

GEOS 3310 Lecture Notes: Geology, Society and the Future

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Medical Geology

Heart Disease

- heart disease has been found to correlate with water *softness* or sodium content
- waters in contact with limestone often have high calcium content (high *hardness*, along with high Mg)
- waters in contact with volcanic materials, or flowing through clays have high sodium (and low calcium) or exchange their calcium for sodium (*natural softening*)
- in Japan heart disease correlates with silicic (high sodium and sulfur) volcanic rocks [Fig. 19.1, Keller, 2011]

- similarly in Ohio increased heart attack rates correlate with high sulfate/low HCO₃ [Fig. 19.2, Keller, 2011]

Radioactive Decay

- naturally-radioactive rocks can emit *radon*, a potentially harmful radioactive gas
- *radioactive decay* is the source of the hazard:
 - it involves the transformation of one *isotope* to another
 - isotopes are elements having the same number of protons in the nucleus but different numbers of neutrons
 - *alpha* decay emits an alpha particle, containing two protons and two neutrons. In this case the element is changed to a different element (e.g. radium changes to radon). These are slow and have too little energy to penetrate paper.
 - *beta* decay are energetic electrons, and can penetrate paper, but not a wooden board

- *gamma* decay emits highly energetic gamma rays, which travel far and can penetrate most materials except lead
- the greater the energy, the more the potential damage and the greater the difficulty in shielding the radiation
- in radioactive decay, the element spontaneously decays to a new isotope at a standard rate, the time for half of the material to decay to another form is called the *half-life*

Radon Gas

- radon is formed as part of a decay chain from uranium [Fig. 13.10, Keller, 2011]
- radon emits an alpha particle during decay, with half-life of 3.8 days
- its gaseous form makes radon exposure likely, its rapid transition to solid makes inhalation of radon quite hazardous
- radon is mostly associated with granitic basement rocks or rocks derived from them (Fig. 1) [Fig. 13.13, Keller, 2000]
- it commonly seeps into the basement or crawlspace of houses [Fig. 19.C, Keller, 2011]

- the simplest remediation technique is to *ventilate* the substructure of the house
- for uncertain reasons, smoking dramatically increases the hazard from radon [Fig. 19-A, Keller, 2011]
- radon is the leading environmental cause of cancer death in North America (see Federal Radon Action Plan).
- EPA is likely to abandon its radon risk reduction program for budgetary reasons in 2013

