CLEARING THE AIR:

TREATIES TO T

PHOTODISC

Welcome to the Anthropocene. What? It means the age of humans, and, according to paleontologists, we're living in it. Although insects outnumber us, our human lives impact the planet more than any other living thing, past or present.

Earth isn't just a planet, it's a system, a kind of complex wonder where oceans, land masses, air, and living things all intimately affect one another to create the familiar surroundings we call home. Take, for example, the atmosphere in which we live and breathe. Here, we find the right amount of oxygen to maintain life, trace gases that react and cleanse the air, a UV-protecting stratospheric ozone layer, and enough greenhouse gases to ensure adequate warmth.

Because nature itself impacts air quality with volcanoes, forest fires, ocean turbulence, and ordinary seasonal variability, it's often difficult to sort out any problems for which human activity is responsible. But evidence is mounting to show that gas-powered machines and the humans they serve gobble resources and spew pollution at volumes and rates that challenge the ability of our Earth system to recover.

A 2004 report published by an international partnership of Earth-observing organizations called IGOS (Integrated Global Observing Strategy), traced several changes in the atmosphere to human activities:

Climate change and the greenhouse effect	Automobile exhaust, industrial emissions, even cattle "emissions" are loading the atmosphere with greenhouse gases like CO_2 and methane (CH_4) that trap energy as heat at the Earth's surface.
London-type smog (Largely eliminated in developed countries, but still a global problem)	Visible soot and sulfur dioxide gas emitted from industries and home heating become trapped at ground level during certain weather patterns.
Los Angeles-type smog or "summer smog"	Automobile exhaust and industrial emissions react in strong sunlight to form unhealthy pollutants like ground-level ozone that are trapped by static weather patterns.
Ozone depletion in the stratosphere (The emissions that cause the depletion have been greatly reduced as a result of an international treaty.)	Chlorofluorocarbons, or CFCs, released from some industrial processes, react with and destroy the fragile layer of atmospheric ozone that filters out life-harming UV radiation.
"Brown clouds" over and downwind of high population areas	Industrial, agricultural, and vehicular emissions and soot often travel by wind currents far from the source.
Acid rain	Sulfur and nitrogen emissions from smokestacks, vehicles, and ships are oxidized in sunlight to form the sulfates and nitrates that result in acidic precipitation harmful to plant and animal life.
Coastal waters overloaded by nitrogen nutrients	Nitrogen-containing vehicle emissions and agricultural fertilizers dissolve in coastal waters where they result in "blooms" of algae that deplete the water of oxygen as they decay.

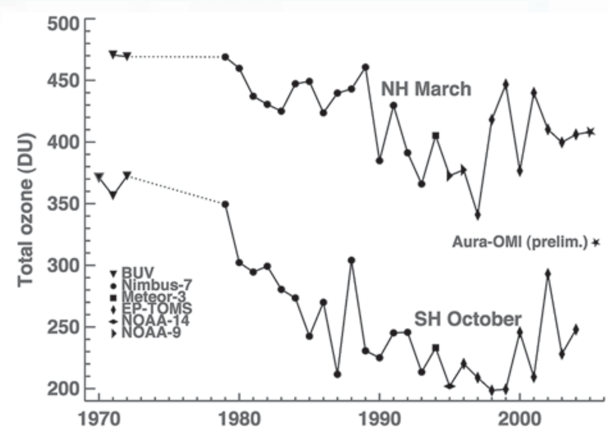
R E A T M E N T S

Who wants to live in a world with vanishing coastlines, brown clouds of thick smog, and foul-smelling polluted water? An even harder question is: Who wants to do something about it? Motivating people to clean up is never easy—especially when there are neighbors refusing to pitch in.

Hopeless? Not quite. Heard the one about the ozone hole over the South Pole? No? it's because what only 30 years ago loomed as a global crisis, is now slowly but steadily improving. As early as 1970, chemists warned about the widespread use of chlorofluorocarbons (CFCs). Released from some industrial processes, CFCs react with and destroy the fragile layer of atmospheric ozone that filters out life-harming UV radiation.

Chemists were clear about the dangers, but the ozone problem was not going to be solved in the laboratory. Instead, the solution required global cooperation of industries, scientists, leaders, and diplomats. The end result of years of discussions was the 1992 "Montreal Protocol". Presently, more than 180 countries are signed in agreement to phase out, by a set of intricately devised strict timetables, all ozone depleting chemicals.

NASA/ AURA



NASA satellites have monitored total ozone over both the northern hemisphere (NH) and the southern hemisphere (SH) for nearly 35 years. Following an alarming downward trend due to stratospheric ozone depletion in the 1980s and 1990s, total ozone data collected in recent years indicate some recovery. The latest NH data point supplied by the Aura satellite's OMI instrument is regarded as "preliminary", as it awaits validation from other monitoring instruments.

