United States
Environmental Protection
Agency

Air Pollution Training Institute (APTI)
MD 17
Environmental Research Center
Research Triangle Park, NC 27711

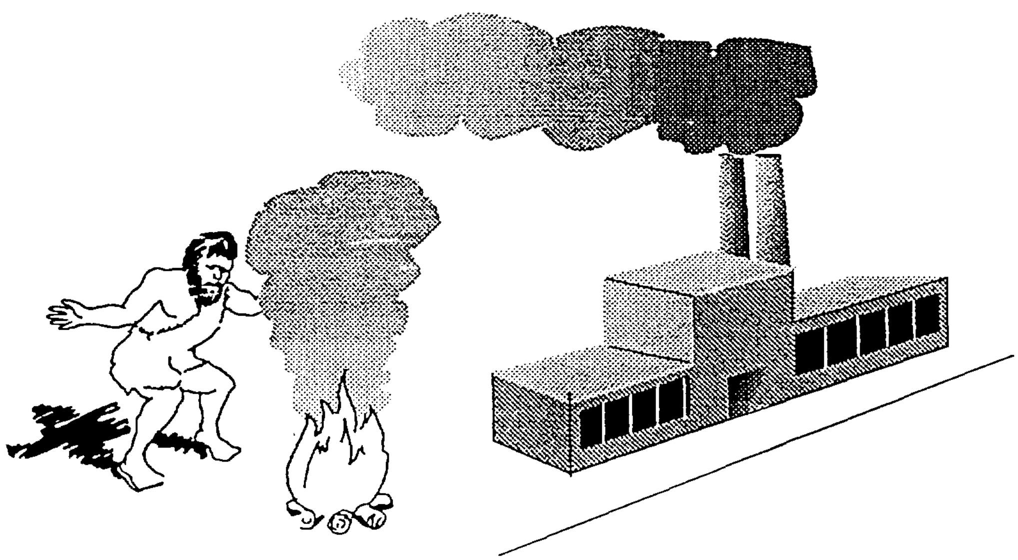
September 1993

Air

EPA

APTI
Course SI:300
Introduction To Air Pollution Toxicology

Self-Instructional Course Guide



United States Environmental Protection Agency

Air Pollution Training Institute (APTI) MD 17 Environmental Research Center Research Triangle Park, NC 27711

September 1993

Air

APTI Course SI:300 Introduction To Air Pollution Toxicology

Course Guide

Research and Evaluation Associates, Inc.

607 14th Street, N.W., Suite 610
Washington, D.C. 20005
(202) 842-2200

100 Europa Drive, Suite 590
Chapel Hill, N.C. 27514
(919) 968-4961

Under Contract No.
68D10139
EPA Project Officer
Charles D. Pratt

United States Environmental Protection Agency
Air Pollution Training Branch
Office of Air Quality Planning and Standards
Research Triangle Park, NC 27711

Contributors

Peer Review:	Dr. Michael A. Berry, U.S. Environmental Protection Agency
	Sandra Carroll, U.S. Environmental Protection Agency
Technical Content:	Tom Bensman
Instructional Design:	Monica L. Loewy
	Glenn Shepherd
Editing:	Kay McLain
Typography:	Carletta Hinton
	Jennifer Mimidis
	Kaytee Bell-Jarrett
Graphics:	Dan Norman
	Scott Hosa
	Linda Hendricks

Notice

This document has been reviewed in accordance with the U.S. Environmental Protection Agency's peer and administrative review policies and has been approved for publication. It is not an official policy and standards document. The opinions are those of the author and not necessarily those of the Environmental Protection Agency. Every attempt has been made to represent the present state of the art, including topics still under evaluation. Any mention or depiction of products or organizations does not constitute endorsement by the United States Environmental Protection Agency.

Contents

List of Tables And Figures

Course Description

This course is intended primarily for staff of local and state air pollution control agencies who might work with criteria pollutants, but are not very familiar with hazardous air pollutants (HAPs) and their effects on human health. Because the course is multidisciplinary in its approach, students from diverse academic backgrounds should be able to understand and use the information presented. Issues are addressed with a level of generality that will allow students from diverse backgrounds to understand the basic principles of air pollution toxicology.

A Note About Terminology

The terms "toxic air pollutant" (TAP) and "air toxicant" are used interchangeably in this course to denote substances found in the earth's atmosphere that are detrimental to human health. The 1970 Clean Air Act identified a specific subset of TAPs that are common in ambient air—the criteria pollutants. A separate subset of TAPs was created when the Clean Air Act was amended in 1990. The CAAA of 1990 identified 189 hazardous air pollutants, or HAPs, (consisting of both individual chemical and chemical categories) that must be regulated to protect human health.

Major Topics

- Air pollution history
- Body systems and how they normally function
- How air toxicants can alter body functioning
- How air toxicants reach target tissues
- Human pharmacokinetics
- Chemical classifications of air toxicants
- How adverse health effects are measured and estimated
- Air pollution regulations
- Where air toxicants are likely to be found
- Acute symptoms of exposure

How To Use This Manual

This self-instructional manual is designed to be used independently, without an instructor. Each lesson has sections that include introductory material, graphics, and review exercises and answers. After studying the information presented in each section, complete that section's review exercises. Check your answers against those provided at the end of the lesson. If you are not sure about an item or an answer, review the material in the section again. After reading all the lessons and completing the review exercises, complete the final examination and follow the directions for grading and certification.

