Air Pollution Control Engineering

Lecturer　Cheng Yan

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To understand the previous discussions, we need to consider:

- What is air pollution?
- What causes air pollution? Where does air pollution come from?
- What are the impacts of air pollution?
- How air pollutants behave in atmosphere？
- How can we control/minimize air pollution? （strategies/technologies）

This course is designed to

1. provide you a comprehensive understanding of air pollutants, sources and their effects, relevant regulations regarding air quality and control.
2. explore how these pollutants interact with the atmosphere and how they travel.
3. equip you with a deep understanding of fundamental principles and design approaches used for air quality and its control.

Today's Lesson

Our four content goals for today are to understand...

1. Definitions and Types of Pollutants (1.2) ;

2. Causes, Sources, and Effects of major pollutants (1.8)

3. Legislative and Regulatory in the United States (1.4)
    - Clean Air Act
    - Standards
    - Air Quality Index
4. Some basic Calculations about emission estimation (1.5-1.6)

Part I

Definitions and Types of Pollutants

(Chapter 1.2-1.3)

Definition of pollution （contamination）

- Air pollution is the presence in the outdoor atmosphere of any one or more substances or pollutants in quantities which are or may be harmful or injurious to human health or welfare, animal or plant life, or property, or unreasonably interfere with the enjoyment of life or property, including outdoor recreation. (Florida Administrative Code 1982)
- Air Pollution may be defined as any atmospheric condition in which substances are present at concentrations high enough above their normal ambient levels to produce a measurable effect on man, animals, vegetation, or materials.
- Air Pollution is the presence of undesirable materials in air, in quantities large enough to produce harmful effects. The undesirable materials may damage human health, vegetation, human property, or the global environment as well as create aesthetic insults in the form of brown or hazy air or unpleasant smells.

Table B.1 Concentrations of Gases Comprising Modern Air (dry basis)

Gas	Concentration (units as listed[a])	
Nitrogen	78.09	%
Oxygen	20.94	%
Argon	0.93	%
Carbon Dioxide	390	ppm
Neon	18	ppm
Helium	5.2	ppm
Methane	1.7	ppm
Krypton	1.0	ppm
Hydrogen	500	ppb
Nitrous Oxide	300	ppb
Xenon	80	ppb
Criteria Pollutants[b]		
CO	100	ppb
O_3	20	ppb
NO_2	1	ppb
SO_2	200	ppt
Others[b]		
Ammonia	10	ppb
Freon (CFC-11)	230	ppt
Hydrogen Sulfide	200	ppt
***		

Criteria air pollutants of National Ambient Air Quality Standards (NAAQS)

- The term criteria pollutant comes from the fact that health-based criteria were used to establish the NAAQS for these pollutants.

Primary pollutants （emitted directly）

- particulate matter (PM-10 and PM-2.5) (less than 10 μm /2.5 μm in diameter)
- particulate lead:
- 3 Gases :

  sulfur dioxide (SO_2) nitrogen dioxide (NO_2) carbon monoxide (CO)

Secondary pollutant （formed by chemical reactions among primary pollutants）

- ozone (O_3)

Another class of compounds—volatile organic compounds (VOCs)

- not a criteria pollutant, recognized as a major primary pollutant
- its large emissions and its importance in the reactions that form ground-level ozone.
- VOCs sometimes are called reactive hydrocarbons, chapter11

Pollutants of Global Concern （1.3 ）

Ozone Depletion

In the 1930s, a “miracle” chemical (extremely stable, nontoxic, nonflammable) invented

This chemical and its derivatives: chlorofluorocarbons (CFCs) (also known as freons)

Commercial Applications:

refrigerants, aerosol propellants, foam-blowing agents, cleaning solvents, air conditioning gases,…

Scientific Findings:

In 1974, CFCs—which are stable in the lower atmosphere—break down in the stratosphere, releasing chlorine atoms.

Video about Ozone Depletion (National Geography)

Roles of ozone

Positive role of Stratospheric ozone:

a key factor in protecting all life on earth

it absorbs almost all of the ultraviolet (UV) radiation coming into the earth’s atmosphere, preventing the UV radiation from reaching ground level.

