AIR POLLUTION

Air pollution:
The presence of solids, liquids, or gases in the outdoor air in amounts that are injurious or detrimental to humans, animal, plants, or property or that unreasonably interfere with comfortable enjoyment of life and property.

Effects of are influenced by:
- Type and quantity of pollutants and their possible interactions
- Wind speed and direction
- Typography
- Sunlight
- Precipitation
- Vertical change in air temperature
- Photochemical reactions
- Height at which pollutant is released
- Susceptibility of individuals and materials to specific contaminants

- We breathe about 35 lb of air per day.

Health effects:
- Particulates > 3 μm collect in lung lobar bronchi
- Particulates < 3 μm end up in alveoli (lower/thoracic region of respiratory tract) and can cause more harm
- **Particulates < 10 μm are very harmful…carry deep into lungs**

Economic factors:
- Sulfur and formaldehyde pollution attack copper roofs and zinc coatings
- Steel corrodes 2–4 times faster in urban and industrial areas due to moisture, chloride, sulfate, and ammonium pollution
- Particulates (including smoke) in polluted air:
  - Cause erosion
  - Accelerate corrosion
  - Soil clothes, building, cars and other property making more frequent cleaning and use of indoor air-filtering equipment necessary
- Ozone:
  - Reduces the useful life of rubber and other elastomers
  - Attacks some paints
  - Discolors dyes
  - Damages textiles

Effects on plants:
- Plants are good indicators of harmful contaminants because of their greater sensitivity to certain specific contaminants
- Compounds that can harm plants include:

- **Hydrogen fluoride**
  - **Plant injury shows up as:**
    - Plant leaf tip and **margin burn**
    - **Chlorosis**
    - **Dwarfing**
    - **Abrupt growth cessation**
    - Lowered yield
- **Sulfur dioxide**
  - **Plant injury shows up as:**
    - **Bleached and necrotic areas between the veins**
    - Growth suppression
    - **Reduction in yield**
- **Smog**
  - **Product of photochemical reaction** involving nitrogen oxides, hydrocarbons, and oxygen
  - More prevalent in congested areas with high motor vehicle traffic
  - Brown clouds associated with smog are due to excess NO
- **Ozone**
  - Indicated in forest decline
  - **Plant injury shows up as:**
    - **Flecks, stipple and bleaching**
    - **Tip burns on conifers**
    - Growth suppression
- Ethylene
- **Peroxyacyl nitrate (PAN)**
  - **Plant injury shows up as:**
    - **Glazing, silvering, or bronzing on the underside of the leaf**

Effects on animals:

- Crippling skeletal damage to cattle in areas where fluorides absorbed by vegetation are ingested
- Deleterious effects
- Poisoning

- Insofar as the public is concerned, smoke, dust, and haze, which are easily seen, cause the greatest concern.

Climatic effects:

- Dust and other particulate matter in the air provide nuclei around which condensation takes place, forming droplets and thereby playing a **role in snowfall and rainfall patterns**
- Haze, dust, smoke, and soot **reduce the amount of solar radiation reaching the surface of the earth**
  - Offsets *some* of the greenhouse effect
- Aerosol emissions from jet planes intercept some of the sun's rays

- **Greenhouse effect:**
  - Carbon dioxide, methane, CFC, clouds, and atmospheric water vapor and NO tend to trap the re-radiated heat
  - Cause refection of heat back to earth and warming of lower atmosphere, oceans, and earth's surface
  - Carbon dioxide constitutes 49% of the greenhouse effect
  - Certain manmade compounds are far more effective greenhouse gases than other naturally occurring compounds
    - NO, both manmade and naturally occurring is 310 times more effective than CO2
    - HFC 23, a manmade refrigerant, is 11,700 times more effective than CO2
- Increased evaporation would also cause an increase in precipitation in some areas
- Processes that remove CO2 from the environment are **carbon sinks**
- Probable net projected effects of increased greenhouse gases include:
  - Changes in rain, snow, and wind patterns
  - Affect agriculture, overall precipitation, humidity, soil, and storm frequency
  - Growing season would be lengthened
  - Melting polar ice would raise ocean levels

