. decreased CO₂ levels on airplanes
- b. increase use of NO_x to be used as sinks for ozone
- c. elimination of CFC production
- d. increase in aerosol use
- 28. What do the following reactions show?

C1 +
$$O_3 \rightarrow C10 + O_2$$

C10 + $O \rightarrow C1 + O_2$

- a. ozone formation
- b. nuclear chain reaction
- c. catalytic chain reaction d. the formation of a polar vortex
- 29. A Dobson unit measures the concentration of which of the following substances?
- a. CO₂ b. ozone c. UVB d. CFC e. any air pollutant
- 30. There are two main reactions that consume chlorine in the stratosphere and interrupt the chlorine chain reaction that destroys ozone:
 - $Clo + NO₂ \rightarrow CloNO₂$ and $4Cl + CH_4 \rightarrow 4HCl + C$ Polar stratospheric clouds deplete ozone in the stratosphere over Antarctica because they contain very little:
- a. chorine b. ozone c. HNO_3 particles d. HCl e. NO_x

- 31. Putting a coating over lead paint in an old home would be an example of:
- a. ventilation c. source removal
- b. source modification d. consumer information and education
- 32. Which of these effects has/have been linked to excessive UV-B exposure? Pick all possible.
- a. skin cancer
- b. emphysema
- c. increased sunburns
- d. eye damage
- e. black lung disease
- 33. One process that increases indoor radon concentration is the "chimney effect" which:
- a. occurs in a building suffering from the 'sick building syndrome'
- b. moves more radon through homes which burn wood for heat
- c. occurs where buildings are warmer than the air around them or the rock below them
- d. occurs in tall, air-conditioned buildings
- e. concentrates radon in the lower floors of tall buildings
- 34. Where would we MOST LIKELY see these sets of reactions take place.

```
N_2 + O_2 \rightarrow 2NO 3NO_2 + H_2O \rightarrow HNO_3

2NO + O_2 \rightarrow NO_2 HC + O_2 + NO_2 \rightarrow PANs

NO_2 + UV \rightarrow NO + O O + O_2 \rightarrow O_3
```

- a. sunny, warm, dry b. cloudy, humid, near a mountain
- c. cool, humid d. sunny, moist, cool
- 35. A temperature inversion would increase the likelihood of an ozone episode in which way:
- a. an increase in cloud cover and decrease sunlight
- b. keep pollutants in troposphere
- c. allow pollutants in troposphere to be washed out of the clouds
- d. allow air to travel over mountains and prevent a chimney effect
- 36. If the hydrogen ion is 0.01, the pH is:
- a. 1 b. 2 c. 3 d. 4 e. 7

- 37. UVB is not the only wavelength of radiation that can be harmful to humans and other organisms. Why is there so much concern about UVB radiation and ozone depletion?
- a. It is so high in energy that it can break a diatomic oxygen (O_2) into two monoatomic oxygen (20).
- b. It is not absorbed by ozone.
- c. It has the lowest energy of the three types of UV radiation and will easily damage cells.
- d. UVB is only absorbed by ozone and exposure to it may decrease phytoplankton productivity.
- 38. How does the Antarctic polar vortex relate to global ozone depletion?
- a. It increases the amount of NOx in the atmosphere.
- b. It reduces the sink for chlorine.
- c. It is caused by the increase in temperature during the polar spring.
- d. It absorbs UVC which is needed to make ozone.
- 38. Raleigh is near the Atlantic Ocean and the Appalachian Mountains. When Ms. Najarian was at NC State last summer she ran every morning before her 8:00AM class. It was usually warm when she ran. However, on the last day the temperature seemed cooler than usual. Initially Ms. N. was grateful for the cool air, but as she ran down a main road (even though it was clear) she noticed that the exhaust from the cars was much more noticeable than on the previous mornings. What was happening in Raleigh that morning?
- a. there was too much convection
- b. there was a heat island effect
- c. there was a thermal inversion
- d. there was an urban dust dome
- 40. In our Indoor Air Quality study we found North to be high in carbon dioxide and humidity. How would you suggest these be reduced?
- a. increased convection
- b. better furnace filters to reduce the particulate matter
- c. better insulated windows
- d. send all of the APES to Max and Erma's for lunch. 😣

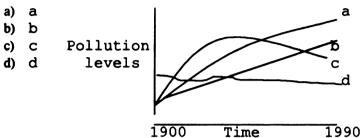
Air Test Short Answer Answer in pen on the paper provided.