How To Find Other Courses

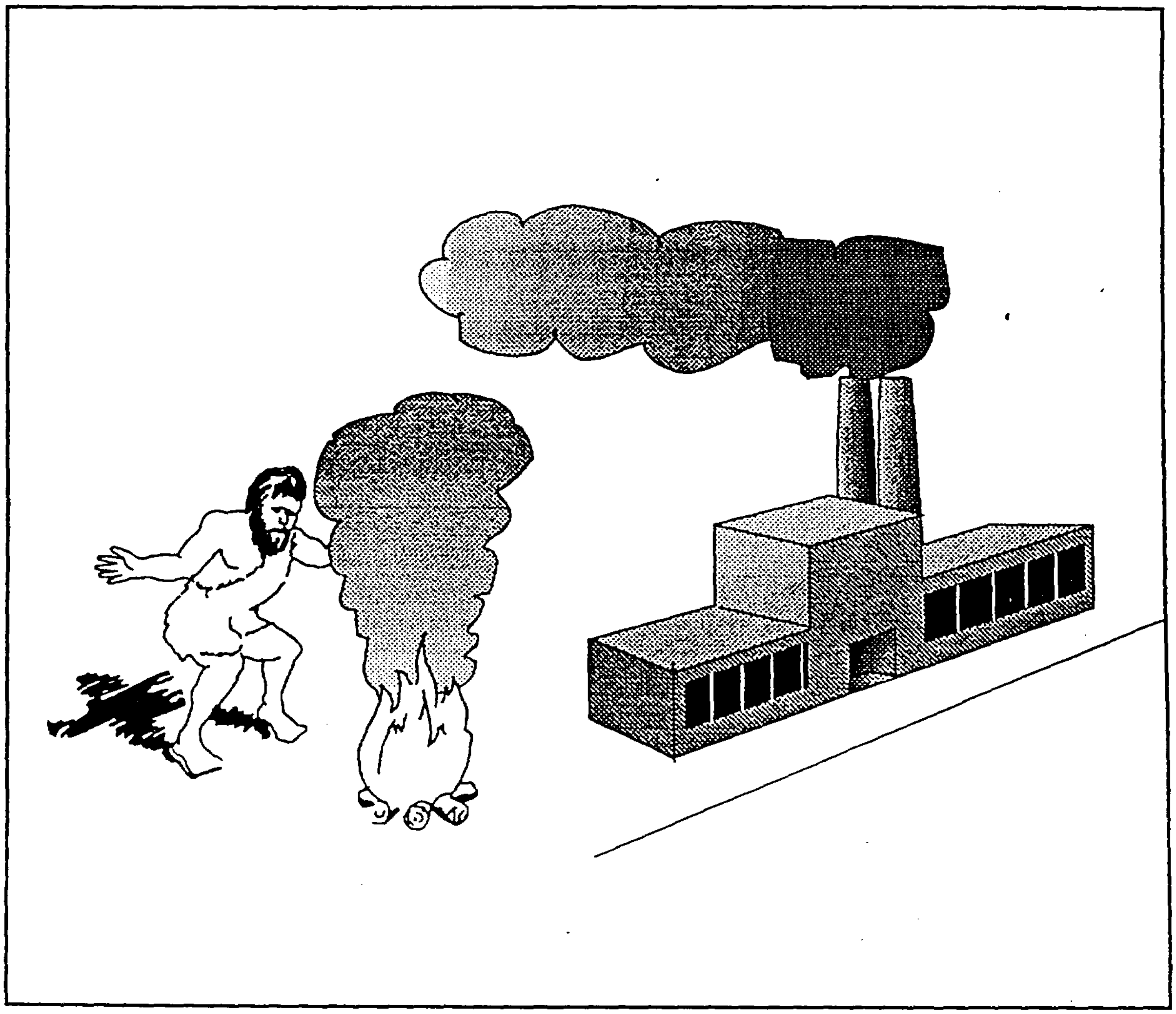
To find other air pollution training courses, consult the APTI bulletin board portion of the EPA/OAQPS bulletin board, (919) 541-5742, or contact the APTI registrar: Air Pollution Training Institute, Mail drop 17, RTP, NC 27711.

Acronyms Used In This Course

TAP	toxic air pollutant
GC	gas chromatography
MS	mass spectrometry
PAH	polycyclic aromatic hydrocarbon
DNA	deoxyribonucleic acid
DDT	dichloro-diphenyl-trichloroethane
GI	gastrointestinal
ADME	absorption, distribution, metabolism, excretion
LD50	lethal dose to 50% of subjects (median lethal dose)
NOEL	no-observed-effect level
NOAEL	no-observed-adverse-effect level
LOEL	lowest-observed-effect level
LOAEL	lowest-observed-adverse-effect level
CAG	Carcinogenic Assessment Group
ACGIH	American Conference of Governmental Industrial Hygienists
TLV	threshold limit value
TLV-C	threshold limit value ceiling
TWA	time-weighted average
STEL	short-term exposure limit
IARC	International Agency for Research on Cancer
MACT	Maximum achievable control technology
NAAQS	National Ambient Air Quality Standards
NESHAP	National Emission Standards For Hazardous Air Pollutants
CAA	Clean Air Act (1970)
CAAA	Clean Air Act Amendments (1990)
RACT	reasonably available control technology
BACT	best available control technology
HAP	hazardous air pollutant

Lesson 1

A History Of Air Pollution And The Study Of Its Effects On Human Health



Questions To Consider

- What major events and developments throughout history have contributed to the pollution of the earth's atmosphere?
- What were some of the major air pollution catastrophes of this century and what were their causes?
- What adverse health conditions does air pollution cause or contribute to?
- What is the difference between epidemiology and toxicology?
- What scientific and technological developments have helped advance the study of air pollution?