Adverse effects of ozone depletion:

the increased UV radiation reaching the earth’s surface:

skin cancers and cataracts among humans, livestock and wild animals billions of dollars of damages in reduced crop yields, and degradation of plastics

What can we do about ozone depletion？

the Montreal Protocol:

The discovery of the ozone hole was dramatic; it shocked the world into action.

In 1985, the dramatic discovery of a huge ozone “hole” over Antarctica proved the theory of ozone depletion. The hole (as big as the United States) showed as much as 50% reduction in the protective ozone layer in that region during the winter months.

In 1987, 46 countries manufacturing CFCs developed a treaty to reduce CFC production and use on a scheduled basis by 1989, 39 countries had ratified it.

Current status :

Because CFCs released in the past are still working their way up to the stratosphere, ozone depletion will be a concern for many years to come.

For more information, www.epa.gov/docs/ozone/index.html.

Pollutants of Global Concern （1.3 ）

Global Climate Change (GCC)

Views

- may be the most significant and the most difficult problem ever faced by humankind.
- a complex issue and can only be addressed briefly in this text.
- if we are to mitigate its potentially devastating effects, collaboration between Engineers, scientists, and political leaders throughout the world must constantly be aware of this problem.

- GCC will be discussed more in Chapter 22

About the term in use

GCC v.s. global warming or the greenhouse effect (a bit misleading)

- Without this natural “greenhouse effect” in our atmosphere, Earth would be approximately 33 degrees C colder than it is right now.

Our comfortably warm climate is only possible because of this heat-trapping ability of (primarily) carbon dioxide and water vapor.

So, when talking of the greenhouse effect, we really want to refer to the recent, rapid, unwanted increases in the atmosphere’s heat-retention ability.

The greenhouse effect

refers to the retention of infrared (IR) radiation (heat) by certain gases in the atmosphere before that heat is lost to space.

- **Sunlight Enters Earth's Atmosphere**

Sunlight, primarily in the form of visible and ultraviolet (UV) light, reaches Earth's atmosphere.

A portion is absorbed by the Earth's surface, warming it.

- **Earth Emits Infrared Radiation**

The Earth's surface emits this heat as infrared radiation, attempting to cool down.

This radiation moves in all directions, including back towards space.

- **Greenhouse Gases Absorb Infrared Radiation**
- Greenhouse gases in the atmosphere absorb this infrared radiation.
- These gases re-emit the energy in all directions, including back towards the Earth's surface, warming it.
- **Stabilization of Earth's Temperature**
- Atmospheric heat retention is essential to life on Earth, keeping it warm enough to support life.

Indicators for the measure of climate change

Average global temperature (AGT): averaging temperatures near the poles with other temperatures near the equator does not allow tracking of any regional trends.

Average global temperature anomaly (AGTA) : most frequently used

A more precise way to track the changes over time is to measure the temperature deviation or temperature anomaly at each station.