- 1. Name two of the suggested substitutes to CFC and give a pro and con for each.
- 2. (a) <u>Briefly</u> tell why some parts of our country have higher radon than others. (b) Why is it possible to have radon in your home and not be aware of its presence? (c) Once a radon problem is detected, what measures (give two) can be taken to alleviate the problem? (d) At what level must you take action?
- 3. Yesterday we have a clear, bright, sunny day. (a) Using your knowledge of air concepts tell why the air temperature at night was so cool. (b) Relate this to the concentration of air pollutants in the air.
- 4. Give three ways air pollution stresses trees. Explain.
- 5. A lake in the Ohio Valley which had a pH of 5.5 in 1902 has been found to now have a pH of 3.0.
 - a. Explain a specific cause for this change in pH.
 - b. Explain the effects of such a change.
 - c. What must you consider if you were to attempt to reverse this process (trend)?
- 6. Pick ONE of the air pollutants from the book. a) What is the source of the pollution? b) Is it anthropogneic c) Is it a primary or secondary pollutant? d) What effect does it have on human health? e) On the environment? f) Can/how can it be reduced? Explain. You should be as specific as possible.

A-TTT APES Final Exam Questions on Air and Air Quality

Which curve on the graph below best represents air pollution trends in major US cities?

Urban Air Pollution Trends in the U.S.



The brown haze in smog is caused by

- a) sulfuric acid
- c) NO2
- b) carbon monoxide
- d) chloroflourocarbons
- A temperature inversion occurs when
- a) two warm air layers surround a cold air layer
- b) air turbulence causes and is partly ringed by mountains
- c) stable, cold air overlays warm air
- d) stable warm air overlays cold air

ozone is harmful, damaging plants and human health while ozone at the level screens out mutagenic ultraviolet radiation.

- a) Stratospheric, troposphere c) Thermospheric, mesosphere
- b) Tropospheric, stratosphere d) Mesospheric, thermosphere

Pollutants such as chloroflourocarbons deplete atmospheric ozone

- a) when nitrogen combines with O_3 to form NO_x
- b) when chlorine-containing molecules are oxidized at the expense of O₃
- c) because chlorine is most stable as ClO₃
- d) all of these are correct

High altitude forests are especially susceptible to acid deposition because

- a) acidic clouds surround them much of the time
- b) high winds blow acids into leaf tissues
- c) low moisture levels fail to dilute acids
- d) high altitude species are especially delicate

A-III Continued

How would the eruption of a volcano cause global climate changes?

- a) dust from the volcano blocks sunlight
- b) sulfuric acid is produced which interferes with solar radiation
- c) it can cause stratospheric ozone reduction allowing increased ultraviolet light to reach the Earth's surface
- d) both a & b

Energy absorbed at the Earth's surface is radiated back to space in the form of

- a) visible light c) ultraviolet radiation
- b) infrared radiationd) microwaves

The phenomenon causing the greenhouse effect is that ____ in the lower atmosphere selectively absorbs re-radiated ____ radiation

- a) ozone; visible light
- b) carbon dioxide, methane, and other gases; infrared (heat)
- c) hydrocarbons; very short wavelength
- d) carbon dioxide; ultraviolet

Radon in houses is suspected of causing

- a) cancer
- b) heart disease
- c) kidney infections
- d) emphysema

APPENDIX B

Experiments

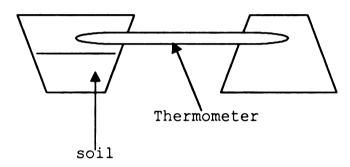
B-I APES Greenhouse Effect Lab	62
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B-VI How Protected Are You?	.78
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D 1

Procedure:

- 1. Obtain the following materials
 - **♦** Thermometer
 - ◆ Plastic cup with hole on top
 - ◆ Plastic cup with hole on bottom

- ♦ Soil
- ♦ Water bottle
- ♦ Rubber band
- ♦ Plastic wrap
- 2. Assemble set-up as shown below.



- 3. Wet soil until moist. There should be no ponds in your set-up.
- 4. Record temperature in one minute intervals for 15 minutes.
- 5. Cover with plastic wrap. Secure with rubber band.
- 6. Repeat.
- 7. Compare data with other groups and soil types.

