Why do we have to care about air pollution?

* Air is an important medium for all organisms that are breathing the air.
* Air that is breathed is about 27 kg/day which is higher than the 1 kg/day of food and 1.5 kg/day of water. One Breath = 1 L / 15 times a minute / density 1.29 kg/m3. We consume too much air than food or water. The exposure daily intake in air is high as compared to the exposure in water and food in case the pollutant has the same partition coefficient in both 3 compartment
* Exposure via food and water is protected in stomach, the stomach has some protective mechanisms but the lung is not protected, the contact of the lung and the blood is very easy as you compared to the situation of stomach and blood.
* The pollutants in air can go easily in the blood because of the large surface area: human total alveoli = 70-100m2 , Short diffusion distance: Alveolus + Capillary(only 2-cells) and maintained concentration gradient: Constant blood flow in capillaries and breathing
* People didn’t care about the particles because they were thinking that the alveoli epithelium act as the barrier against particles and that the big particles remains in the nose while the small particles follow the air and cannot enter the blood but the reality is that particles find a way through the membrane and goes into the blood.

How does exposure concerns started

* It started with people looking how they can make environment more safe, it started on Physical and mechanical hazards: ergonometric at work and after this the Biological and chemical hazards becomes a concern as people were using industries and coal for energy and the occupational were more dangerous, and nowadays the Psychosocial hazards is also a concerns.
* Benzene was not dangerous and now it is dangerous because it is carcinogenic but toluene is not carcinogenic. This is because the enzyme oxidizes the toluene into a water soluble benzoic acid while the benzene is oxidized to carcinogenic products with to oxygen that has replaced the hydrogen on the benzene ring and the product can react with DNA.

What are the possible exposures of pollutants in air?

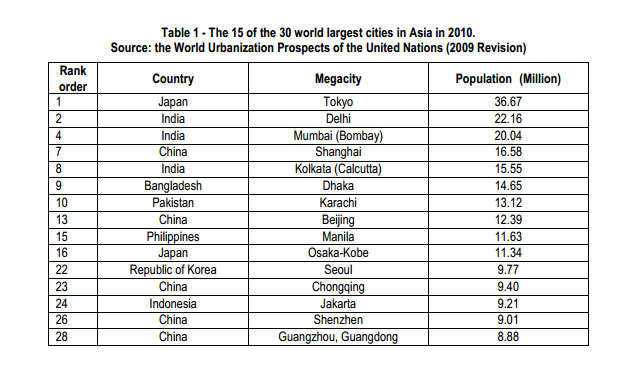
* Ambient air in rural or urban area, this is contaminated by industrial emission, energy production in heating
* Indoor air: working places and home, people spend more time in indoor air than the ambient air.

Megacities in Africa

* Megacities are generally defined as cities with at least 10 million inhabitants. In Africa, Johannesburg in South Africa, Cairo in Northern Africa and Lagos (Nigeria) are such megacities.
* In these cities, population is exposed to high pollution levels. Nevertheless, in Lagos, Nigeria, Abidjan, Accra and other capitals, there is an explosive growth of population, partly due to high levels of rural migration towards coastal cities.
* Consequently, by 2020 population is expected to increase extremely. This population pressure greatly increases pollution levels from traffic, burning of household wastes and charcoal and wood as domestic energy sources.
* In addition, refineries and other industries, thermal and cement plants, power plants, roads and building construction are strong sources of pollutants, which also significantly impact air quality in African urban areas.

Megacities in Asia

* With more than 50% of the world population, Asia is the most intensely populated continent on the earth.
* 10 of the 21 world megacities and 15 of the world’s 30 largest cities are in Asia.



* The bottom-up and top-down methods for estimating population in Asia may have large differences. One of the major reasons for this large difference is that urbanization in Asia is occurring at a fast speed due to the dynamic social and economical development.
* Projections based on the census data years ago might not be able to reflect the real situation in many cities in Asia.
* The continent of Asia is characterized by high diversity and inhomogeneity in geography, this leads to large spatial variation in the population density in Asia.
* Besides the large cities with high population density, Asia also has large regions with high population density such as Bangladesh, Indo-Gange plain, and North China plain. Bangladesh is one of the most densely populated regions in the world.