Key Terms

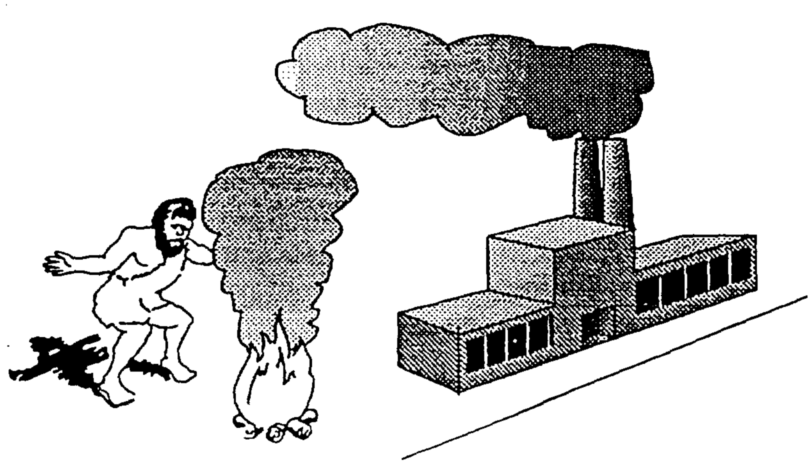
- Bronchitis
- Epidemiology
- Pulmonary emphysema
- Temperature inversion
- Toxicology

Overview Of The Problem

In regard to pollution, what you don't know *can* hurt you. This realization has fueled the quest to know more about pollution and its consequences, particularly adverse human health effects.

This first lesson provides a general historical overview of the problem of air pollution and its adverse effects on human health. Subsequent lessons will lead you through a more thorough investigation of specific types of toxic air pollutants and the harm they can cause.

Generally, as man has become more technologically advanced, the earth's atmosphere has become more polluted. From the first use of fire for heat and light to the highly advanced industrial processes of today, man has continually been involved in activities that have undesirable effects on the environment and human health. Unfortunately, many of these undesirable consequences were never suspected, and even once they were suspected and actually observed, they were too often underestimated. Only recently has man begun to comprehend the extent and depth of the problems created by pollution. And only recently has technology been applied toward solving the pollution problems it helped create.



Many of man's technological achievements have come at the expense of polluting the atmosphere.

To make it easier for you to understand exactly what air pollution is, first take a look at the earth's atmosphere in the "pre-pollution era."

What Is Clean Air?

The earth's atmosphere is primarily composed of nitrogen and oxygen.

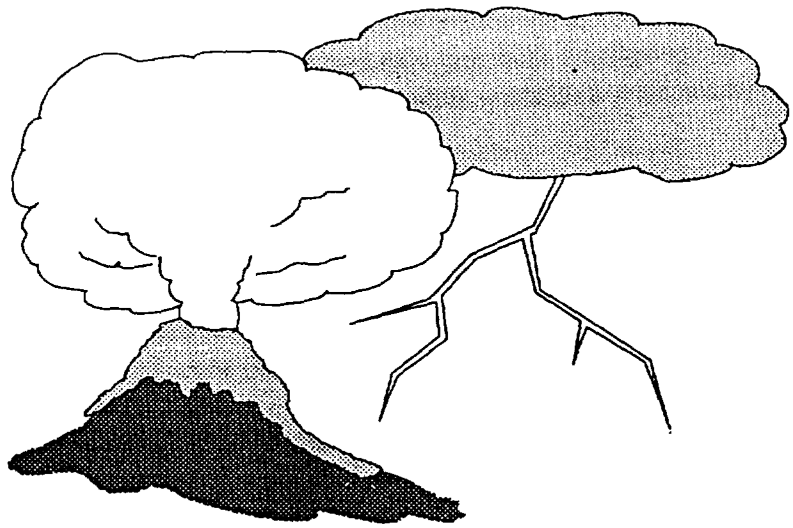
The earth's atmosphere is simply a mixture of gases and tiny particles that surrounds the planet. In all probability, the composition of the mixture has changed at various times in the earth's history. The current mixture, the one that man is physiologically comfortable with, is outlined below.

Nitrogen (N_2) 78.1%
Oxygen (O_2) 21%
Argon (Ar) 0.9%
Carbon dioxide (CO_2) 330 ppmv
(parts per million by volume)
Neon (Ne) 18 ppmv
Helium (He) 5 ppmv
Methane (CH_4) 1.5 ppmv
Others at concentrations less than 1.0 ppmv

NOTE: The percentages indicated are for the major constituents of dry air at ground level. Air also commonly contains varying amounts of water (H_2O) in droplets of various sizes and states.

Throw all these ingredients together in the proportions indicated and you have unadulterated earth atmosphere, good for breathing. There is one catch, however: few places on earth (if any) have this pure, wholesome air. Air usually includes additives, or pollutants. Some places with relatively clean air might have only a few pollutants, but an increasing number of places today have dozens of pollutants mixed into the air.

Some air pollutants have natural origins. Lightning can cause wildfires, which pollute the air with various gases and particles. Volcanoes, too, can send tons of gaseous and particulate pollutants into the atmosphere. Even the seemingly benign wind can lift particles from the surfaces of the land and the sea and transform them into air pollutants. Although the pollutants from these natural sources can adversely affect your health, they are not the concern of this course.



Some atmospheric pollutants have natural causes, but the main concern in air pollution toxicology is with man-made pollutants.

The concern here is with air pollutants that are anthropogenic—caused by man. One of the uncrowning achievements of man is that over the years the earth's atmosphere has accumulated not only more but also a greater variety of toxic substances. Let's step back in time to see how this situation developed.

1. Of all the components in air, which two have the highest concentrations?

2. Name some natural causes of air pollution.

Earth's Polluted Atmosphere—How Did This Happen?

Although no rock-solid proof exists, it is assumed that man first polluted the air when he discovered fire. At that point in history, however, man's contribution to air pollution was probably still overshadowed by natural sources.

The next advancement in civilization with major air pollution consequences was the establishment of populous, permanent communities. Man had first lived in relatively small, nomadic groups. Typically, these groups lived in an area for only a short while, and the environmental damage they caused was minimal. That began to change with the formation of permanent agrarian communities. Two consequences of man's "settling down" are notable in the study of air pollution: a larger, more concentrated assault on the environment and local depletions of fuel for fires.

When coal became a common fuel for heat and energy, air pollution skyrocketed.

In Europe during the 12th and 13th centuries, supplies of wood for fuel became so scarce that an alternative fuel was needed, and coal filled the bill. It seemed to be a godsend, for it was abundant and slow-burning. The dense black smoke, created by burning coal was viewed as only a minor disadvantage. In fact, it was minor compared to what was coming.