Radon Risk

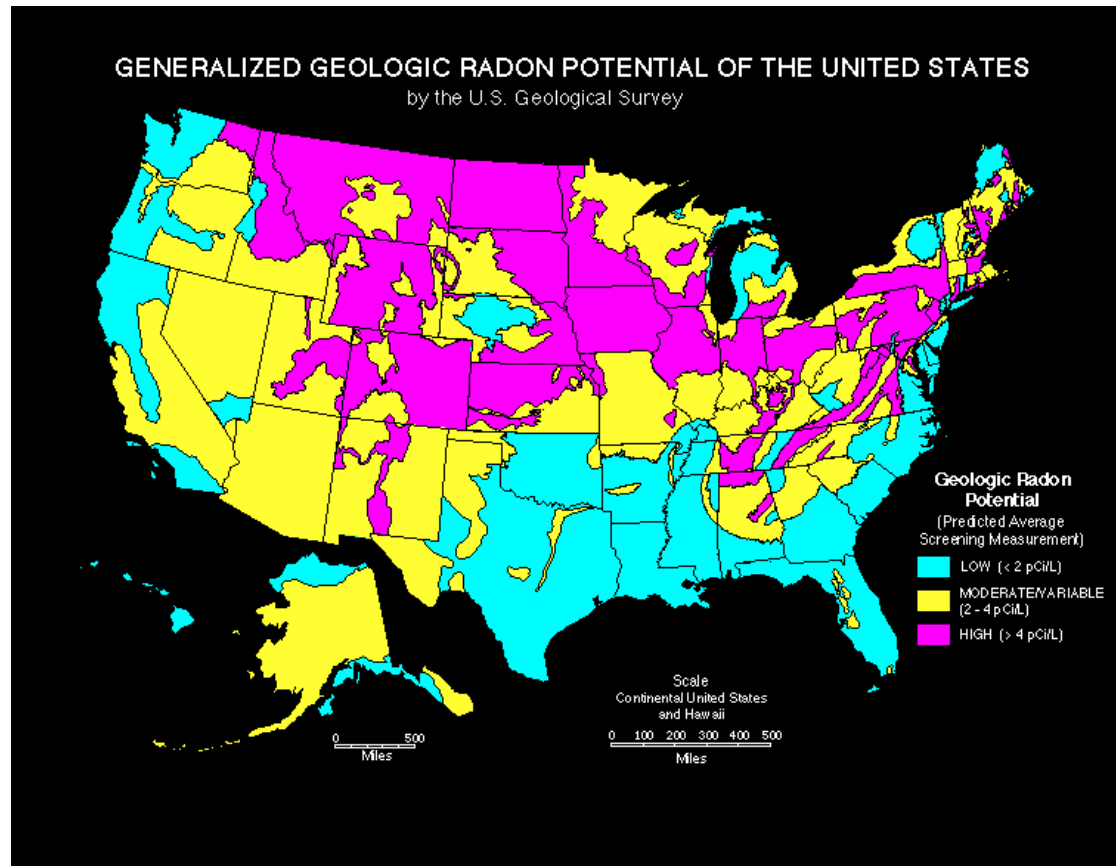


Figure 1: Generalized geologic risk of radon, after USGS .

Air Pollution

- see TCEQ current conditions map

Introduction

- General Information
 - see EPA Air Quality Trends for good summary
 - and AirNow for nationwide current AQI and much background information
- air pollution is the most widespread human impact on the planet
- many trends are encouraging, for instance for the *U.S. as a whole air quality is improving* [Fig. 17.10, Keller, 2000]
- some are discouraging, e.g. the number of unhealthy days is increasingly a result of ozone pollution (Fig. 4)

- Texas (especially Houston, Figs. 6–7) stands out as one of the worst areas of increasing air pollution
 - Dallas Metroplex trends are mixed, but generally show mild decline (Fig. 5) despite increasing number of vehicle miles/day
 - some summertime exceptions, see interactive Texas exceedence areas
 - air pollution events available from TCEQ , (e.g. Level Red warning, Aug. 26, 2011, see TCEQ Air Pollution Events webpage)
 - the Metroplex is chronically out of compliance with EPA regulations, and recently has been the smoggiest city <http://www.dallasnews.com/opinion/editorials/20111104-editorial-earning-smog-capital-title-leaves-dallas-fort-worth->

- choking.ece in Texas, new lower standards have brought increased regulatory pressure
- enforcement may increase with new regional EPA administrator

Air Quality Trends, U.S.

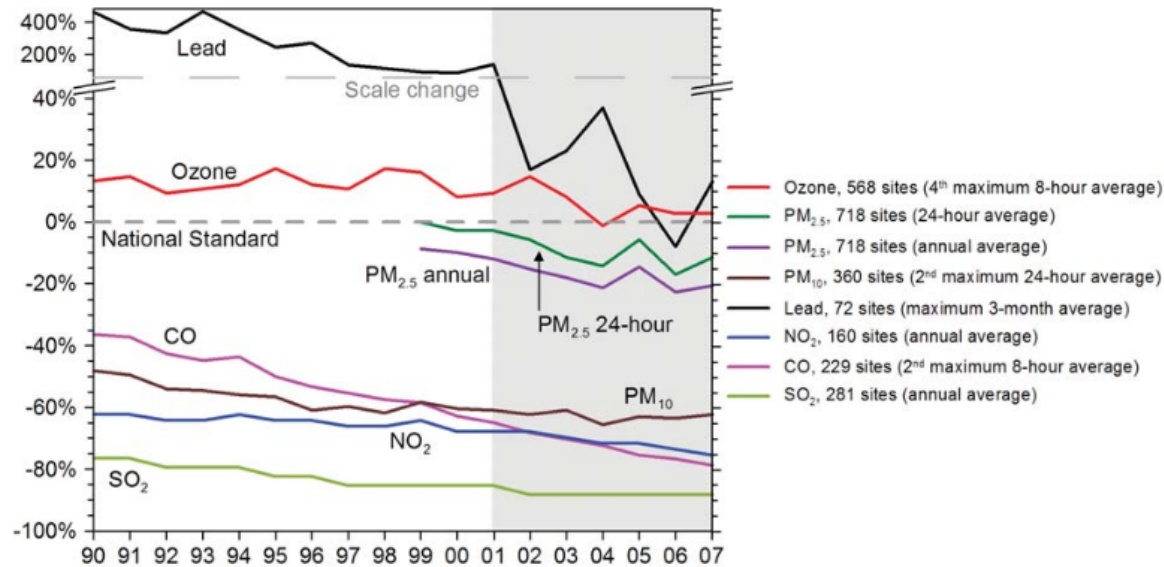


Figure 4. Comparison of national levels of the six common pollutants to national ambient air quality standards, 1990-2007. National levels are averages across all sites with complete data for the time period.

Figure 2: Air quality index trends in the U.S. for six principal pollutants, 1990-2007. From USEPA . See comparison to economic and population growth .