Over 130yrs 1C

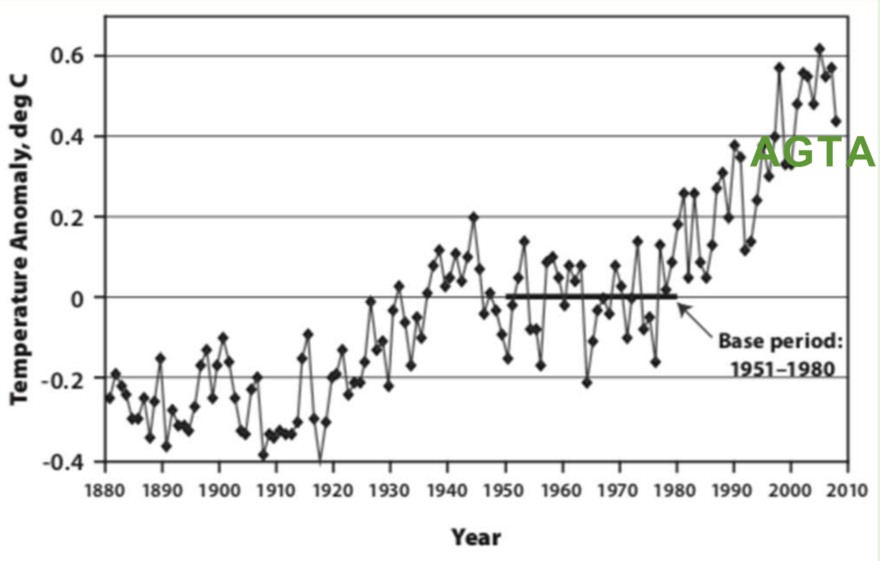

Figure 1.3
Recent behavior of average global temperature anomaly (land and ocean combined).

The main contributor to GCC

carbon dioxide (CO); methane (CH_4), nitrous oxide (N_2O), and CFCs.

ozone (O_3) , water (H_2O)

The main source of excess carbon dioxide emissions into the atmosphere is the burning of fossil fuels—coal, oil, and gas.

What Can We Do on GCC?

The "Rio Accord": 66 country signatories in 1993

a very general treaty, but established three very important agreements.

—it acknowledged that there was a problem of human making, and that countries should begin taking steps to address the problem.

— it strongly supported the concept of sustainable development for future growth.

— it laid the groundwork for future, more specific agreements.

(World political leaders created the United Nations Framework Convention on Climate Change (UNFCCC) and opened it for signatures in Rio de Janeiro, Brazil, in June 1992.)

The Kyoto Protocol was one subsequent product of the UNFCCC. 1997

This agreement was adopted in Kyoto, Japan, in December 1997, 84 signatories in 2000.

170 signatories now commits the industrial countries to reducing greenhouse gas emissions to 7% below their 1990 levels by 2012.

Estimation of CO2 Emission （Chapter22）

Global CO2 emissions are measured in gigatons (Gt, one billion metric tons).

The emissions can be reported as either Gt of CO2 or as Gt of carbon (C); the two are related by the ratio of their molecular weights.

Table 1.1 data on the history of CO2 emissions from the burning of fossil fuels by geographic area of the world.

Strategies and technologies （Chapter22）

Part II

Causes, Sources, and Effects

（Chapter 1.8 ）

Misconception:

a cause is fundamental;

explains why or how a pollutant is formed

a source is locational;

identifies what type of process, industry, or device discharges a particular pollutant.

Main focus of this course:

the control of air pollution from stationary sources. (industrial-scale air pollution control)

Less consideration is given to the control of air pollution from mobile sources, despite of the significance .

Why the scope of our coverage of mobile sources is restricted?

The design of vehicular pollution control equipment is a specialized field,

limited essentially to the vehicle and engine manufacturing companies,

About PM

Causes:

Materials-handling processes, such as crushing or grinding ores or loading dry materials in bulk.

Combustion processes can emit small particles of noncombustible ash or incompletely burned soot.

gas conversion reactions in the atmosphere between certain pollutant gases that were emitted previously.

Sources:

industrial processes, coal- and oil-burning electric power plants, residential fuel combustion, and highway vehicles.

Effects:

Damages to human and animal health, and retard plant growth.

Reductions in visibility such as smog or haze,

soiling of buildings and other materials,

corrosive and erosive damage of materials,

alteration of local weather.

About nitrogen oxides (NOx)

oxide NO , a colorless, odorless gas;

dioxide NO_2 : a brownish color

Causes : fuel burning

Sources: mobile sources and stationary combustion sources (point sources)

Effects:

— aesthetically displeasing and can reduce visibility

—- health impacts : nose and eye irritation, severe lung-related problems

—- react with certain VOCs (reactive hydrocarbons) in the presence of sunlight to form photochemical oxidants, including ozone;

(main reason for setting the NAAQS standard for NO_2 at 0.053 ppm)

About sulfur dioxide (SO_2)

sulfur oxide SO_2: the primary pollutant :

some SO_3 is also formed in furnaces;

SO_2 is slowly oxidized to SO_3 in the atmosphere

SO_2 and SO_3 can form acids when they hydrolyze with water

Causes : burning sulfur or any material containing sulfur.