In the mid-18th century the Industrial Revolution began in Europe and quickly spread throughout the world. All the various emerging industries needed power, and power at that time meant the combustion of coal. Besides pollution from fuel combustion, many of the new industries involved chemical processes that created various toxic air pollutants of their own. The metallurgical industry flourished at this time and quickly displaced coal as the main source of sulfur dioxide in the atmosphere.

Throughout the 19th century and into the early 20th century, coal was the primary source of heat, power, and pollution in the world. Beginning with the drilling of the first commercial oil well in Pennsylvania in 1859, however, coal had competition. Oil refining and the automobile industry have fueled each other's tremendous growth in the 20th century, along with their various spin-off industries, such as steel and rubber manufacturing.

World War II and its aftermath heightened and accelerated man's virtually unchecked assault on the atmosphere. The proliferation of the petrochemical industry and the development of the nuclear power industry led the way. The transportation industry with its burning of fossil fuels still reigns supreme, however. It is directly responsible for nearly 60% of all atmospheric pollution. The smog that Los Angeles is famous for results from transportation exhaust fumes.

The next section will show that the phenomenal technological progress that has characterized the past century was achieved only with a trade-off—a costly trade-off in terms of human life and health.

3. What situation caused the adoption of coal as the primary fuel in 13th- century Europe?

4. In the mid-18th century, why was there an expansion in the use of coal for power?

5. Name at least three major industries that have contributed to air pollution in the 20th century.

Health Problems Caused By Toxic Air Pollutants (TAPs)

The Solution To Pollution Is Dilution —NOT!

The earth system cannot adequately dilute, or spread out, all the pollutants being intentionally and unintentionally dumped into the atmosphere.

For years it was believed that "the solution to pollution is dilution." This adage was based on a widespread assumption that the earth was equipped with a natural cleansing mechanism that could defuse or absorb any and all pollution assaults devised by man. Several local air pollution catastrophes in this century have dramatically and tragically shown that the natural dissipation of pollutant buildup is not a fail-safe system. More critical, perhaps, are the increasing indications that pollutant buildup is a global rather than only a local concern. The incidence of various adverse health conditions, from local irritations to cancers, has been steadily increasing, and one of the culprits is air pollution.

Air Pollution In The 20th Century: Episodes And Accidents

The distinction between an air pollution episode and an air pollution accident is fundamental. An episode is an instance when "harmless," everyday, 20th-century air pollutants combine with other factors, such as meteorological abnormalities and topography, to create a health-threatening atmosphere. Although man is responsible for the pollution factor, the co-occurrence of the other factors is beyond control. An air pollution accident, on the other hand, is an inadvertent, preventable release of toxic chemicals into the air, often attributable to mechanical failure or human error.

Episodes

The most-publicized air pollution episodes of this century, the "big three," occurred in the Meuse Valley, Belgium; Donora, Pennsylvania; and London, England.

Episode	Year	Excess deaths	Proposed causes
Meuse Valley	1930	60+	SO_2, fluorides, H_2SO_4
Donora	1948	20	SO_2, particulate matter
London	1952	4000+	SO_2, particulate matter, H_2SO_4

During a temperature inversion, the atmosphere's normal circulation patterns are halted.

All three tragedies coincided with a meteorological condition known as a temperature inversion. Normally, warm air at the earth's surface rises and cooler air from higher in the atmosphere falls, creating a natural circulation that disperses surface air pollutants. An inversion occurs when the air in the lower atmosphere becomes cooler than the air above it. The natural circulation grinds to a halt, surface air stagnates, and air pollutants become concentrated around their sources (see Figure 1-1 on the next page).

Another important characteristic common to these three episodes is that the suspected causative agents were typical, everyday, supposedly safe, waste products of 20th-century living. The widespread burning of fossil fuels and the proliferation of industrial processes make sulfur dioxide, sulfuric acid, particulate matter, fluorides, and other air pollutants fairly common components of today's atmospheric mix.

The London episode, the most catastrophic of the three mainly because it occurred in an area of denser population, spurred productive political and scientific actions. As a result, air pollution episodes of such magnitude are a thing of the past. Today, most major cities have instituted programs to predict and detect air pollution levels and weather conditions that could combine to produce tragic consequences. Air quality alerts routinely warn citizens of the danger of adverse conditions and encourage them to stay indoors as much as possible during these times. Despite such precautionary programs, as recently as 1966 a four-day temperature inversion in New York City resulted in 168 deaths and uncountable illnesses. Man has learned, albeit slowly, that there is no such thing as a harmless air pollutant.