Data:

Soil Type_____

Time	Temperature	Temperature
(minutes)	Covered	Uncovered
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
13		
14		
15		

B-I continued

- 8. Prepare a formal lab report. It should be typed, double-spaced with a 12 point font, and one inch margins. Use the following information as your guideline.
 - a. Introduction includes background information, purpose and hypothesis
 - b. Materials and Methods
 - 1. List the material used including quantities
 - 2. Draw a picture of the set-up
 - 3. Describe procedure in detail
 - c. Data, Observation and Results
 - 1. Data table should be neat and in a titled table
 - 2. Include a graph that is computer generated
 - 3. Describe results without interpreting them
 - d. Analysis answer the following lab questions here
 - 1. With the cover on the cup, why did the temperature increase more or less? Explain.
 - 2. How do you compare this activity with the greenhouse effect on Earth?
 - 3. Did you notice any differences in the temperature readings between the soil types and or color? Explain.
 - 4. What do you think the effect of increased cloud cover would be on the Earth's temperature?
 - 5. What effect would a significant rise in average global temperature have on the Earth's coastlines?
 - 6. What are two sources of error and how did they affect your results?
 - e. Conclusion
 - 1. Interpret your results (what do they mean?)
 - 2. Did you support or reject your hypothesis?
 - 3. What conclusions can you draw from your lab data?

Please note that I included the protocol and data table here for clarity. I give students verbal instructions and the last section here; they are to include the rest in their report.

Acid Rain and Its Effects on Daphnia

Rainwater normally has a pH between 5.4-5.6. This makes rain slightly acidic. This is because atmospheric carbon dioxide (CO₂) will dissolve in water found in the atmosphere and will form carbonic acid or H_2CO_3 . This is a natural process. A similar reaction takes place when sulfur dioxide, sulfur trioxide and the nitrogen oxides dissolve in water. The sulfur oxides are produced during the combustion of sulfur containing coal and will form sulfurous and sulfuric acids. Nitrogen oxides are produced during the combustion of gasoline in cars and will for nitrous and nitric acids. The reactions are

$$SO_2 + H_2O \rightarrow H_2SO_3$$

 $SO_3 + H_2O \rightarrow H_2SO_4$
 $NO + H_2O \rightarrow HNO_2$
 $NO_2 + H_2O \rightarrow HNO_3$

We have all heard about acid rain and have heard that it is "harmful" to plants and animals. Since rainwater is normally acidic, we must determine at which pH it begins to harm organisms.

Purpose: In this investigation we will determine the effects of "acid rain" water on Daphnia.

Procedure:

Each lab group will be assigned a pH and you will run two trials simultaneously.

- 1. Observe the activity of the *Daphnia* in their pond water. Describe below.
- 2. Obtain your acid rain water. Note the pH.
- 3. Using an eyedropper add 5 Daphnia to your sample.
- 4. Record the number of *Daphnia* living at the indicated time intervals.
- 5. Describe the activity of the *Daphnia* at each time interval.
- 6. Record class data.