AQI

Air Quality Index (AQI) Values	Levels of Health Concern	Colors
<i>When the AQI is in this range:</i>	<i>...air quality conditions are:</i>	<i>...as symbolized by this color:</i>
0 to 50	Good	Green
51 to 100	Moderate	Yellow
101 to 150	Unhealthy for Sensitive Groups	Orange
151 to 200	Unhealthy	Red
201 to 300	Very Unhealthy	Purple
301 to 500	Hazardous	Maroon

Figure 3: Air Quality Index (AQI) scale. An AQI for each major pollutant is computed using various EPA formulas . The highest AQI among all the pollutants is reported for that day.

Ozone Impact on AQI

Figure 3-3. Percentage of days over 100 due to ozone.

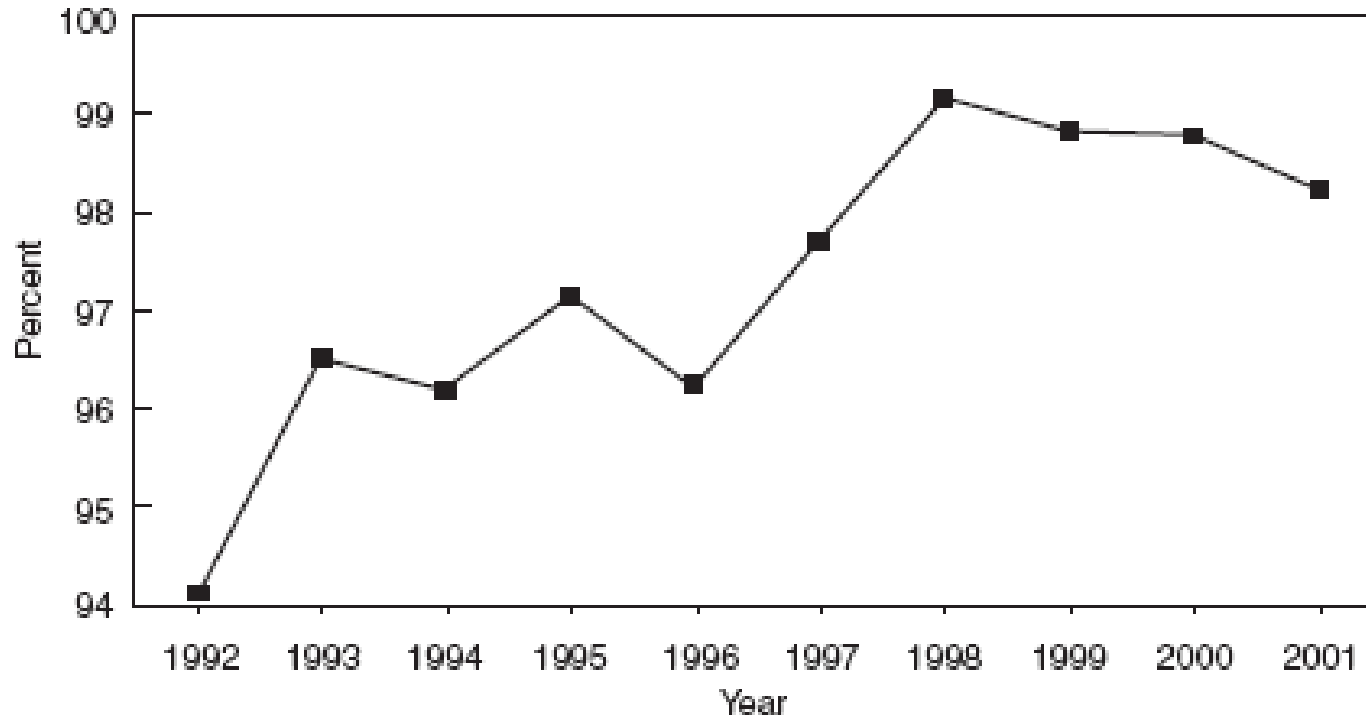


Figure 4: Ozone contribution to increase in air quality index. Increasing air pollution is chiefly a result of increased ozone pollution, which in turn is chiefly a result of automobile exhaust. See USEPA air quality trends .