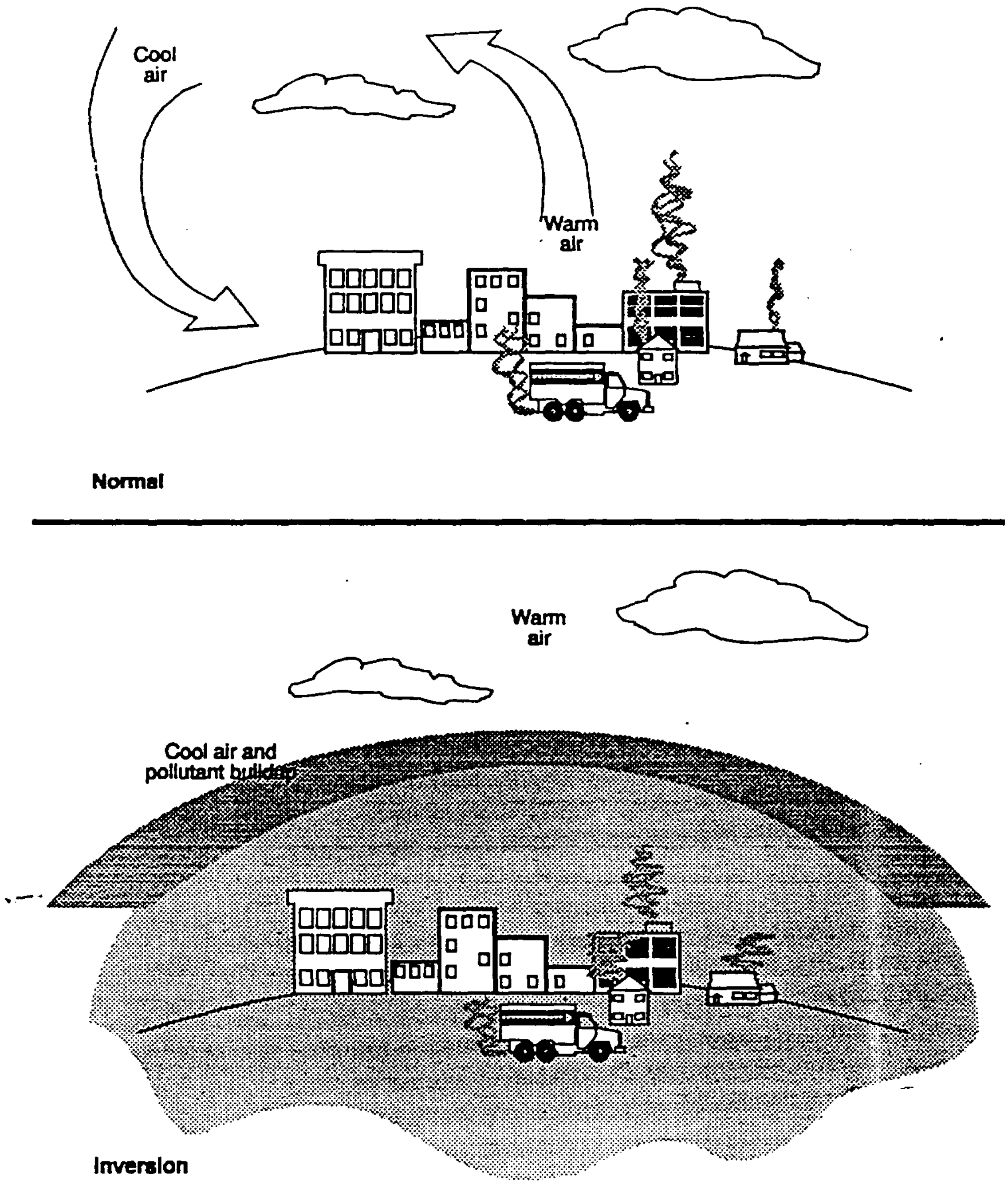


Figure 1-1. Normal Atmospheric Circulation Compared To An Inversion

Accidents

So, it seems that technological advancements and increased industrialization have caused a certain level of regular, planned toxic air emissions that are accepted by most everyone as necessary evils—part of the trade-off for all the benefits of 20th-century living. Industrialization has also brought with it an increased risk of accidental releases of toxic air pollutants. The typical causes of industrial air pollution accidents are mechanical failure and human error. Most accidents of this type involve small amounts of chemicals and are easily controlled, with few or no adverse effects on humans. Some, however, have tragic consequences.

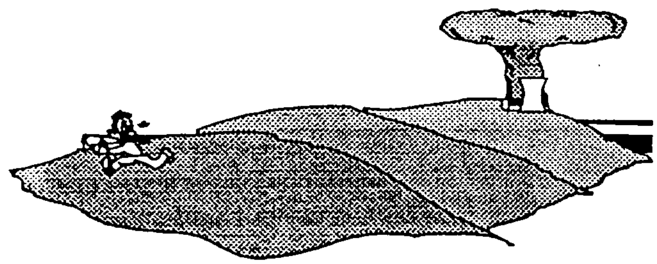
Industrial air pollution accidents are typically caused by mechanical failure and human error.

One of the first well-documented cases of an industrial air pollution accident with a clearly defined cause occurred in 1950 in Poza Rica, Mexico. The problem began when a natural-gas refinery inadvertently discharged hydrogen sulfide into the air. A simultaneous temperature inversion magnified the problem. Results: 22 deaths and over 300 cases of associated illnesses, mostly respiratory tract irritation and nervous system disorders.

Perhaps the most graphic example of how the accidental release of a toxic chemical into the air can adversely affect a large population is the Bhopal, India, incident of 1984. Thirty tons of methyl isocyanate escaped through a broken valve and enveloped a community surrounding a chemical manufacturing plant. Over 2500 deaths were attributed to this event, and 17,000 people were permanently disabled.

In 1986, the Soviet city of Chernobyl became synonymous with industrial disaster. Although it was not the first accident involving a nuclear power plant, it was (and still is, to this date) the worst. The explosion was the culmination of a chain of events, including both mechanical malfunction and human error. The after-effects are sobering. Thirty workers died from radiation exposure in the first few months, and 200 other workers and firefighters were hospitalized with severe radiation sickness. Millions of people in the Soviet Union and Eastern Europe were exposed to the fallout and, therefore, are at greater risk of dying of cancer than they were before. Others were affected through food sources, from both plants and animals that were exposed to the radiation. What's more, because radiation is mutagenic (i.e., able to alter genetic material), the adverse effects of the Chernobyl accident are likely to be felt for generations to come.

The Chernobyl nuclear power plant explosion in 1986 was the worst radiation accident in history.



Obviously, toxic air pollutant effects can be magnified by various factors, such as weather patterns, mechanical breakdowns, and human error. Most catastrophic accidents tend to be localized, however, with the area and population affected both easily identified. But what about people in supposedly safe areas? What about the woman walking downtown, the child at the playground, and the family living three blocks from the accident-free chemical plant? Studies and statistics indicate that as the 20th century draws to a close, the general population is at risk of developing certain adverse health effects due to the toxic chemical burden in the earth's atmosphere.