B-II continued Data and Observation

1. Describe the *Daphnia* activity:

2. Hypothesis:

pH la

p.: 14		
Time	# Living	Activity
0 min		
10 min		
20 min		
30 min		
24 hr		

pH 1b

Time	# Living	Activity
0 min		
10 min		
20 min		
30 min		
24 hr		

pH 2a

Time	# Living	Activity
0 min		
10 min		
20 min		
30 min		
24 hr		

pH 2b

Time	# Living	Activity
0 min		
10 min		
20 min		
30 min		
24 hr		

рН За

Time	# Living	Activity
0 min		
10 min		
20 min		
30 min		
24 hr		

pH 3b

Time	# Living	Activity
0 min		
10 min		
20 min		
30 min		
24 hr		

B-II continued

pH 4a

<u> P.I u</u>		
Time	# Living	Activity
0 min		
10 min		
20 min		
30 min		
24 hr		

pH 4b

Time	# Living	Activity
0 min		
10 min		
20 min		
30 min		
24 hr		

pH 5a

Time	# Living	Activity
0 min		
10 min		
20 min		
30 min		
24 hr		

pH 5b

Time	# Living	Activity
0 min		
10 min		
20 min		
30 min		
24 hr		

pH 5.5a

pii 3.3a		
Time	# Living	Activity
0 min		
10 min		
20 min		
30 min		
24 hr	-	

pH 5.5b

p 0.02		
Time	# Living	Activity
0 min		
10 min		
20 min		
30 min		
24 hr		

pH 6a

Time	# Living	Activity
0 min		
10 min		
20 min		
30 min		
24 hr		

pH 6b

Time	# Living	Activity
0 min		
10 min		
20 min		
30 min		
24 hr		

pH 7a

Time	# Living	Activity
0 min		
10 min		
20 min		
30 min		
24 hr		

pH 7b

Time	# Living	Activity
0 min		
10 min		
20 min		
30 min		
24 hr		

B-II continued

Discussion and Conclusion Questions

- 1. At what pH is the activity of the *Daphnia* altered? How has it changed?
- 2. Which pH is the most lethal to Daphnia? What evidence do you have to support this?
- 3. Did your data support your hypothesis? Explain.
- 4. What conclusions can be drawn from this experiment? Support your answer using lab data.

- 5. (a) Name two sources of error.
 - (b) Explain how they affected the results.
 - (c) How could we correct for these errors?

Teacher notes:

You must first prepare a salt solution for the brine shrimp. Add sea salt or Kosher salt (not iodized) until the salt concentration is 30 - 34 ppt or the specific gravity is between 1.022 - 1.025. Then allow the salt solution to sit overnight. This will allow the chlorine from the tap water to bubble out of solution. Use this salt-water solution to prepare the pH solutions. I used hydrochloric acid and prepared a 0.1M solution of HCl. I then performed a series of serial dilutions until I had the desired solutions. Be sure to test each solution for proper pH. You will need approximately 20mL of "acid rain water" per beaker.

APES PARTICULATE MATTER LAB

Purpose:

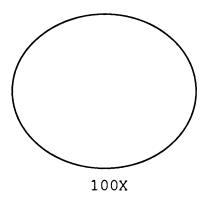
In this investigation we will collect and examine the particulate matter that is emitted from automobile exhaust. We will also observe the effects of emphysema, anthracosis, and coal dust on the human lung. These will be compared to normal lung tissue.

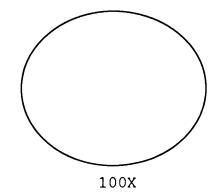
Procedure:

- 1. Place a clean sock on the exhaust pipe of a car. (If you have two exhaust pipes on your car use two socks.)
- 2. Allow car to run for 15 minutes.
- 3. <u>CAREFULLY</u> remove the sock. The exhaust pipe should not be hot. Use tongs if it is.
- 4. Wait until the entire class is finished.
- 5. When you reach the classroom carefully turn your sock inside out and label it with the make, model, and year. If you just got a new muffler or catalytic converter please note it.
- 6. Observe the results of the rest of the groups.
- 7. Gently shake some of the particulate matter from your sock onto a clean dry microscope slide. Add a coverslip.
- 8. Observe the particulate matter under low power or 100X.
- 9. Draw what you see.
- 10. Observe each of the prepared slides and neatly draw each under low power in the indicated area. You will be graded on your drawings. They do not need to be works of art, but remember scribbles do not count.

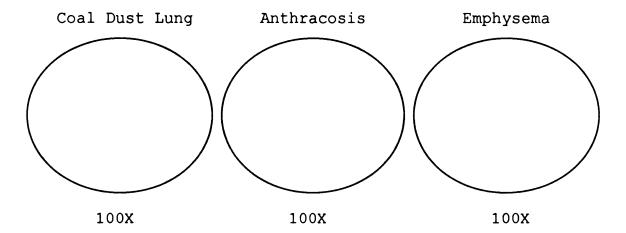
Particulate Matter from Car Exhaust

Normal Lung Tissue





B-III continued



Discussion Questions:

- 1. Describe what the socks looked like. What differences did you see?
- 2. How could you reduce the amount of particulate matter that is being emitted from your car?
- 3. Describe what happens to normal lung tissue when you develop anthracosis, emphysema, and black lung disease.
- 4. Relate the particulate matter you collected with the above question.
- 5. Describe two sources of error and how each affected your results.

Source: The Search for Clean Air Continues: Educational

Supplement for the Video The Search for

Clean Air. 1995. North Carolina State
University

APES Indoor Air Quality Analysis

General air quality is determined by the following: air flow, air temperature, relative humidity and carbon dioxide levels. If an air quality complaint is filed, the first measurements taken by an industrial hygienist involve these areas. In our study we will examine the indoor air quality in various locations in school.