Today, chemists warn us about other problems in the atmosphere. Greenhouse gases, especially those released from the burning of fossil fuels, are made of molecules that allow the lower atmosphere to retain more energy from the sun. The surface warming that results is uneven on a region-to-region basis, but, overall, the net effects of rising surface temperatures are seen as negative. Besides melting glaciers and ice caps, rising seas, eroding coastlines, and altered rain patterns, warming may cause fertile agricultural areas to become arid deserts.

By now, you may be wondering whether someone plans to do something to reduce the alarming annual increase in greenhouse gas emissions. In fact, a treaty to do just that went into effect in February of 2005. The Kyoto Protocol is a 1997 United Nations pact that legally binds 39 developed countries to cut their emissions of greenhouse gases by 5.2% of 1990 levels by 2012. Will it be as effective as the Montreal Protocol?

Mario Molina, MIT chemist, shared a 1995 Nobel Prize with University of California-Irvine chemist Sherwood Rowland and Dutch chemist Paul Crutzen for their ozone research. In a recent online *Tierramerica* interview, he expresses his concern: "The Kyoto problem is more complicated because it is related to the use of energy. It is more difficult to replace fossil fuels (the combustion of which contributes to global warming) than it was to find a substitute for ozone-destroying CFCs." In other words, it's easier to redesign a refrigerator than it is to redesign the power grid.

Kyoto is also challenged from the start by global politics, the most significant challenge being the fact that the United States didn't sign. A resolution passed by the U.S. Senate in June 1997 states that the United States should not agree to any binding commitment for reducing greenhouse gas emissions unless developing countries also agree to specific commitments. (Kyoto exempts developing countries from the protocol.)

Does that mean that the United States, the world's largest industrial power and the world's largest consumer of fossil fuel, plans to do nothing about curbing greenhouse gas emissions? No. But it does mean that the United States plans to act independently as it responds to the challenge of global climate change.

By some proposals recently considered in the U.S. Congress, power companies, transportation, industries, and commerce units might receive emission allowances according to a complex formula based on their current emissions of six greenhouse gases. That's where it gets interesting. As in some elaborate card game, players can trade emission credits with each other and even with players from Europe engaged in a similar trading scheme set up by the rules of the Kyoto agreement to which they subscribe. As long as the overall goal of reducing emissions down to 2000 levels remains on track, the trading can continue.

LOGO COURTESY OF THE UNITED NATIONS

For many of us, it's difficult to understand what makes this so hard. The old-fashioned approach of "if there's a problem, fix it" just doesn't seem to be working here. Maybe it's because the stakes are so high and the economic sacrifices are so large that lawmakers and industry lobbyists want to be sure that they are attacking a problem that really exists. Dr. Linda Mearns of the National Council on Atmospheric Research in Colorado cautions against inaction or "policy paralysis" in the face of uncertainty. Speaking at a 2003 session for science journalists, she commented that most U.S. policy goes forward with far less certainty about the outcome than what is known about climate change. Should we wait for more data? That's tricky. She states that "When data are gathered to eliminate uncertainty, knowledge and meaning suffer in the process."

So what is a lawmaker to do? Vote for cutting emissions and risk getting local voters upset over restrictions on vehicle use and local industries upset over expensive emission controls? To do so, the congressional leader wants scientists to say. "If you don't do this, here are the absolute negative consequences. Guaranteed!" But science only speaks in terms of probable outcomes, not certainties.

This much is clear: Failing to act is a decision—one that may prove more costly in the long run than the economic punch we'd endure by capping emissions now. *Probably*, but not certainly. This isn't easy, is it?

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CHEMMATTERS

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About the Guide

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Content Reading Guide

National Science Education Content Standard Addressed As a result of activities in grades 9-12, all students should develop understanding	**Clearing the Air**	**How Earth Got Its Aura**	**Equilibrium**	**Flight of WB-57F**	**Student Gardens & Air Quality**
Science as Inquiry Standard A: of abilities necessary to do scientific inquiry				✔	
Science as Inquiry Standard A: about scientific inquiry.	✔	✔	✔	✔	✔
Physical Science Standard B: of the structure and properties of matter.			✔		
Physical Science Standard B: of chemical reactions.	✔		✔		
Physical Science Standard B: of conservation of energy and increase in disorder.	✔		✔		
Life Science Standard C: of interdependence of organisms.	✔		✔		
Physical Science Standard D: of energy in the Earth system	✔		✔		
Physical Science Standard D: of geochemical cycles.	✔	✔	✔		✔
Science and Technology Standard E: about science and technology.	✔	✔	✔	✔	
Science in Personal and Social Perspectives Standard F: of science and technology in local, national, and global challenges.	✔	✔	✔	✔	✔
Science in Personal and Social Perspectives Standard F: of natural resources.	✔		✔		
Science in Personal and Social Perspectives Standard F: of environmental quality.	✔	✔	✔		✔
History and Nature of Science Standard G: of science as a human endeavor.	✔	✔	✔	✔	✔
History and Nature of Science Standard G: of the nature of scientific knowledge.	✔	✔	✔	✔	✔
History and Nature of Science Standard G: of historical perspectives.	✔	✔	✔	✔	

Anticipation Guides

Anticipation guides help engage students by activating prior knowledge and stimulating student interest before reading. If class time permits, discuss their responses to each statement before reading each article. As they read, students should look for evidence supporting or refuting their initial responses.