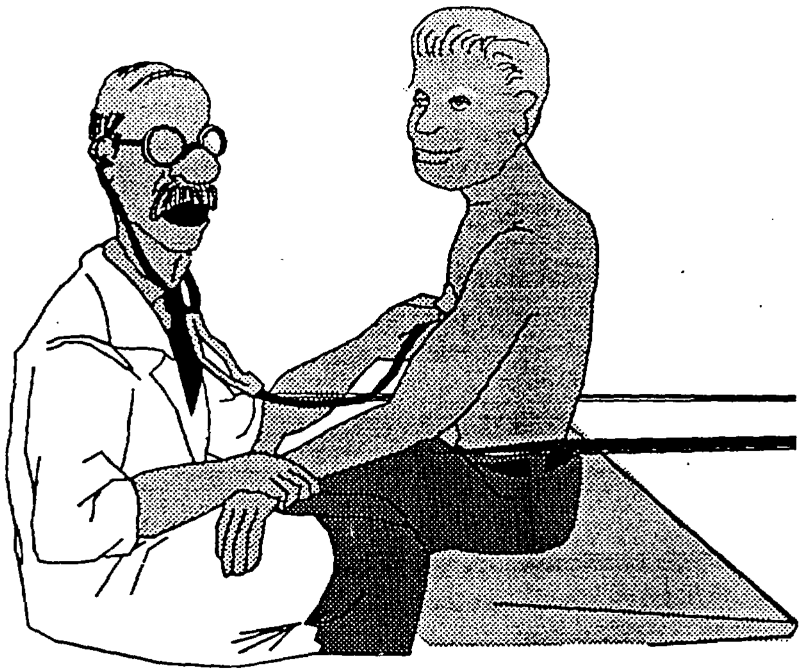
6. Name four air pollution episodes of this century.

7. Explain the difference between normal atmospheric conditions and a temperature inversion.

8. What are the typical causes of industrial air pollution accidents?

Adverse Health Effects Related To Air Pollution

The air pollution episodes and accidents you just learned about, particularly the 1952 London episode, raised concerns about the health consequences of chronic exposure to standard atmospheric concentrations of pollutants. By the late 1950s numerous studies had begun to document a relationship between general air contamination and certain chronic diseases. There is now general consensus that ambient concentrations of air contaminants either cause or promote the development of chronic bronchitis and lung cancer, and a similar relationship with pulmonary emphysema is strongly suggested.



Ambient concentrations of air contaminants present health risks for the general public.

Bronchitis actually means "inflammation of the bronchi." Evidence of the link between air pollution and chronic bronchitis is well-established. In chronic bronchitis the characteristic inflammation is accompanied by production of excess mucus and a persistent, productive cough. The main causative factors in the ambient air seem to be SO_2 (sulfur dioxide) and particulate matter.

Pulmonary emphysema is characterized by overdistension (i.e., overinflation) and destruction of the alveoli, the tiny air sacs in the lung where gas exchange takes place. This progressive disease, though not unquestionably tied to air pollutants, is increasing in incidence, especially in highly polluted urban areas.

Other, more minor, ailments that exhibit increased incidence in areas with higher ambient levels of pollution include the common cold, nasopharyngeal and optic irritation, asthma attacks, and general respiratory distress.

The evidence linking lung cancer to air pollution is mostly circumstantial, based on hundreds of studies that show a higher incidence of lung cancer in urban areas than in rural areas. Though circumstantial, the evidence is so widespread and consistent that it is commonly accepted as proof of a cause-effect relationship. There is less agreement on the mortality that can be attributed to exposure to air pollutants. Estimates of the percentage of deaths in which air pollution is a major contributing factor range from 0.1 percent (1 in 1,000) to 10 percent (1 in 10).

9. What major respiratory diseases are associated in some way with air pollution?

10. Name at least three other adverse health conditions related to air pollution.

Milestones In The Study Of Air Pollution

Before you can study a problem, you first have to recognize it. Although this is obvious, the problem itself is often not so obvious. Recognizing the adverse health effects of air pollution is a case in point. For centuries, smoke from combustion was viewed as a problem only because it was ugly and had a terrible odor.

The second necessary step in studying a problem is identifying exactly what is causing the problem. What substances in the air cause adverse health effects? It is also critical to identify the chemical concentrations necessary to cause the toxic effects.

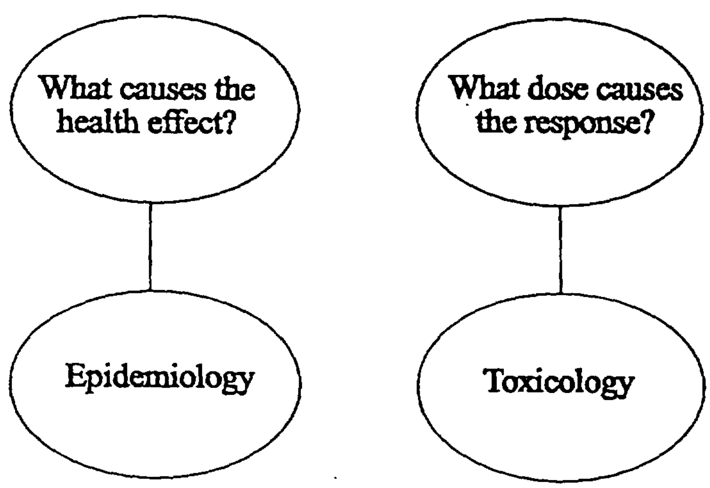
Recognition, identification, and detection are three critical steps in dealing with air pollution problems.

Finally, all of these determinations are of no consequence unless there also exists the capability to detect the harmful substances at the toxic levels. Current technology allows us to detect most chemicals in the ppb (parts-per-billion) range and a few chemicals in the ppq (parts-per-quadrillion) range. (Think of being able to detect one teaspoonful of a substance in a body of water the size of Lake Michigan!) With all of this information, policies and practices can be implemented to eliminate, or at least minimize, exposure to chemicals that are toxic to man.