Procedure:

- 1. In your assigned team
 - a. describe the area you are examining
 - b. measure air flow in feet per minute
 - c. record the temperature, in Celsius
 - d. record the relative humidity using the sling
 psychrometers (remember this takes 3 minutes)
 - e. using the CO_2 meter record the carbon dioxide level in parts per million (we will need to share.) Please be sure NOT to breathe into the meter. It will significantly alter your results.
- 2. Meet at the room and record class data.
- 3. Determine whether our measurements fall within the acceptable parameters.

Data:			
Location I			
Description of	area:		
Air Flow	Air Temperature	Relative	CO ₂
(feet per	°C	Humidity in %	in ppm
minute or			
fpm)			
			<u> </u>
Location 2			
Description of	area:		
7 i 171	7 - m	Deletion	

(feet per minute or fpm)	°C	Relative Humidity in %	CO₂ in ppm

B-IV continued			
Location 3			
Description of	area:		
Air Flow (feet per	Air Temperature °C	Relative Humidity in %	CO ₂ in ppm
minute or		namiately in o	III pp
fpm)			
		<u> </u>	<u></u>
Location 4			
Description of	area:		
Air Flow	Air Temperature	Relative	CO ₂
(feet per minute or	°C	Humidity in %	in ppm
fpm)			
Location 5			
Description of	area:		
-			
Air Flow	Air Temperature	Relative	CO ₂
(feet per minute or	°C	Humidity in %	in ppm
fpm)			

B-IV continued	
Location 6	
Description of area:	

Air Flow (feet per minute or fpm)	Air Temperature	Relative	CO ₂
	°C	Humidity in %	in ppm

Questions:

1. Do our results fall within the acceptable levels? Explain.

2. Relate the chimney (or stack) effect to indoor air quality.

3. How does the sampling area affect the results?

B-IV continued

4. Is it possible to have an indoor air quality problem and still get acceptable results here? Explain.

5. List two sources of error and tell how they affected your results.

Sources:

Ceru, Robert and Sarah Buehler from the Office of Radiation, Chemical and Biological Safety at Michigan State University. Personal interview. July 1998.

Jacobs, Bruce W. 1995. Measuring Air Flow, Air

Temperature, Relative Humidity, and Carbon Dioxide in
Schools. Maryland. Maryland State Department of
Education.

SPATIALLY PLOTTED OZONE TRACKING SYSTEM (SPOTS)

I. Tracking an Ozone Episode

Click 'Select Episode" on your menu bar. Choose the Southeast Michigan episode for June 15-18 1994. Read the following paragraphs describing this episode and answer the related questions. For help, terms and concepts in bold typeface are explained in the glossary.

June 15

A cold front, which had passed through the region on the 13th reversed direction and began moving NE through the region as a warm front on the 14th. These winds pumped warm moist air from the gulf states into SE Mich.

1. What is the temperature, wind speed, and wind direction in Detroit at 10 a.m.?

Scattered showers and thunderstorms occurred over Indiana, Ohio, and the extreme southern portion of Michigan throughout the time period of the 15th to the 18th. The showers over Ohio helped reduce the pollutant concentrations in the air coming into SE Michigan on the afternoon of the 15th, however, a lobe of elevated ozone concentrations moved north through the Detroit area prior to the showers. Additional emissions from the Detroit Metropolitan area reacted to form increased ozone concentrations downwind. Harbor Beach reported 159 ppb at start hour 16:00 (see thumb area).

3. What are the ozone readings at the Southeast Michigan monitors at 12:00?

Allen	Algonac	Det.	Det.	New	Oak	Port	Tecum	Warren
Park		(a)	(b)	Haven	Park	Huron		
	, , , , , , , , , , , , , , , , , , , ,							

- 4. At this time is the Detroit metropolitan area upwind or downwind in Michigan's thumb area?
- 5. Were high ozone levels in Port Huron caused by emissions in Port Huron Beach? Explain.

^{2.} Why might this warm, moist southerly wind be important to ozone formation?

B-V continued

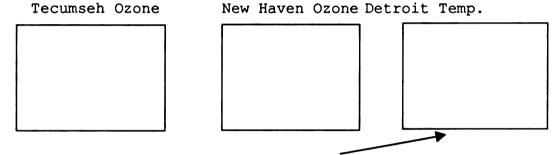
June 16

On the 16th, there was significant midday heating and abundant sunlight. The winds were lighter than the previous day and therefore ozone concentration peaks were found much closer to downtown Detroit.