DFW Ozone Trends

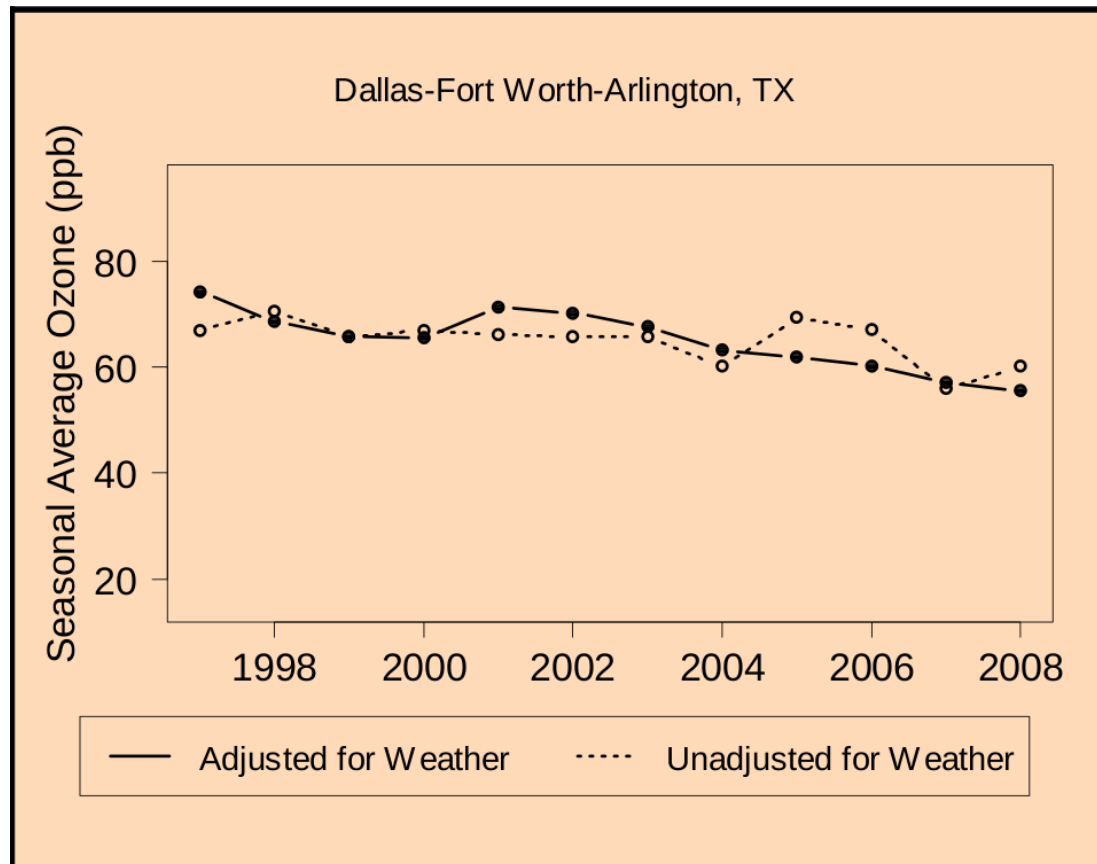
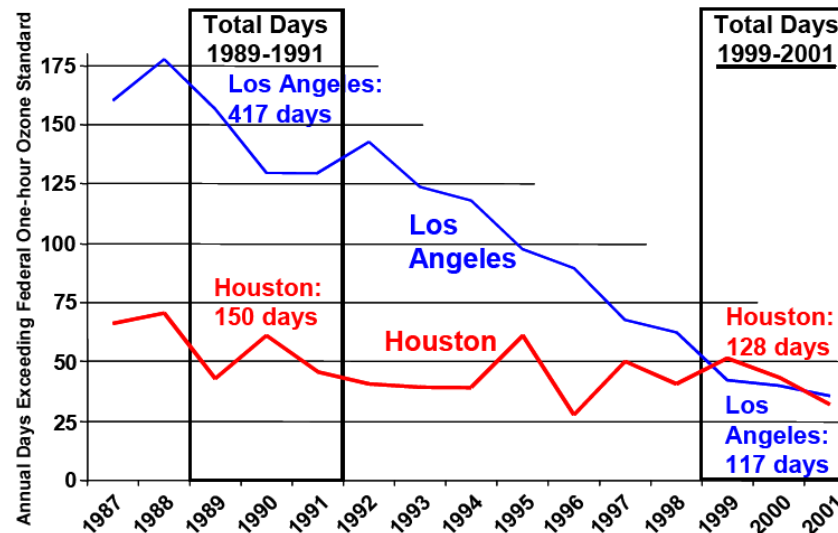


Figure 5: Summary of DFW ozone trends 1998-2010, from EPA .

Houston-LA Ozone Trends

Figure 1: Steady Progress in Los Angeles
Leaves Houston With Most Exposures to Ozone Smog