Epidemiological And Toxicological Studies

Epidemiology and toxicology are two branches of science intimately tied to the study of the adverse health effects of air pollution. Although they are related, each has its own unique focus and concerns. Before taking a look at how these disciplines have developed, let's establish the distinction between them.

Epidemiology seeks to answer the question: What is causing this person (or these people) to experience this particular harmful effect? In essence, adverse health effects are observed and causes for them are sought. **Toxicology**, on the other hand, begins with a known or suspected cause of adverse health effects and seeks to discover the relationship between the amount of the toxin taken in (dose) and the degree of effect (response). The question that drives toxicology studies is: How much of this substance is needed to produce harmful effects? In other words, causative factors are observed and critical effect levels are sought.

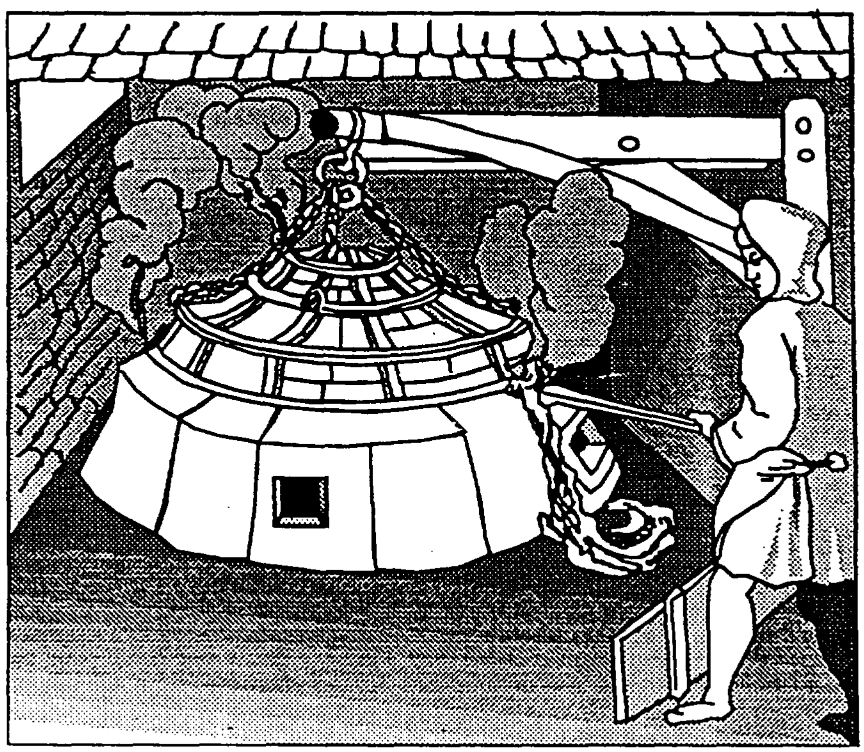


Although they are both concerned with adverse health effects, epidemiology and toxicology focus on different issues.

Early Historical Development

Some of the first efforts to link adverse health conditions to specific causes dealt with occupation-related diseases. The early Greeks and Romans noticed that miners and metallurgists often developed particular diseases, and these conditions were attributed to the acid mists they were breathing and the toxic metals they were handling. In the Middle Ages in Europe, studies and reports of occupational health concerns flourished. Beginning in the mid-18th century, the Industrial Revolution brought new industries, new occupations, and new ways to endanger health. Owing much to the Industrial Revolution was the first description of occupation-related cancer, scrotal cancer in chimney sweeps, in the late-18th century. Although the connections were often obvious, requiring little or no actual investigation, this was early epidemiology at its best.

The Greeks and Romans were actually some of the first "toxicologists" also, because developing hand-in-hand with the identification of occupational risks were efforts to discover cures in therapeutic doses. Hence the birth of modern medicine.

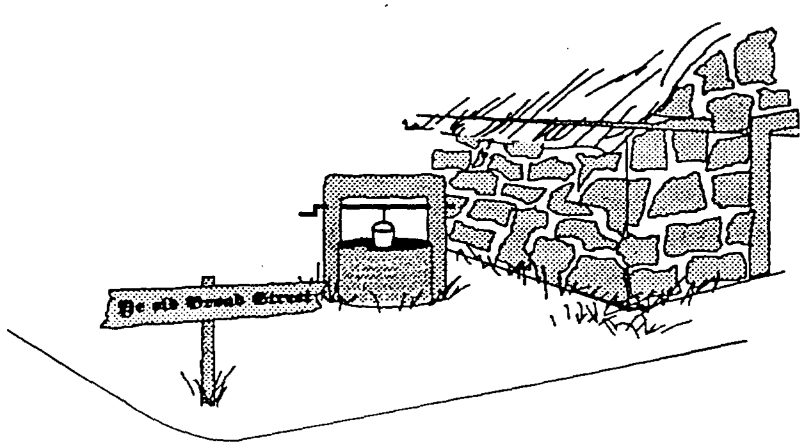


"Toxicology" actually means "the study of poisons", and this emerging science got a big boost from the rise of the "art" of poisoning. From the earliest times, poisons were used as political weapons, and their use became more widespread and more diverse as time passed.. In the Middle Ages, a poisoner was a well-respected and well-compensated member of society. Of course, along with the proliferation of toxic substances and their use came the need for effective antidotes to undo accidental poisonings. Both poisoners and "unpoisoners" were interested in discovering what amounts of the poisons and antidotes were necessary and sufficient to do the job. When experiments began to focus on pinpointing these critical levels of chemicals, toxicology was in full swing.

In the Middle Ages, the science of toxicology was advanced by poisoners seeking effective doses for poisons and antidotes.