Effect of ozone and CFCs:

- **Ozone is formed naturally by action of sunlight on the oxygen molecule**
- Ozone in ***upper*** **layer of atmosphere (stratosphere) 8–30 miles above earth's surface**
- Ozone in ***lower*** **layer of atmosphere (troposphere) upward for about 8 miles**
- Ozone at ground level causes lung dysfunction and irritation of the mucous membranes of the eyes, nose, and throat as well as tree and crop damage
- CFCs and halons in troposphere migrate upward toward stratosphere through mixing force of wind and remain stable for up to 400 years
- Destruction of ozone in atmosphere permits more solar radiation to reach earth
- Ozone destruction could **cause increase in cancer, eye cataracts, and changes in climate and animal and plant life**
- **CFCs remain in stratosphere for 75–100 years**
- U.S. (and 80 other countries) agreed to phase out CFCs by year 2000 if possible

Acid rain:

- Releases of NO, SO, and CO2, as well as other pollutants, are carried into the atmosphere, where they interact with sunlight and vapor and may be deposited into as **acid rain** many miles from the source
- **In NY and the Northeast, 60–70% of reported acidity is due to sulfuric acid and 30–40% nitric acid**
- **Major sources** of SO, NO, and CO2 are ***coal- and oil*****-burning power plants, refineries, and copper and other metal smelters**
- **Principal sources of NO emissions include *motor vehicles***

- About ½ of all atmospheric sulfur worldwide is reported to come from natural sources
- **Main contributor of *natural* acidity is carbon dioxide**
- Natural acidity of precipitation may vary from pH of 5.4–5.7 (lower in Northeast)
- Forest canopy may reduce acidity and ammonia
- Particulates in air may, in part, neutralize acid
- Adversely affects lakes and streams where pH may be reduced to less than 5.0 with resultant reduced fish production
- May also be accumulation in fish of 10–100 times the normal range (metals)

Sources and types of air pollution:

- May be in form of:
  - Particulates
    - Range from less than 0.01 μm to 1000 μm in size, but generally smaller than 50μm
    - Those **< 10 μm can penetrate the lower respiratory tract**
    - Those **< 3 μm reach the tissues in the deep parts of the lung**
    - Those > 10 μm are removed by the hairs at front of nose
  - Aerosols
  - Gases
  - Microorganisms
- Result of industrialization and mechanization
- **Carbon *mono*xide is the principal pollutant by weight, and the motor vehicle is the major contributor**
- Particulates, gases, and vapors that find their way into the air without being vented through a stack are referred to as **fugitive emissions**
- Wood stoves contribute significantly to air pollution

Natural sources:

- Ozone is found in the stratosphere at an altitude beginning at 7–10 miles
- Principal natural sources in the *lower* atmosphere are lightning discharges and reactions involving VOCs released by forests and other vegetation
- Formed naturally in the *upper* atmosphere by photochemical reaction with UV solar radiation

Types of air pollutants:

- **Primary**
  - **Found in the atmosphere in the same form as it exists when emitted from the stack**
  - Examples: sulfur dioxide, nitrogen dioxide, and hydrocarbons
- **Secondary**
  - **Formed in the atmosphere as a result of reactions such as hydrolysis, oxidation, and photochemistry**
  - Example: photochemical smog

- Photochemical oxidants (e.g., ozone, PANs, formaldehydes, peroxides) are produced in the troposphere as a result of the reaction of oxides of nitrogen and volatile organics in the presence of solar radiation
- Nitrogen dioxide (as is found in photochemical smog) colors air reddish-brown

Sampling and measurement:

- EPA has specified a daily uniform air pollution index known as the **pollutant standard index (PSI)** for public use in comparing air quality
- Continuous analyzers using **gas-phase measurements with electronic designs are preferred over wet chemistry** because they are more accurate/reliable
- Particulates can be collected and tested for mutagenic properties
- Particulates can also be measured for radioactivity
- Of all particulate ambient air sampling devices, the high-volume sampler is most commonly used
- **High-volume sampling is the EPA reference method**
- **Orifice with a manometer is recommended for flow measurement**
- Inertial/centrifuged collection equipment most efficient for collection of particles larger than 10 μm
- Impingers
  - Wet used to collect small particles
  - Dry used to collect larger particles
- Nuclei counters
  - Particle count above 50,000 is said to be characteristic of an urban area

Gas sampling:

- Concentrations of gases when reported in terms of ppm and ppb are by volume rather than weight
- **Gas chromatography** separates compounds that can be volatilized
- **Liquid chromatography** separates compounds that are not volatile
- **Mass spectrometry** identifies a separated pure component by its characteristic mass spectrum
- NO is measured by the gas-phase chemiluminescent reaction between NO and ozone
- Ozone is measured by the gas-phase chemiluminescence technique, which utilizes the reaction between ethylene and ozone
- Ozone is also measured by UV light instrumentation
- It is necessary to remove water vapor interference as the humidity in ambient air absorbed by IR energy can introduce significant error in CO readings

Smoke and soiling measurement:

- **Ringlemann smoke chart measures smoke and/or opacity**
  - Five rectangular grids over white background
  - When held at a distance (50 ft from observer), grids appear to give shades of gray between white and black

        - 30 observations are made in 15 minutes
        - Weighted average is computed of the recorded Ringlemann numbers
        - System *cannot* be applied to dusts, mists, and fumes
        - Reading of zero would correspond to all white
        - Reading of five would correspond to all black
        - Ringlemann chart has been replaced by a determination of the **percent opacity** of a particular emission as seen by a trained observer
    - Tape sampler (**coefficient of haze**…COH):
        - Can be designed to measure light transmittance rather than reflectance
        - Produces soiling measurements expressed as COH
        - **COH is an index of contaminant concentration, which is EPA-preferred method**
        - White light is used
    - Stack sampling:
        - Common piece of equipment for boiler and incinerator stack sampling is the **Orsat apparatus**

Environmental factors:

- Meteorology involves physics, chemistry, and dynamics of the atmosphere
- Meteorology includes many direct effects of the atmosphere on earth's surface, ocean, and life
- Topography refers to both the natural and manmade features of the earth's surface
- Meteorology
    - **Elements that have the most direct and significant effects on the distribution of air pollutants are:**
        - **Wind speed and direction**
        - **Solar radiation**
        - **Stability**
        - **Precipitation**
    - Wind
        - The motion of the air relative to the earth's surface
        - Motion **derives from the unequal heating of the earth's surface and the adjacent air**, which in turn gives rise to a horizontal variation in temperature and pressure
        - **Pressure gradient** constitutes an imbalance in forces so that **air motion from high to low pressure is generated**
        - Primary/general (global) circulation…between tropical and polar regions
        - Secondary circulation (highs and lows)…developed by unequal distribution of large land and water masses
        - Tertiary (local) circulation…valley winds and land and sea breezes
        - **Turbulence (provide most effective mechanism for the dispersion/dilution of a cloud/plume of pollutants**
            - Induced by thermal convective currents resulting from heating below (**thermal turbulence**)