Directions for all Anticipation Guides: In the first column, write "A" or "D" indicating your agreement or disagreement with each statement. As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

Clearing the Air—Treaties to Treatments

Me	Text	Statement
		1. London smog and Los Angeles smog are formed by similar processes.
		2. The 1992 Montreal Protocol, signed by more than 180 countries including the U. S., set a timetable to phase out ozone depleting chemicals.
		3. The 1997 Kyoto Protocol aims to cut greenhouse gas emissions.
		4. There is only one significant greenhouse gas, and that is CO_2.
		5. "Brown clouds" usually remain over the high population areas where they are formed.
		6. Greenhouse gas emissions are tied to our energy use.

Reading Strategies

These content frames, matrices, and organizers help students locate and analyze information from the articles. Student understanding will be enhanced when they explore and evaluate the information themselves, with input from the teacher if students are struggling. If you use these reading strategies to evaluate student performance, you may want to develop a grading rubric such as the one below.

Score	Description	Evidence
4	Excellent	Complete; details provided; demonstrates deep understanding.
3	Good	Complete; few details provided; demonstrates some understanding.
2	Fair	Incomplete; few details provided; some misconceptions evident.
1	Poor	Very incomplete; no details provided; many misconceptions evident.
0	Not acceptable	So incomplete that no judgment can be made about student understanding

Clearing the Air—Treaties to Treatments

Compare and contrast the Montreal Protocol and the Kyoto Protocol in the chart below.

	Montreal Protocol	**Kyoto Protocol**
Year signed		
Countries that signed		
Purpose		
How the goal is to be met		
Problems in implementing the pact		

Clearing the Air—Treaties to Treatments

Background

International treaties for solving global environmental crises present political challenges unparalleled in other categories of human interaction. The central question of this article is: Why are these treaties so difficult?

You and your students might want to prepare for reading this article by thinking about other instances and situations in which action is called for before outcomes can be predicted with certainty. In daily life, we are urged to adopt healthy lifestyles without the guarantee they will insure long life. Adults invest money in stocks based on certain hunches and performance patterns with no guarantee that they will increase in value. Our government ordered pre-emptive military action be taken based on uncertain intelligence reports with no guarantee that the action would improve national security. In short, it is not unusual for individuals and nations to take action even when outcomes are uncertain. As the article points out—deciding to take NO action is also a decision.

What makes global environmental agreements even more difficult is the uneven distribution of sacrifice and risk they require. Is it fair to ask a developing country to make the same economic sacrifice that a prosperous industrial power makes? On the other hand, is it fair to expect disproportionate cutbacks on the part of industrial nations while neighboring countries continue to pollute the atmosphere with environmentally destructive industrial practices?

And all of this decision making takes place while the global climate changes in a slow, often uneven manner. Some locales even report cooler than average temperatures as weather patterns slowly shift with changing ocean and air currents.

Excellent additional background for this article may be found on the NASA Goddard Spaceflight website called Earth Observatory. The site map is at http://earthobservatory.nasa.gov/masthead.html. The "Features" option is especially rich with articles on evidence of global climate change.

For a look at serious policy issues facing global decision making efforts, see the Pew Center on Global Climate Change. The web page describes the current status of policy making, both national and international: http://www.pewclimate.org/

Connection to Chemical Concepts

More about the release of CO_2 into the atmosphere from human activities

The technical term that is applied to materials released into the atmosphere because of human activities is *anthropogenic*. For example, there is a "natural" greenhouse effect that is the result of the normal concentration of carbon dioxide, water vapor and other gases that would be in Earth's atmosphere even if humans did not exist. Then there are the additional gases, especially carbon dioxide, that enter the atmosphere as a result of human activities, particularly the burning of fossil fuels. This results in what is called the *enhanced greenhouse effect.*

The amount of carbon dioxide released into the atmosphere is astounding. A table containing a vast amount of data from a large number of countries can be found at: http://www.emep.int/emis_tables/tab7.html

If you access any of this data, one thing should probably be kept in mind. Anthropogenic emissions are typically expressed in terms of metric tons of carbon. This means that if you are looking at anthropogenic emissions of carbon dioxide, for example, you need to convert the values to an equivalent amount of carbon. This is accomplished simply by using the relative molecular weight of the molecule in question compared to the atomic weight of carbon. For example, an anthropogenic emission of 5500 million metric tons of carbon dioxide is equivalent to:

$$(5550)(12/44) = 1514 \text{ million metric tons of carbon}$$

Because the molar mass of carbon dioxide is 44, while the atomic weight of carbon is 12.