Dr. Snow And The Broad Street Well

An interesting case from mid-19th-century London is exemplary as an early application of the epidemiological approach. It seems Londoners at that time suffered from frequent outbreaks of cholera, with staggering mortality rates. Dr. John Snow, a general practitioner, devoted his time and energy to discovering the cause of the mysterious disease. He suspected contaminated water but needed solid proof. It seemed a hopeless task: cholera deaths occurred throughout the city, with no apparent connections. In 1854 another cholera epidemic broke out, and Dr. Snow finally had the setting he needed to prove what was causing the disease.



Using classic epidemiological theory, Dr. Snow traced London's 19th-century cholera outbreaks to the water supply.

Shortly before the 1854 epidemic, one of London's water suppliers had moved its intake on the River Thames to a point above the city where the water was noticeably cleaner. Quite by accident, this created a control test group; Dr. Snow could now perform a comparative study. He was not surprised when none of the residences supplied by the new water source were affected by the new outbreak of cholera. With perseverance, Dr. Snow eliminated one possible source after another until he found one commonality among all cholera deaths—the Broad Street well. When the well cover was removed, the water was found to be contaminated and the case was closed.

Mid-To-Late 1800s

Other developments in the mid-to-late 1800s helped define and refine the fields of epidemiology and toxicology. The American Civil War provided some of the impetus for a search for safe, effective anesthetics and disinfectants. Dr. Snow's efforts and other similar epidemiological studies led to the development and general acceptance in the late 1800s of the germ theory of disease causation. This, in turn, fueled the search for antibiotics to fight germs.

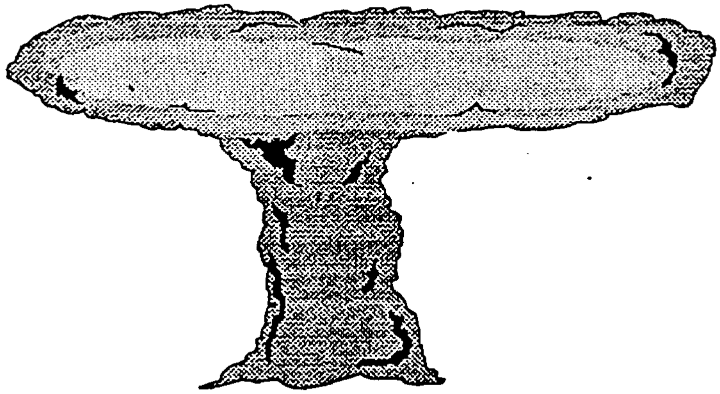
Also, near the turn of the century, the first of many radioactivity studies began in France. Today we are finding, as the Chernobyl disaster aptly demonstrated, that radiation is one of the more insidious forms of air pollution.

20th-Century Advancements

Vitamin safety studies in the 1920s introduced the now-common practice of using animals in large-scale experiments.

The discovery of vitamins in the early 1920s is associated with a major milestone in toxicology—the first use of large-scale, animal safety studies. Small mammals were used to determine the safety profiles of vitamins, and animals have been used to test many other substances since then.

World War II spawned a variety of scientific and technological studies that further stimulated the fields of toxicology and epidemiology. Radioactivity studies, a spin-off of nuclear weapon explosions, were designed to identify the effects of radiation on the human system. These were some of the first attempts to understand the health effects of exposure to this fairly new and potent air pollutant.



Nuclear weapons testing during World War II spawned numerous radioactivity studies.

Efforts to deal with the hordes of insect pests in the South Pacific region, and associated health problems, led to the development of new pesticides and antimalarial drugs. It was in the search for safe, effective, easily available (as opposed to natural quinine) antimalarial agents that nonhuman primates were first used in efficacy and toxicity tests as models for man.

The science of toxicology experienced tremendous growth in the 1960s. Early in the decade, the common sedative thalidomide was found to cause serious birth defects when taken by pregnant women. This tragic episode gave momentum to studies designed to discover the effects of chemicals on the developing embryo and fetus. Further support for such studies came from new product liability laws and regulations spurred by the incident. Today, the fields of epidemiology and toxicology are essential tools in man's struggle to comprehend and cope with the adverse health effects related to toxic air pollutants.

Technological Advances In Chemical Analysis

As mentioned earlier, all the efforts to define harmful levels of air pollutants would lead down a dead-end road without the technology to detect the substances in the atmosphere at these critical levels.

Mass spectrometry was first applied to the analysis of gaseous pollutants in the late 1940s. The nondispersive infrared analyzer became popular in the late 1950s and early 1960s for automotive emissions analysis. At about the same time, gas chromatography (GC) was developed. Today, GC in its current refined form is coupled with mass spectrometry (MS) to provide chemical analysis in the parts per quadrillion range for some chemicals. GC/MS analysis is currently the standard for detecting most air pollutants, particularly organic compounds and trace metals.

11. Describe how toxicology and epidemiology are different.

12. In the late 1800s, what new theory helped fuel the search for antibiotics?

13. Nonhuman primates were first used in safety studies of what type of drugs?

14. Current gas chromatography/mass spectrometry technology is capable of detecting some chemicals in the ______ range.

Answers to Review Questions

1. Nitrogen, oxygen

2. Fires started by lightning, volcanoes, wind

3. The depletion of wood supplies

4. Industrial Revolution (emerging industries needed power and power at this time meant the combustion of coal)

5. Oil refining, steel, rubber, automobile, petrochemical, nuclear power

6. The Meuse Valley, Belgium
   Donora, Pennsylvania
   London
   New York

7. Normally, air at the earth's surface is warmer than the air above it; during an inversion, the opposite is true—cool air at the surface is trapped by warm air above it.

8. Mechanical failure, human error

9. Chronic bronchitis, pulmonary emphysema, lung cancer

10. Common cold, nasopharyngeal and optic irritation, asthma attacks, general respiratory distress

11. Toxicology basically takes a substance with known adverse effects and attempts to determine what amount of the substance is necessary to cause the effects. Epidemiology attempts to discover causes and mechanisms for observed adverse health effects.

12. The germ theory

13. Antimalarial agents

14. ppq (parts per quadrillion)