Sources:

fossil-fuel combustion for electric power generation

industrial processes in specific locations such as petroleum refining, metal smelting can also be important sources

Effects:

detrimental effects on the environment

human health problems, damage to plants and animals,

smog and haze through the formation of acid mists,

corrosion of materials.

Acid rain / acidic deposition

A pollutant with PH<5.6, with serious regional-scale impact

Acid precursors:

sulfur oxides and nitrogen oxides

react with oxygen and water in the atmosphere to form acids

then fall to the ground with rain, snow, sleet, or as dry particulates.

The two most important constituents of acid deposition are HNO_3 and H_2SO_4

Adverse effects of Acidic deposition:

pH< 4.5, fish die; pH 5, most fish eggs cannot hatch

disruption of terrestrial ecosystems, forest and soil degradation,

corrosion of steel structures

deterioration of paint and stone

indirect effects on human health.

(after emission control efforts: sulfur based:2/3 —1/3 ; nitrogen based : 1/3 —1/2)

Trends in annual Emission rates for these six pollutants: Fig1.1 and 1.2

About Carbon monoxide (CO)

a colorless, odorless gas

Causes : incomplete combustion of any carbonaceous fuel.

Sources: transportation sector, closely related with mobile sources

Effects: significant effects on human health through reacting with the hemoglobin in blood to prevent oxygen transfer.

About Pb

How does lead get in the air?

Major sources of lead in the air :

ore and metals processing and piston-engine aircraft operating on leaded aviation fuel.

Other sources:

waste incinerators, utilities, and lead-acid battery manufacturers.

The highest air concentrations of lead are usually found near lead smelters.

What are the effects of lead on human health?

Once taken into the body, lead distributes throughout the body in the blood and is accumulated in the bones.

— adversely affect the nervous system, kidney function, immune system, reproductive and developmental systems and the cardiovascular system, depending on the level of exposure)

— Lead exposure also affects the oxygen carrying capacity of the blood.

—Children are especially sensitive to lead exposures, which may contribute to behavioral problems, learning deficits and lowered IQ.

What are the effects of lead on ecosystems?

Elevated lead in the environment can result in decreased growth and reproduction in plants and animals, and neurological effects in vertebrates.

(Lead can be added to soils and sediments through deposition from sources of lead air pollution or direct discharge of waste streams to water bodies and mining)

Current status:

As a result of EPA's regulatory efforts including the removal of lead from motor vehicle gasoline, levels of lead in the air decreased by 98 percent between 1980 and 2014.

About VOCs

All large industrial boilers, process furnaces, and stationary internal combustion engines are potential major sources. (like steel plants or petrochemical facilities)

A major source is defined as any facility that emits more than 10 tons/year of any one HAP or more than 25 tons/year of all HAPs combined.

Small area sources like dry cleaners, gas stations, and printers are also regulated.

Because HAPs are formed as by-products of incomplete combustion of fuels, they can be emitted (in small or not so small) concentrations from every combustion source.

Mobile Sources （Chapter18）

Mobile Sources v.s. Stationary Sources

What are mobile sources:

all things that move and emit air pollutants including both on-road and non-road vehicles

On-road vehicles:

Cars, trucks, buses, motorcycles, trains, tractors

non-road vehicles:

aircraft and vessels, from construction equipment, lawn and garden equipment, motorboats and jet skis

Impact of mobile sources:

fundamentally altered the field of air pollution control around the world

（mostly major urban areas）.

key reasons for this change:

1st, huge numbers of small, diverse, decentralized sources that move around are far more difficult to regulate and control than a much smaller number of the larger stationary sources.

2nd, the sources of the emissions (the vehicles on roadways) are usually very close to the receptors of interest (people living and working in urban areas).

3rd, cars have become economic status symbols in countries all around the globe, and driving is now an integral part of the lifestyles of hundreds of millions of people.