Find the Tecumseh and New Haven sites:

6. Plot the hourly ozone values from 10:00 a.m. to 8:00 p.m. (20:00).

While these are rough sketches, I still want labels.



- 7. Plot the temperatures in Detroit for this same time period. While this is a rough sketch, I still want labels.
- 8. Explain the difference in ozone values between the two sites.

Look at the Port Huron site:

- 9. At 18:00, Port Huron ozone levels are still high (111ppb). Why might this be?
- 10. At what time do ozone levels generally decline for the day? Why is that?
- 11. So, when is it less harmful to do certain emissioncausing activities?

B-V continued June 17

We had record-breaking temperatures on both the 17th and the 18th. On the 17th, thunderstorms began early and the associated clouds reduced available sunshine, keeping ozone concentrations low. Calm winds overnight on the 17th, along with the development of a shallow nocturnal inversion, prevented any significant mixing of pollutants, so precursors hovered over the area.

- 12. What are the general wind directions during the day?
- 14. What are the temperature readings for Selfridge Air Force Base, Detroit City, and Detroit Metro at 9:00 a.m. on the 17th? Selfridge______ Detroit City______ Detroit Metro
- 15. When do temperatures peak?
- 16. When do they start going down for the day?
- 17. At midnight, the temperature hovers at 80 F, why might this be significant on the 18th?

Track ozone from noon to 4 p.m. for Warren, the two Detroit sites, Allen Park and Oak Park:

- 18. Why do you thing they never get much higher than 100 ppb?
- 19. Considering we had rain and clouds, why might 110 ppb be considered high?

June 18

On the morning of the 18th ozone concentrations at Port Huron increased quickly in the morning. This type of localized concentration increase indicates that there was an isolated layer of high ozone aloft that had been formed on previous days and was mixed to the ground when the nighttime inversion was broken by the heat from the morning sun. Down close to Detroit, light morning winds appear to have moved Detroit's morning rush hour emissions out over Lake St. Clair where they reacted to form high ozone. Pollutants over a lake generally do not disperse very much due to the lack of turbulence of the atmosphere immediately above the lake surface. When a lake breeze developed around midday, the ozone was carried on shore. Overnight, a cold front finally moved through the area bringing in a clean air mass on the 19th.

B-V continued

- 20. What is the concentration at Port Huron at 10:00?
 ____At 11:00?____
- 21. See Detroit and Windsor monitors at 14:00, what are their readings? Detroit ______ Windsor _____ Why might these sites be so high when their neighboring sites are not?
- 22. What indicates a lake breeze developed around midday?
- II. Comparing regional ozone episodes
 Check out the 8/25/91 episodes in Southeast Michigan. Note
 wind, temperature, and general ozone levels. Next, go to the
 Lake Michigan episode for the same date. What major urban
 areas are shown here? Click through the day on an hourly
 basis. What do you notice about wind speed, direction, and
 ozone? Where are the highest concentrations of ozone? Why?
- III. Test Your Knowledge

Choose from the following Southeast Michigan episodes. What SPOTS data supports these descriptions?

7/4-7/7 1988

The dominating feature during this period was the building high pressure over the Eastern U.S. This produced SE to SW winds at the surface. The light Se winds, early in the period, allowed already polluted air to move into SE Michigan. In addition, the atmosphere was very stable, suppressing any vertical mixing throughout the period. Skies were generally clear with hazy sunshine the region allowing the photochemistry to progress. The SW winds also sent the temperatures soaring into the hundreds on the sixth. 7th, with the surface high beginning to weaken and actually move backwards toward the SW, the surface winds shifted to the WNW and remained relatively light. The temperatures still reached in to the hundreds which caused more exceedances. On the 8th, the winds increased out of the NW keeping the ozone concentrations in the immediate Detroit area below the exceedance levels.

Source: Monosmith, Tom. <u>Spatially Plotted Ozone Tracking</u> System (SPOTS) v3.6e. 1994-5.

How Protected Are You?