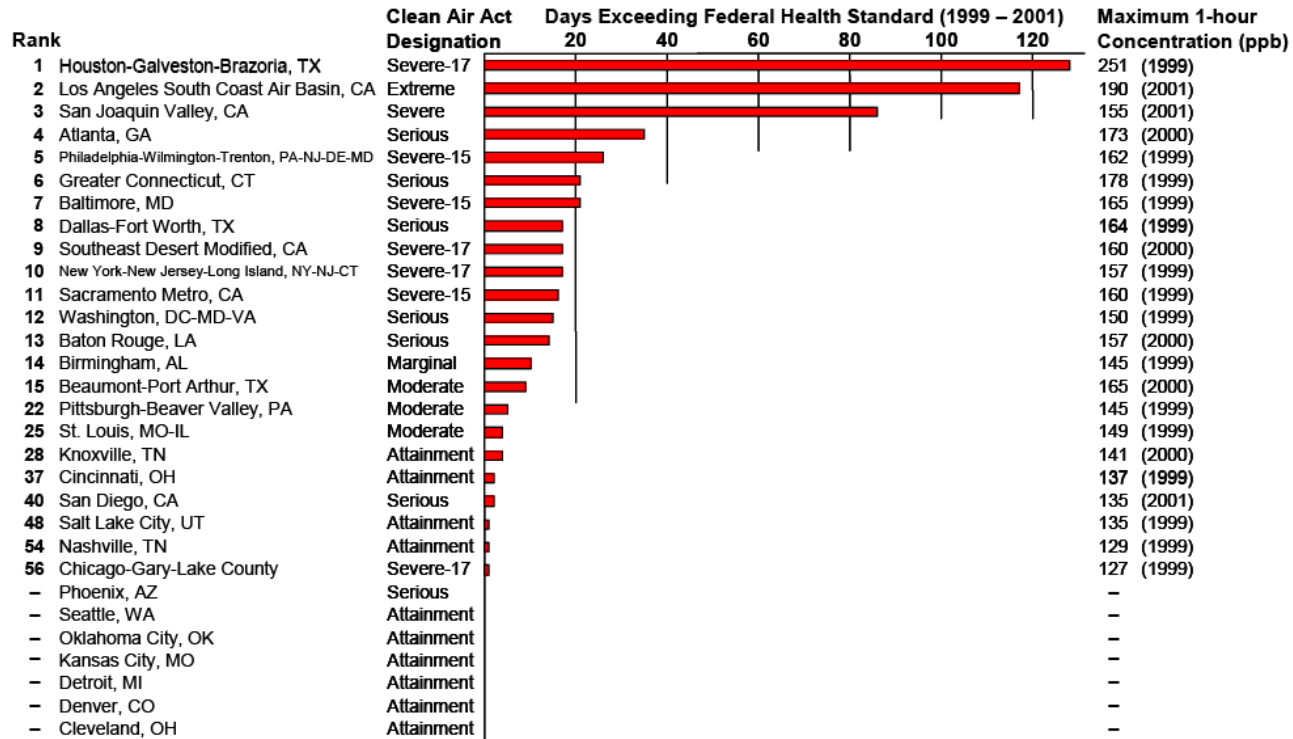


Sources: South Coast Air Quality Management District; Texas Natural Resource Conservation Commission; and US Environmental Protection Agency.

Figure 6: Trend in number of high ozone days for Houston and Los Angeles. Both cities experienced similar growth rates during this period, LA population is approximately 3.7 million, Houston 2 million. After GHASP webpage.

US City Smog Rankings

Figure 5: Houston Smog is More Frequent and Intense than in Every Other U.S. City, 1999 - 2001
Performance of 15 Most Polluted Cities and 15 Other Selected Cities on One-Hour Federal Health Standard for Ozone



Sources: US Environmental Protection Agency and various state environmental agencies. Data selected from an analysis that includes 63 cities.

Figure 7: Ranking of major US cities by number of standard-exceeded days. After GHASP webpage. See American Lung Assn. State of the Air for this year's results.

Ozone Kills

- a 2004 study [Bell et al., 2004] shows Dallas as the U.S. city with the 8th largest link between deaths and ozone increase
- a 10ppb decrease in average ozone would reduce daily death rates by 1%
- annual expected deaths from all causes in Dallas County are 40.6/100,000 population, or about 1,000/year (2,500/yr in Metroplex)

Los Angeles Smog



Figure 8: Pasadena looking north at the San Gabriel Mountains with and without smog. Left image typical of mid-summer days, right image typical of mid-winter. After [California Smog Check](#) webpage.