Control of mobile source pollution / Control strategies

control of new cars (alone is not sufficient to ensure clean air)

state and local regulation:

of in-use vehicle maintenance practices,

of fuel quality and composition,

of individual driving habits.

Views:

Reductions in per vehicle emissions are achieved due to the development of pollution control technology and regulatory strategies

Gains in reduction are offset by the continuing growth in the number and usage of motor vehicles.

Importance of Policy on pollution from mobile sources!

Category of Emission Sources

Stationary sources v.s Mobile Sources

- Anthropogenic sources
  - Transportation
  - Electric power generation
  - Industrial processes
  - Industrial and domestic fuel burning
  - Refuse burning Etc.

v.s

- Natural sources
  - Geological: volcano
  - Meteorological: lightning
  - Fauna: ruminants
  - Etc.

Part III

Legislative and Regulatory in the United States

（Chapter 1.4 ）

3.1 Federal Legislation

	Legislation	Highlights/Major significance
1955	Air Pollution Control Act	Provided funds only for federal research and technical assistance, not control
1963	Clean Air Act	Established federal authority to address air pollution problems
1965	Motor Vehicle Air Pollution Control Act	Established a federal program for the regulation of emissions from new motor vehicles.
1967	Air Quality Act	a novel concept: regulatory standards precede existing technology

	Legislation	Highlights/Major significance
1970	Clean Air Act Amendments (CAAA)	required the EPA to establish National Ambient Air Quality Standards (NAAQS)
		required the states to submit State Implementation Plans (SIPs)
		*Technology-forcing registration
1977	Clean Air Act Amendments (CAAA)	required the EPA to issue performance standards for new and existing industrial sources.
		Introduced the "prevention of significant deterioration" (PSD) of air quality in regions cleaner than the NAAQS.
		designated regulations for nonattainment areas; A policy known as emissions offset was adopted
		allowed the attainment of the emissions standards for automobiles to be further delayed;

	Legislation	Highlights/Major significance
		standard for NOx was permanently relaxed from original goals 5.5 to 1.0 g/mile; standards were proposed for heavy duty vehicles such as trucks and buses.
1990	Clean Air Act Amendments (CAAA)	impact: industrial operations + everyday activities (driving a car, mowing grass, getting laundry dry-cleaned, a charcoal grill)
	(CAAA 1990) Title I	applies to urban areas that are in non- attainment of one or more of the NAAQS.
		ozone: various control measures to be implemented depending on category and the level of pollution;
	(CAAA 1990) Title II	clean fuels are required for certain areas, lead was banned from use in motor vehicle fuel.
	(CAAA 1990) Title III	deals with air toxics; 189 hazardous air pollutants (HAPs) were identified for potential regulation. (2010)

	Legislation	Highlights/Major significance
		Industrial and commercial waste incinerators, industrial boilers and process heaters, and other combustion sources
	(CAAA 1990) Title IV	About acid deposition; called for significant reductions of both SO2 and NOx emissions.
	(CAAA 1990) Title V	establishes a new federal operating permit program
	(CAAA 1990) Title VI	stratospheric ozone protection
	(CAAA 1990) Title VII	makes the Act more easily enforceable
	(CAAA 1990) Other Titles	deal with clean air research, disadvantaged businesses, employment transition assistance, and miscellaneous provisions

3.2 Federal Regulations and Standards

Two types of standards:

Ambient Air Quality Standards (AAQSs)

Source Performance Standards (SPSs)

Ambient Air Quality Standards (AAQSs)

- About concentrations of pollutants in the outdoor atmosphere
- written in terms of concentration (μg/ m3 or ppm, or ppb) *be able to convert between them
- 6 pollutants: particulate matter (PM-10 and PM-2.5),
  sulfur dioxide, nitrogen dioxide, carbon monoxide, ozone, and lead

National AAQSs for these pollutants based on two criteria:

- The primary standards were established to protect the public health,
- The secondary standards were established to protect the public well-being

  non-health effects such as visibility reduction (aesthetic) or crop damage (economic).