The active ingredient in many suntan lotions is para-aminobenzoic acid (PABA). It contains a benzene ring, which captures the UV energy and spreads it over its C-C bonds. This lengthens the wavelength of the radiation and converts it to harmless infrared, or heat energy. Zinc oxide also is also used in some sunscreens because it completely blocks UV light. This relates to our study of ozone in that ozone also absorbs UV light (UVB and UVC to be exact.) When it does, it is broken down into oxygen and monatomic oxygen. The reaction is:

$$O_3$$
-UV \rightarrow O_2 + O

In this investigation you will use sun sensitive paper to test a variety of sunscreens at a variety of sun protection factors, or SPF. The relative quantities of sunlight each allows to pass will be indicated by the effect on the sun-sensitive paper.

Procedure:

- 1. Using a black Sharpie® marker clearly label your acetate sheet C, for control, O for opaque object, and then list the appropriate SPFs you will be testing.
- 2. Place an acetate sheet over your film.
- 3. Spread ONE drop of oil or cream that is the size of a small pea onto the spot you labeled in step one. Do this as evenly as possible.
- 4. Put lotion without SPF on the control and a bottle lid in the spot labeled O for opaque.
- 5. Lay the sun sensitive paper/acetate on a flat surface in the sunlight. (If we have bad weather we will use UV lights.)
- 6. Allow the sample to remain in the sunlight until the paper fades to a very light blue.
- 7. Remove from sunlight and place the paper only, not the acetate sheets, into water for one minute.
- 8. Remove from water and place on apiece of paper towel for drying.
- 9. Record the relative shading of each sample.
- 10. Wash hands and clean up!

B-VI continued

Data:

Rank samples from lightest to most opaque. Use a one for the sample that was the most like the control and a 10 for the one that is the most like the jar lid.

SAMPLE			
Rank			

Questions

1.	Describe	your	results	:
----	----------	------	---------	---

2. How is PABA like the ozone layer?

3. How is zinc oxide like the ozone layer?

4. Relate the problems concerning the stratospheric ozone layer to sunscreen use.

5. Compare two brands of lotion with the same SPF number. Did you get the same results?

6. What are two sources of error and how did these errors affect your results?

Source: Chemistry in the Community. 2^{nd} edition p. 441-442 and 3^{rd} edition p. 492-494.

Stratospheric ozone helps prevent damaging ultraviolet radiation from reaching the earth. However, troposphere ozone is considered a secondary pollutant that will cause both eye and lung irritations. In this lab you will investigating the presence of ozone on the school grounds. In order to detect ozone we will take advantage of its ability to reduce iodine. Ozone in the air will reduce the iodide ion in potassium iodide to produce iodine. The potassium iodine will be located on Schoenbein paper, which contains a paste of starch and the potassium iodide. The iodide in potassium iodide is clear, but when oxidized to iodine it will turn the starch a shade of purple. There is a correlation between the shade produced and the amount of ozone present in the air. The overall reaction is as follows:

2 KI +
$$O_3$$
 + H_2O \rightarrow 2 KOH + O_2 + I_2

Procedure:

- 1. Report to room 316 between 7:00AM and 7:20AM to collect your test strips.
- Label each test strip before you add the KI/starch paste to it.
- 3. If step one was done prior to the test and is dry, you must dip it into distilled water. If the paper is wet you may place it at your assigned collection site. Make sure the strip is hanging freely and out of direct sunlight.
- 4. One person in the class will use the sling psychrometer to determine the relative humidity. Round to the nearest 10%.
- 5. After approximately eight hours collect test strips. (If you will not be analyzing them immediately, place into a sealed baggie.)
- 6. Use the Schoenbein Number chart and color scale to determine the ozone concentration in parts per billion or ppb.

Data:

Table 1: Schoenbein Color Scale

0 - 3	Little or no change		
4 - 6	Lavender hue		
7 - 10	Blue or purple		



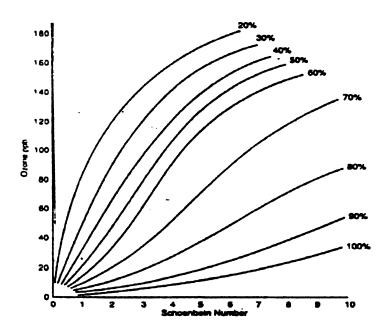


Figure 2: Relative Humidity Schoenbein Number Chart

Relative Humidity_____

LOCATION	COLOR	schoenbein #	OZONE (PPB)
			

Questions:

1. What change in the test paper did you observe?

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- 2. Compare you test paper to those of other students. Do all the test papers appear the same? Why or why not?
- 3. Would the parts per billion of ozone be the same for a Schoenbein Number of 4 at a relative humidity of 30% and 70%?