India Smog

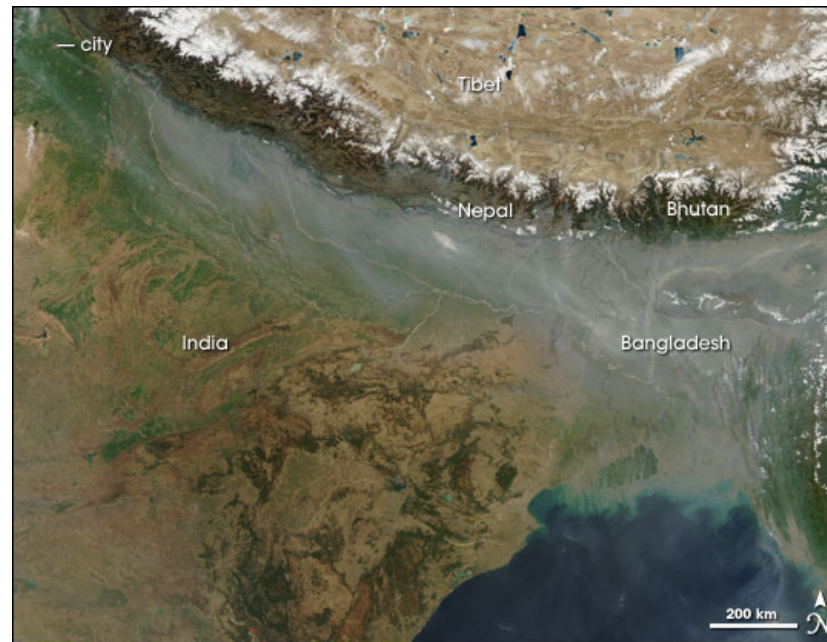


Figure 9: Heavy smog and haze is common over northern India in winter and spring. Mostly originating from agricultural fires and cities, trapped by temperature inversion in winter. After NASA . See also Beijing smog images and eastern China .

Source Categories

- *Stationary*: fixed location, includes fugitive, point and area sources
- *Point*: emits from a discrete (controllable) site
- *Fugitive*: open areas that generate particulates
- *Area*: emit from distributed or multiple sources within a well-defined area
- *Mobile*: moving source, e.g. vehicles

Pollutants Categories

- *gaseous*
- *particulate*: small solid particles, e.g. PM-10 are particles less than 10 microns
- *primary* pollutants are emitted directly into the air
- *secondary* pollutants are formed when primary pollutants react or combine (e.g. *ozone*)

Major Pollutants

- *sulfur dioxide*
 - colorless and odorless, associated with gray smog
 - primarily from coal-fired power plants
 - major component of acid rain
 - major impact is corrosion of paint and metals, crop damage, and plant damage in general [Fig. 18.9, Keller, 2008]

- *Nitrogen Oxides*
 - many forms, most prominently NO_2 , light brown gas
 - toxic and quite corrosive
 - its major impact is in the formation of *photochemical smog*, secondary contribution is as acid rain

- newly recognized as making significant contribution to ozone layer depletion
- almost all NO_x is anthropogenic, mostly automobiles and power plants

- *CO*, carbon monoxide
 - main impact is to interrupt blood oxygen uptake, causing asphyxia
 - sometimes so high in Los Angeles outdoor air that household detectors sound alter
 - mostly natural sources, but in city it is concentrated automobile emissions

- *Ozone*

- a photochemical oxidant produced by sunlight acting on several primary pollutants
- main impact is plant and lung tissue damage, breakdown of rubber, paint, etc.
- main source is automobiles (which release the precursors of ozone)

- *VOC's*, volatile organic compounds
 - an important constituent in forming photochemical smog
 - globally only 5% of emissions are anthropogenic, but half the emissions in the U.S. are anthropogenic, primarily automobiles
 - other large sources are 2-stroke engines (e.g. leaf blowers), charcoal lighter fluid, etc.

- *PM-10*: particulate matter
 - main sources are industrial processes, power plant effluent and disturbed ground (dust)
 - acts as a lung irritant, and causes significant lung damage
 - important particulates are sulfates and nitrates, which are secondary pollutants
 - globally most particulates are natural, but in cities anthropogenic particulates may dominate
 - reduction in particulate pollution shown to increase life expectancy in the U.S. by 5% (see interactive graphic)

Urban Air Pollution

Inversions

- meteorological conditions can act to trap pollutants, making them deadly
- *atmospheric inversions* occur when cold air is trapped in an enclosed area (e.g. valley) by overlying warm air [Fig. 19.3, Keller, 2011]
- these are especially a problem in the Western U.S., where topography favors trapping of air [Fig. 18.7, Keller, 2008]. See also Mexico City image , although that city has cleaned up its air remarkably
- the *chimney effect* allows pollutants to move past topographic barriers if emissions are high (concentrating

pollutants) and horizontal winds are sufficient to perturb the inversion layer [Fig. 19.4, Keller, 2011]

- the *heat island* effect traps pollutants in cities by limiting horizontal air circulation when air heated over pavement moves vertically upward in a *convective pattern* [Fig. 17.6, Keller, 2000]
- see also satellite observations

Smog Production

- *sulfurous smog*:
 - produced when SO₂ and particulates combine with moisture
 - a thick gray fog is produced
 - mostly occurs in areas of extensive coal burning (e.g. steel mill towns) [Fig. 18.9, Keller, 2008]
- *photochemical smog*
 - produced by combination of NO_x and hydrocarbon primary pollutants in the presence of sunlight [Fig. 18.10a, Keller, 2008]
 - note this is a complex reaction that is incompletely understood