Table 1.2 National Ambient Air Quality Standards (NAAQS)

Pollutant	Level	Averaging Time
Carbon Monoxide (CO)	9 ppm (10 mg/m^3) 35 ppm (40 mg/m^3)	8 hours[a] 1 hour[a]
Nitrogen Dioxide (NO_2)	0.053 ppm (100 µg/m^3) 0.100 ppm	Annual arithmetic mean 1 hour[b]
Ozone	0.075 ppm	8 hours[c]
Sulfur Dioxide	0.03 ppm 0.14 ppm 0.5 ppm	Annual arithmetic mean 24 hours[a] 3 hours (secondary standard)
Particulate Matter (PM-10)	150 µg/m^3	24 hours[d]
Particulate Matter (PM-2.5)	15.0 µg/m^3 35 µg/m^3	Annual arithmetic mean[e] 24 hours[f]
Lead	0.15 µg/m^3	3-month rolling average

(omitted)

Source Performance Standards (SPSs)

- Apply to emissions of pollutants from specific sources

- Written in terms of mass emissions per unit of time or unit of production

Mass emission rates: g/min or kg of pollutant per metric ton of product produced

Table 1.3 Selected Examples of National New Source Performance Standards (NSPSs)

1. Steam electric power plants (coal-fired)
   a. Particulate Matter: 0.015 lb/million Btu heat input, or 0.03 lb/million Btu heat input and 99.9% reduction.
   b. NO_x: 1.0 lb/ MWh gross energy output
   c. SO_2: 1.4 lb/MWh gross energy output or 95% reduction
   d. Hg: 0.020 lb/GWh gross energy output
2. Large (>250 tons/day) municipal solid waste (MSW) combustors: There are individual standards for dioxins/furans, cadmium, lead, mercury, HCl, particulate matter, NO_x and SO_2. Three examples are:
   a. PM: 20 mg/dscm* corrected to 7% O_2
   b. HCl: 25 ppm dry volume, corrected to 7% O_2
   c. Hg: 50 μg/dscm* corrected to 7% O_2
3. Nitric acid plants: The standard is a maximum 3-hr average NO_x emission of 1.5 kg/metric ton of 100% acid produced. All NO_x emissions are to be expressed as 100% NO_2. Also, the stack gases must meet 10% opacity (where 0% opacity represents perfectly clear stack gas, and 100% opacity means completely opaque).
4. Sulfuric acid plants: The standard is a maximum 3-hr average emission of SO_2 of 2 kg/metric ton of 100% acid produced. An acid mist standard is a maximum 3-hr emission of 0.075 kg SO_2 per metric ton of acid produced. Also, the stack gases must meet 10% opacity.

(selected)

Note that:

- some states have set their own stricter standards
- the World Health Organization (WHO) has published stricter guidelines for air quality standards.

  e.g. the WHO (2006) recommended an annual average value of 10 µg/m3 for PM-2.5.

- There are many other compounds that have been considered air pollutants, some of which may be extremely important in certain regions.

National Emission Standards for Hazardous Air Pollutants (NESHAPs)

A separate category of standards for emissions from point sources

apply to those substances that do not have AAQSs but that may result in “an increase in serious irreversible, or incapacitating, reversible illness.”

Some of the HAPs that are likely to be regulated are:

the acid gas HCl;

metals such as mercury, lead, cadmium, nickel, chromium, and others;

organic HAPs such as benzene, 1,3-butadiene, formaldehyde, acrolein, and others.

CO acts as a surrogate for all organic HAPs (a product of incomplete combustion).

PM has been proposed as a surrogate for metal HAPs.