        - Also induced by disturbances or eddies resulting from passage of air over irregular, rough ground surfaces (**mechanical turbulence**)
    - Customary to present long-term wind data at a given location graphically in the form of a **wind rose**
    - **Concentration resulting from a continuous emission of a pollutant is inversely proportional to the wind speed** (the higher the wind speed, the greater the dispersion/separation of particles as they are emitted)
    - Wind speed generally increases with height in the lower levels due to lower frictional drag effect
- Stability and instability
    - Unstable conditions
        - Air motion is enhanced
        - Increase turbulent motions
        - Enhance dispersion of pollutants
        - If the decrease of temperature with height is > 5.4 degrees F/1,000 ft
    - Stable conditions
        - Air motion is suppressed
        - If the decrease of temperature with height is < 5.4 degrees F/1,000 ft
    - Neutral conditions
        - If the decrease of temperature with height is = 5.4 degrees F/1,000 ft
    - Conditions determined by the vertical distribution of temperature (*decrease* of temperature with height is called **lapse rate**)
- Inversions
    - When temperature *increases* with height
    - *Extremely stable* condition
    - Three types that develop in the atmosphere:
        - Radiational (surface)
            - Develops at night under relatively clear skies and very light winds
        - Subsidence (aloft)
            - Develops in high-pressure systems (generally associated with fair weather)
            - Acts as barrier/lid to vertical dispersion of pollutants
            - Can persist for several days
            - Resulting accumulation of pollutants can cause a serious health hazard
        - Frontal (aloft)
            - Forms when air masses of different temperature characteristics meet and interact so that warm air overruns cold air
    - For stack emissions in inversions
        - After sunrise, continued radiation from sun heat's earth's surface and adjacent air
        - Inversion is "burned off"
        - Lower layer becomes unstable
        - All pollutant that has accumulated at the level aloft is rapidly dispersed downward to the surface (**fumigation**)

        - Results in high concentrations during this period
    - Precipitation
        - Constitutes an effective cleansing process of pollutants in the atmosphere in three ways
            - Removal of large particles by raindrops or snowflakes (**washout**)
                - Most effective and most prevalent
                - Especially in lower atmosphere where most pollutants are released
            - Removal of small particles by formation of raindrops or snowflakes in clouds (**rainout**)
            - Dissolution and adsorption (removal of gaseous pollutants)
- Topography:
    - Prime significance is its effect on the meteorological elements
    - Increased roughness of surface over city due to buildings can enhance turbulence and improve dispersion of pollutants
    - **Surface inversions**
        - Develop in valley areas, especially in winter
        - Caused by drainage down the slopes of air cooled by the radiationally cooled valley wall surfaces
        - If bottom valley is significantly populated and industrialized, can be subject to critical accumulation of pollutants during these periods
    - **Urban heat island effect**
        - Heat from nighttime space heating during cool months created temp and pressure differential between city and surrounding rural area
        - Local circulation inward to city if developed
        - Circulation tends to concentrate pollutants in the city
    - **Areas on windward side of mountains can expect added precipitation** due to forced rising, expansion, and cooling of moving air mass with resultant release of moisture

Ambient air quality standards:

- **Ambient air** is the portion of the atmosphere, external to buildings, to which the general public has access
- **Primary** ambient air quality standards
    - Required to protect the public health
- **Secondary** ambient air quality standards
    - Required to protect the public welfare from any known or anticipated adverse effects associated with the presence of air pollutants in the ambient air
- Clean Air Act (CAA) amended in 1970 (previously the federal Air Quality Act of 1967)
    - Emissions from stationary sources and motor vehicles are regulated under this act
    - Class I
        - Air quality must remain virtually unchanged (international parks, wilderness, etc…)
    - Class II
        - Moderate industrial growth allowed

    - Class III
        - More intensive industrial activity permitted
    - Amended 1990
        - Title I = attainment of ambient air quality standards
        - Title II = mobile sources of air pollution
        - Title III = reduction and regulation of 188 toxic air emissions from commercial and industrial sources and municipal incinerators
        - Title IV = control of acid deposition/acid rain
        - Title V = development and requirement of permit system
        - Title VI = phasing out of ozone-depleting chemicals
        - Title VII = enforcement
    - Amended 1997
        - New standard for particulate matter drafted (regulated particulates less than 2.5 μm)
- SARA Title III has most dramatic and far-reaching impact on industry regarding control of toxic chemicals in the air
- **Pollutant Standards Index (PSI)**
    - Uniform method recommended to classify and report urban air quality
    - **PSI > 300…hazardous conditions**
    - PSI 200–300…very unhealthful conditions
    - PSI 100–200…unhealthful conditions
    - PSI 50–100…moderate conditions
    - PSI 0–50…good conditions