- formation of this smog is directly related to automobile use
- as morning traffic builds up NO and Hydrocarbon concentrations increase [Fig. 18.10b, Keller, 2008]
- ozone is produced by photodissociation of NO₂
- simultaneously hydrocarbons react with NO yielding more NO₂
- by midday peaks in ozone and NO₂ (brown haze) are seen

Waste Management

Introduction

Solid waste management is a large and growing industry in the U.S. as waste volume and population continue to increase:

- the average American produces 4.5 lbs of trash per day, which totals 236 million tons per year
- around half of U.S. cities are running out of landfill space
- new landfills are unpopular, and difficult to establish
- ultimately the optimum solution is a combination of source reduction, recycling, composting, landfill and incineration termed *integrated waste management* (Fig. 10)
- a big business

- integration has also fostered growth of a few large companies that manage much of the waste in the U.S. (e.g. Waste Management, Inc. with 22 million customers and around 300 active landfills)
- also a favorite activity of organized crime here and abroad (esp. Italy)

Urban Waste Composition

TABLE 17.1 Generalized Composition of Urban Solid Waste (by Weight)

Material	Percentage
Paper	38
Yard waste	18
Plastics	8
Metals	8
Food waste	7
Glass	7
Other	14

U.S. Environmental Protection Agency. 1998. Office of Solid Waste.
Accessed 10/9/98 at www.epa.gov

Figure 10: Composition of urban solid waste 1998 [Tbl. 17.2, Keller, 2008]. The two largest categories, paper and yard waste can be readily reduced through recycling and composting.

Disposal of Solid Waste

- *On-site disposal*: transformation of waste, e.g. mechanical grinding or garbage disposal
- *composting*: transformation (decomposition) of organic waste, generating a useful fertilizer. Separation of organics from the general waste stream can be difficult.
- *Incineration*: burning of waste, either solid or liquid
 - useful as an alternative heat source, air pollution a negative
 - reduces waste volume by same amount as reduction/recycling
 - only feasible method for difficult wastes (e.g. chemical weapons)

- *Open Dumps*: uncontrolled surface disposal. Was the standard method until the mid-1970's. Leakage from such dumps is a major source of contaminants [Fig. 17.3, Keller, 2008]
- *Sanitary Landfill*:
 - carefully designed to minimize downward leakage of *leachate* and upward leakage of *methane* gas [Fig. 19.9, Keller, 2011]
 - Case studies:
 - * British house explosions adjacent to landfill
 - * Belmont Shores Mobile Estates, Los Angeles. Explosion of mobile home with one death. Active monitoring today.
 - site selection:

- * arid regions are best, dry lakebeds often good locations
- * humid regions: leachate is inevitable, so low-perm host sediments are best site
- Design
 - * generally a plastic liner is first, containing a leachate removal system above
 - * above that is compacted clay liner
 - * when landfill is closed, a clay cap is added to minimize infiltration from above
 - * after closure monitoring wells, leachate and methane removal systems are operated for at least 30 years afterward
- leachate and methane recovery systems (Fig. 11) are now standard on most landfills
 - * Texas has 24 active landfill gas projects

- * closest is the McCommas Bluff landfill in Dallas
- * see also Lewisville landfill, producing enough methane to power 5,000 homes/yr