Table 1.4 Summary of National Emission Standards for Hazardous Air Pollutants (NESHAPs)

1. Beryllium:	The emissions from all point sources are limited to 10 grams of beryllium per 24 hours. If the EPA approves, the source owner/operator may substitute the requirement to meet an ambient air quality standard of 0.01 μg/m^3 averaged over a 30-day period. Separate standards are listed for rocket motor testing using a beryllium-containing propellant.
2. Mercury:	The emissions from mercury ore processing facilities and mercury cell chlor-alkali plants shall not exceed 2300 grams of mercury per 24 hours. Emissions from sludge incinerators or dryers shall not exceed 3200 g/24 hours.
3. Vinyl chloride:	The standards are listed for specific equipment and processes in ethylene dichloride plants, vinyl chloride plants, and PVC plants. In general, the standard is 10 ppm of vinyl chloride in any exhaust gases.
4. Benzene:	The standard is very specific and basically applies to plants and equipment within plants that handle benzene. The standards are designed to prevent or minimize leakage of benzene into the atmosphere.
5. Asbestos:	The standards apply to asbestos mills, eleven manufacturing operations using commercial asbestos, demolition and renovation of facilities containing asbestos, and other processes. Basically, the standard requires that any air exhausts must contain no visible emissions.

Adapted from 40 CFR 61 (Code of Federal Regulations).

Note :

Reasons for the delay of successful rule-making/long process

（only for a few sources of pollutants）:

—- It is almost impossible to write one comprehensive set of rules that applies to all sources.

— There are arguments about how the material being burned was to be classified.

3.3 Air Quality Index (AQI)

What it is:

A tool for communicating daily air quality. (daily index)

It’s also used as the basis for air quality forecasts and current air quality reporting.

When and Who issues it:

The AQI was issued in 1999 by EPA;

It’s been updated several times since to reflect the latest health-based air quality standards.

AQI Basics for Ozone and Particle Pollution

Daily AQI Color	Levels of Concern	Values of Index	Description of Air Quality
Green	Good	0 to 50	Air quality is satisfactory, and air pollution poses little or no risk.
Yellow	Moderate	51 to 100	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.
Orange	Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is less likely to be affected.
Red	Unhealthy	151 to 200	Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.
Purple	Very Unhealthy	201 to 300	Health alert: The risk of health effects is increased for everyone.
Maroon	Hazardous	301 and higher	Health warning of emergency conditions: everyone is more likely to be affected.

color-coded categories

It provides statements for each category that tell you about air quality in your area, which groups of people may be affected, and steps you can take to reduce your exposure to air pollution.

3.3 Air Quality Index

What pollutants it covers:

five major pollutants that are regulated by the Clean Air Act:

(ozone, particulate matter, carbon monoxide, nitrogen dioxide and sulfur dioxide.)

The AQI for each pollutant is generally based on the health-based national ambient air quality standard for that pollutant and the scientific information that supports that standard.

What time frame it covers:

The ozone AQI is an 8-hour index; for particle pollution, it’s 24 hours.

3.3 Air Quality Index

How to calculate:

Example 1.18

Calculate the AQI and give a description of air that contains 5 ppm CO (8-hour average), 300 μg/m^3 PM-10 (24-hour average), and 0.10 ppm SO_2 (24-hour average).

Solution

By inspection of Table 1.11, the PM-10 concentration corresponds to a subindex value between 150 and 200. Also, by inspection, the CO concentration results in an I value between 50 and 100, as does the SO_2 concentration. CO and SO_2 can be eliminated from further consideration because only the maximum I value is needed. To calculate the actual I value, we use Eq. (1.33) as

$$I = \frac{200-150}{354-254}[300-254]+150$$

$$\text{AQI} = I = 173$$

The air quality description for this AQI value is "unhealthy," and the color shown on TV broadcasts is red.

Table 1.11 Individual AQI Subindex Breakpoints

I Value	8-hr O_3 ppm	1-hr O_3 ppm	24-hr PM-2.5 μg/m^3	24-hr PM-10 μg/m^3	8-hr CO ppm	24-hr SO_2 ppm
0	0	—	0	0	0	0
50	0.059	—	15.4	54	4.4	0.034
100	0.075	0.124	40.4	154	9.4	0.144
150	0.095	0.164	65.4	254	12.4	0.224
200	0.115	0.194	150.4	354	15.4	0.304
300	0.374	0.404	250.4	424	30.4	0.604
400	(*)	0.504	350.4	504	40.4	0.804
500	(*)	0.604	500.4	604	50.4	1.004

Note: (*) means that only the 1-hr ozone concentration is used to calculate the index in these ranges.