Controls:

- **Internal combustion engine is major producer of air pollutants**
- Settling chambers cause velocity reduction
- Cyclones impose a downward spiraling movement
- Sonic collectors used to facilitate separation of liquid or solid particles in settling chambers or cyclones
- Two types of filters
    - Baghouse
        - Efficiencies exceeding 99%
        - Particle removal below 10 μm in size
        - Usually supplemented by scrubber systems
    - Cloth screen
        - Usually used in smaller grinding, tumbling, and abrasive cleaning operations
- Electrostatic precipitators
    - Efficient for collection of particles less than 0.5 μm in size
    - Cyclones and settling chambers, which are more efficient at large particle removal) are sometimes used ahead of precipitators
    - Commonly used at large power stations and incinerators to remove particulates from flue gases
    - Considered one of the most effective devices for this purpose
- Scrubbers

- A**d**sorption (molecules of fluid brought into contact w/the adsorbent, which collect the contaminant in the pores or capillaries)
- A**b**sorption (passed through tower and absorbers where it comes in contact w/a liquid absorbing medium or spray that selectively dissolves or reacts with the air contaminants to be removed

Dilution by stack height:

- Wind speed increases with height in the troposphere
- **Release of pollutants through a tall stack enhances transport and diffusion of material**
- If plume is transported to hill areas, surfaces will be closer to the center of the plume and will experience higher concentrations
- **With unstable lapse rate** (heavy turbulence), **plume will loop** as it travels downwind
- **With neutral lapse rate, coning will occur** (plume will form overlapping cones)
- **With stable lapse rate** (like in an inversion with little turbulence)**, fumigation will occur** (plume fans out gradually)
- High stacks are generally used for emission of large quantities of pollutants
- High stacks may improve conditions locally, but may worsen conditions with long-range transport downwind

Air quality modeling:

- Four classes:
  - Gaussian
    - Most often used for estimating ground-level impact
  - Numerical
    - Most often used for estimating impact of reactive and non-reactive pollutants in complex terrain
  - Statistical
    - Used in situations where physical or chemical processes are not well understood
  - Physical
    - Experimental investigation of source impact in a wind tunnel facility
- Sources of pollutants can be classifies as:
  - Point
    - Individual stacks
  - Line
    - Confined to roadways
  - Area
    - All minor point and line sources that are too small to require individual consideration
- **Data needed** to represent meteorological characteristics of a given area consist of:
  - **Wind direction**
  - **Wind speed**
  - **Atmospheric stability**

        - **Mixing height**

Enforcement:
- EPA
    - Primary gov't force involved with air pollution
    - Role includes research into cause/effect relationships and control of international and interstate air pollution on behalf of affected parties
    - Also responsible for national air-sampling network, training, prep of manuals, and dissemination of information
    - Assist state and local gov't
- State role is similar to federal role
    - Setting of statewide standards
    - Establishment of sampling network
    - Authority to declare emergencies and possession of appropriate powers during emergencies
    - Delegation of powers to local agencies
- Local gov't
    - Duties delegated to it by the state
    - Could include complete program implementation and enforcement

- Breathing zone air sampler = individual space

- **Psychrometer** measure temp and humidity.

- **Halon 1301** = Used in fixed "flood" fire extinguishers

- **Halon 1211** = Used in portable extinguishers

If sick building syndrome is suspected:
- Eliminate VOCs
- Up HVAC air exchange
- Eliminate allergens and mold