Methane-Leachate Recovery

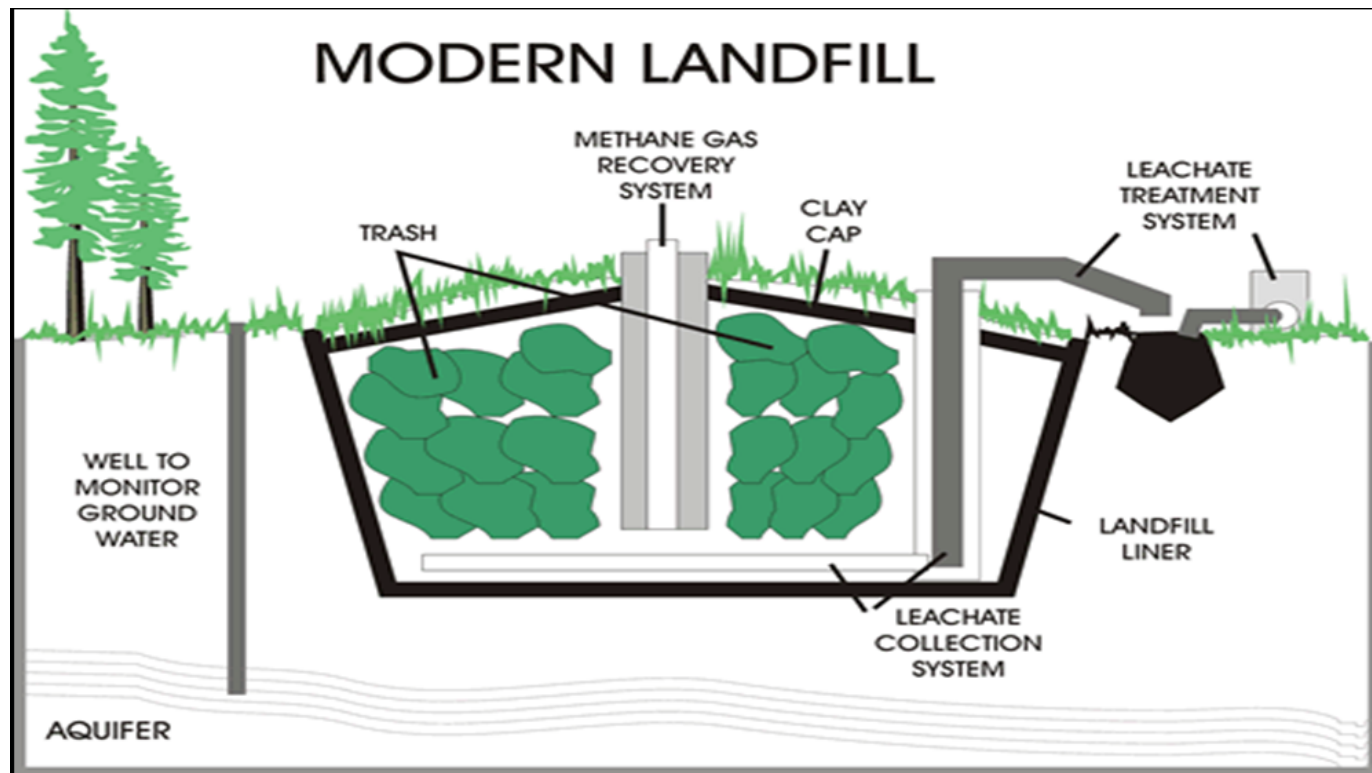


Figure 11: Landfill methane recovery design, as encouraged by EPA. After Utah State University .

Hazardous Waste Law

- *hazardous waste* is generally in liquid form, and is heavily regulated in the U.S.
- *RCRA*: Resource Conservation and Recovery Act (1976), “cradle to grave” management of hazardous chemicals to avoid future contamination
 - established controls on the manufacture, distribution and disposal of hazardous waste
 - chemicals are maintained in a chain of custody for most highly toxic, corrosive or explosive/unstable substances
- *CERCLA*, Comprehensive Environmental Response Compensation and Liability Act (1980):

- provided funds for cleanup of earlier contaminated sites
- main program is *Superfund* (now depleted)
- *SARA*, Superfund Amendment and Reauthorization Act: limits liability for pre-existing contaminant plumes provided an *environmental audit* is performed prior to commercial real-estate transfer

Hazardous Waste Disposal

A large variety of land-disposal methods are available, none of them perfect Keller [Fig. 17.13, 2008]

- *Secure Landfill*: landfill designed to fully contain or treat high-volume leachate settings [Fig. 19.13, Keller, 2011]
- *Surface Impoundment*: a surface pond. Most common method prior to 1970's, usually leak heavily and evaporate hazardous chemicals
- *Deep-well disposal*: injection deep underground. Good for otherwise-unmanageable wastes (e.g. chemical weapons). Oilfield brines are most common material disposed-of. Also prone to earthquake hazard [Fig. 19.14, Keller, 2011]. Can

be prone to leakage, and must be monitored, [Fig. 12.11, Keller, 2000] .

- *Incineration*: combustion at extremely high temperatures, converts waste to carbon dioxide and water. Only option for some “nasty “ chemicals [Fig. 17.12, Keller, 2008] .

Other Resources

Useful Links

This is intended to be an ever-evolving list of useful links on the general topic of this note set.

- ozone forecast now available for Texas (most states have similar sites)
- animation of global CO₂ “pollution” transport. Forest and grassland fires in Africa & South America, industrial pollution in Southeast Asia.
- animation of global ozone showing seasonal variation by hemisphere, and hole in Antarctica
- regional high ozone in central Texas contributes to lack of compliance

- ozone breaks down flower scent, possibly explaining decline of bees in some areas
- atmospheric chemistry of photochemical smog
- ozone formation animation
- natural H_2S emissions from anaerobic bacteria after “Dead Zone” phenomena. Same thing eventually led to Permo-Triassic mass extinction
- more whale sunburns , related to ozone hole?
- Waste to energy in Europe, using trash as fuel
- variable success rates in recycling across U.S.

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