Adapted from U.S. EPA, February 2009.

Part IV About Calculations

(Chapter 1.5-1.6)

Part IV   About Calculations (1.)

Prior knowledge to review before your start…

1. About Conversion Factors (Appendix A: P766)

Mass： lb = 453.59g = 454g

Metric system ：

1 metric ton (tonne，t）=1000 kg =0.984 long ton

British system：

1 long ton =1.016 tonne = 2240 lb

American system：

1 sh.ton =0.907 tonne = 2000 lb

- 1 Gt = $(10)^9$ tonnes $=(10)^{12}$ kg
- 1 Tg (Teragrams) = 1 trillion grams $=10^{12}$ grams =1 million metric tons = $(10)^6$ tonnes

  1 trillion $(10)^{12}$ billon $(10)^9$ million $(10)^6$

- Volume : gal=gallon
- Energy : Btu （British Thermal Units） :

  1 Btu = 1.055 KJ = 252 cal

- Power : 1Btu/hr = 0.293W =2.93 $(10)^{-4}$kWh

°C = (F-32)÷1.8

2. About The Ideal Gas Law（1.5）

$$PV = nRT \quad \text{or} \quad PV = (M/MW)*RT$$

P = absolute pressure

V = volume

n = number of moles

R = ideal gas law constant T = absolute temperature

M = mass of the sample

MW = molecular weight of the gas

Example 1.1 CO_2 emissions from vehicles

Assume an average car in the United States gets 20 miles per gallon of gasoline, is driven 12,000 miles per year, and weighs 3500 pounds. Further assume that gasoline weighs 5.9 pounds per gallon and contains 85% carbon by weight.

Is there any truth to the statement that each car emits its own weight in carbon dioxide each year!?

Next, given that there are about 800 million vehicles worldwide, estimate the annual global carbon emissions from motor vehicles. Give your answer in Teragrams per year.

Example 1.2 Estimate the collection efficiency of a scrubber

(Table 1.3-6)

- Conversion between μg/ m^3 and ppm, or ppb

Summary

1. Common misconception:

Pollution v.s. pollutant

Pollution causes v.s. pollution Sources

Global climate change v.s. greenhouse effect

Tropospheric ozone v.s. stratospheric ozone

Acid rain v.s. acid precipitation

2. Distinguish

global scale v.s. regional-scale v.s. urban or local scale v.s. Indoor

Outdoor

Category of air pollutants:

primary v.s. secondary;

Gaseous v.s. particulate (aerosol/solid or liquid)

Category of air pollution source:

Stationary source v.s. mobile source

Point v.s. line v.s. area source

Indoor Air Pollutions

(not covered in)

Homework

Conduct a post-class reading and compare the major national standards, as well as the Air Quality Index (AQI) systems, between China and the United States. To make it concise and clear, a table format is suggested.

In-class Quiz

Please judge the following statements as true or false and correct the errors.

1. The federal 6 criteria pollutants are PM，SO_2，NO_2，CO，CO_2，VOCs.（ ）
2. Particulate matter is a solid.（ ）
3. Carbon dioxide, methane, ozone, nitrogen oxide, and water vapor all are major greenhouse gases. （ ）
4. The ozone pollution primarily occurs only in the stratosphere of the Earth's atmosphere. （ ）
5. Acid precipitation refers to a pollutant with PH<6.5. （ ）
6. NO_2 、SO_3 are primary pollutants.（ ）
7. CO is contributed mostly from incomplete combustion in power plants. ( )
8. The AQI index consists of five sub-indicators, with higher values indicating better air quality. ( )
9. When there is a local performance standard, national standard tend to be used in priority.（ ）
10. The Air Pollution Control Act marks the most significant and far-reaching legislation in the history of air pollution regulation in the United States. （ ）