An interesting table of conversion factors relating to different carbon containing compounds can be found at: http://www.eia.doe.gov/oiaf/1605/gg00rpt/appendixf.htm

Some interesting statistics

Population and energy consumption statistics will vary, depending upon the source of the information, so the data below should not be taken to represent definitive values, but rather as reasonable estimates.

The total population of the World is about 6,400,000,000, and is growing at about 150 people per minute.

The population of the United States is about 277,000,000, and is growing at the rate of about 5-6 people per minute.

So the U.S. represents about 4.5% of the total population of the world.

We account for about 35% of the world's energy consumption.

Less than 8% of our energy consumption is comes from renewable resources.

About 85% of our energy consumption comes from fossil fuels, almost half of which is imported.

Possible Student Misconceptions

There is a lot of misunderstanding about what the "greenhouse effect" really is. Perhaps one of the most common is that the only reason a greenhouse becomes warm is that light energy enters, but cannot escape. While that may basically be true, the major reason the greenhouse becomes hot is due to the fact that it is more or less sealed up and cannot exchange its inside air with outside air. There is an interesting discussion of this at:
http://www.ems.psu.edu/~fraser/Bad/BadGreenhouse.html

You may also need to consider the common misconception about the term "proof" in science. Scientists gather information and conduct experiments to support and, in some cases, reject theories. And a theory is simply the best statement that can be made based upon all available verifiable information. Scientists understand uncertainties, and they easily accept that knowledge and understanding advances without achieving 100% certainty. For the general public, this acceptance does not come as easily. The moment a theory is questioned and revised with new information, many voices rise to say, "Again, a major theory is disproved!"

For people deliberating treaties for controlling global climate change, the prospect of taking action, often expensive action, in the context of uncertainties makes progress especially difficult.

Demonstrations and Lessons

The article suggests that finding a solution to the world's energy crises will loom large in decades to come. *ChemMatters* April 2003 featured an activity titled "Green Energy—It's Your Decision". The activity challenged students to select the most efficient method in terms of energy and cost for heating 200 mL of water to a required temperature. They were to consider a laboratory hot plate, a bunsen burner, and a microwave oven. The activity was adapted from *Introduction to Green Chemistry: Instructional Activities for Introductory Chemistry,* published by the American Chemical Society, 2002. The activity is included on the 20-year CD Rom of *ChemMatters* articles available for purchase on this *ChemMatters* website.

Suggestion For Student Projects

There are many environmental regulations and public policies under scrutiny and debate at the national and intermantional level. Students could work in groups to research the underlying science and the various positions taken by opposing groups. Some of these regulations involve emissions of specific chemicals like arsenic, mercury, and various organic species.

Regulations ofter refer to industry standards for pollutants and emissions. Students will find that these standards translate into the thresholds below which the presence of these substances are legal. Sometimes the decisions made about setting standards revolve around the limits of affordable testing equipment. An amount that can be detected using expensive analytical tests in laboratories might go undetected with the day to day equipment used in the field. Students might interview water-quality or air-quality experts for more information on the subject of regulations and standards.

Anticipating Student Questions

What would the climate be like if we got rid of ALL greenhouse gases?

The complete answer involves some complex thinking. Basically, we know how much energy reaches the Earth from the Sun. We know how much of this energy is absorbed by the Earth and how much is reflected. The energy that is absorbed warms the Earth. The Earth, like all objects, emits energy, and if it became warmer, it would emit even more energy. Of course the energy arriving on the Earth and the energy leaving the Earth must be equal. Otherwise the Earth would either be getting hotter or colder. So from this "energy balance," scientists can calculate how warm the Earth would be in order to emit the same amount of energy it receives every day. That comes out to be –18 ^oC. Brrrrr.

Is there anything that can be done about the smog problem short of giving up our use of internal combustion automobiles?

Yes, and much has been done already. One of the major technological advances has been the installation of catalytic converters on automobiles. The name suggests what they do. A catalytic converter contains catalysts, often transition metals such as palladium, Pd, or platinum, Pt. These catalysts transform unburned hydrocarbons and carbon monoxide into carbon dioxide while at the same time converting NO_x back into the elements nitrogen and oxygen.

Websites For Additional Information

Several excellent Websites have been cited in this Teacher's Guide entry. Use these cites to find additional links to information about greenhouse gases, ozone, and policy making.