4. Based upon your data collected, do you think this method is a good way to measure tropospheric ozone? Support your answer.

Source: Lee, Judy and Joyce DeRulle. "Field - Testing for Ozone: Analyzing air quality in your hometown." The Science Teacher. December 1995. 62(9): 16 - 19.

LITERATURE CITED

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- American Chemical Society. 1993. ChemCom: Chemistry in the Community. 2nd edition. Dubuque, IA: Kendall Hunt Publishing.
- American Chemical Society. 1998. ChemCom: Chemistry in the Community. 3rd edition. Dubuque, IA: Kendall Hunt Publishing.
- Bodkin, Daniel B. and Edward A. Keller. 1998.

 Environmental Science: Earth As A Living Planet. 2nd
 ed. New York: John Wiley & Sons, Inc.
- Bruck, Robert L. 1994. The Search for Clean Air. Films for The Humanities, Inc.
- Bunce, Nigel. 1991. Environmental Chemistry. Canada: Wuerz Publishing LtD.
- Bybee, Rodger W. and Leslie W. Trowbridge. 1990, Becoming

 A Secondary School Science Teacher. 5th ed. Columbus,

 OH: Merrill Publishing Company.
- Ceru, Robert and Sarah Buehler from the Office of Radiation, Chemical and Biological Safety at Michigan State University. Personal interview. July 1998.
- Cunningham, William P. and Barbara Woodworth Saigo. 1997.

 <u>Environmental Science: A Global Concern</u>. Dubuque, IA:

 Wm. C. Brown Publishers.
- Environmental Protection Agency. Global Warming Site:
 Reports and Slides: Publications: The Regional
 Impacts of Climate Change, (IPCC, 1998) North America
 Chapter 8 [Online] Available.
 http://www.epa.gov/oppeoee1/globalwarming/reports/pubs/ipcc/chp8/america10.html, June 14, 1999.

- Environmental Protection Agency. The Effects of Ozone Depletion [Online] Available.

 http://www.epa.gov/ozone/science/effects.html June 14, 1999.
- Jacobs, Bruce W. 1995. Measuring Air Flow, Air

 Temperature, Relative Humidity, and Carbon Dioxide in

 Schools. Maryland. Maryland State Department of
 Education.
- Intellimation, Inc. 1998. Resource Manager to accompany
 Environmental Science: Earth as a Living
 Planet. Version 1.0. CD-ROM. New York: John Wiley &
 Sons, Inc.
- Lee, Judy and Joyce De Rulle. *Field Testing for Ozone."
 The Science Teacher. (Dec 1995). 62(9):16 19.
- Miller, G. Tyler Jr. 1997. Environmental Science. 6th ed. Belmont, CA. Wadsworth Publishing Company.
- Miller, G. Tyler Jr. 2000. <u>Living in the Environment</u>. 11th ed. Pacific Grove, CA. Brooks/Cole Publishing.
- Monosmith, Tom. Spatially Plotted Ozone Tracking System (SPOTS). v3.6e. 1994 5.
- The Search for Clean Air Continues: Educational Supplement for the Video The Search for Clean Air. 1995. North Carolina State University
- Staver, John R. and Small Larry. *Toward a Clearer Representation of the Crisis in Science Education."

 <u>Journal of Research in Science Teaching.</u> (Jan 1990)

 27(1): 79 89.

- Staver, John R. *Constructivism: Sound Theory for Explicating the Practice of Science and Science Teaching."

 [May 1998]. 35(5): 501 20
- von Glaserfield, E. 1995. <u>Radical Constructivism: A way of knowing and learning.</u> Washington, DC: Falmer Press.
- Waxman, Henry A. The Clean Air Act: An Act That Works.
 [Online] Available
 http://www.house.gov/waxman/caa/caafacts/fact197.htm,
 June 15, 1999.
- Wolff, Carol Wirth. 1984. Source Book on Air Pollution
 Topics for Grade and High School Teachers. Part III.
 Pittsburgh, PA. Air Pollution Control Association.
- World Resources Institute. 1996. World Resources: A Guide to the Global Environment The Urban Environment. New York. The Oxford Press.