Megacities in South America

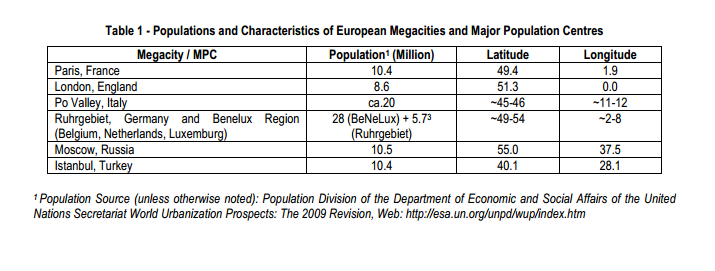
* population growth and urbanization result in a convergence of a variety of air pollutant emission drivers such at industry, transportation, and energy production and consumption amongst others is extreme in South America and about 84% of the population today lives in mid- to large size cities
* The emptiness of the South American continent is also striking as cities, and population densities, are mainly located close to coastal areas or a few hundreds of kilometers in land.

Megacities in North America

* North American megacities include Mexico City, perhaps the second largest metropolitan area in the world, and Los Angeles and New York City in the United States, two of the ten largest metropolitan areas.
* Apart from the megacities of Los Angeles, New York, and Mexico City, there are several other high-density urban areas such as Houston, Texas.
* Summertime photochemical smog was first recognized as a severe environmental problem in Los Angeles, and has been the subject of extensive studies there since the 1940’s
* Differences in topography, meteorological conditions and anthropogenic emissions lead to marked differences in the air quality considerations in these North American megacities as well as their impacts on the larger troposphere.

Megacities in Europe

* The megacities and major population centres (MPCs) of Europe are London, Paris, Moscow, the Benelux/Rhine-Ruhr region, the Po Valley, and the Eastern Mediterranean including Istanbul.



* In contrast to MPCs in several other parts of the world, e.g., Asia and Africa, the populations of the European MPCs, with the exception of Istanbul, have been relatively stable over the past several decades, and are predicted to remain so for at least the next couple decades.
* the six European MPCs listed in Table above is characterized by a large central region with a population density exceeding 1000 persons/km2.
* There are also a handful of other cities within Europe with population densities as high as this, e.g., Berlin and Madrid, but the total populations of these cities are not large enough to generally be classified as Megacities or MPCs for the sake of this overview.
* Beyond the commonality of a dense core region, however, there are substantial differences in the geographical locations and urban and suburban structure of the European MPCs. One interesting feature is that while a large fraction of the MPCs worldwide are either coastal or close to large bodies of water, only one of the European MPCs, Istanbul, is really a coastal city.
* London is also relatively close to the coast, while Paris, the Po Valley and the Benelux/Rhine-Ruhr region are all several hundred km away from the nearest coast, and Moscow is the most land-locked of all megacities worldwide.

Discuss the global atmospheric report on megacity and the air pollution?

* The increase in the world population is paralleled by an increase in the percentage of the world’s citizens living in urban areas.
* A **megacity** is usually defined as a metropolitan area with a total population in excess of ten million people
* In the context of atmospheric chemistry, one of the most important characteristics of a “megacity” is an area of highly concentrated anthropogenic emissions.
* the proportion of the population living in urban areas is expected to be over 50% in all major geographical areas of the world by 2030
* Urban population fractions are higher in developed than developing countries, with the exception of South America where the urban population can reach as high as 83% of the population.
* most of the world population growth expected to occur in developing countries, urbanization is increasing at a higher rate in developing countries
* These dramatic increases in population and urbanization, especially in the developing world, have been accompanied by technological and economic growth and development, yielding changes in land use, energy use, and transportation. The resulting changes due to urbanization have dramatic impacts on anthropogenic and biogenic emissions and have notably altered local to global-scale atmospheric composition.
* Emissions associated with the economic activity required to feed, house, clothe and otherwise provide for the needs of the 9.1 billion people expected in 2050 will inevitably impact the atmosphere.
* When addressing the fraction of emissions that originate from megacities, it is important to consider how the magnitude and the impact of these emissions would be different if the population and associated economic activity of the megacities were dispersed in a less concentrated population distribution
* The geographic scale and intensity of megacities’ impact on air pollution and climate is determined not only by the extent of their emissions but also by their regional geography and meteorology.
* These factors affect the degree to which the emissions are trapped, such as by valley or basin walls or by persistent atmospheric inversions, and the degree to which the emissions are transported to the regional to global scale, such as via uplift in deep convective systems.
* These factors also combine to determine how megacity emissions interact with emissions from surrounding areas.
* Notably, most of the world’s megacities are situated in coastal zones. In these areas, the mixture of urban and marine air masses result in a unique set of chemistry. For instance, meso-scale circulations export sulphur and nitrogen compounds out to sea, which can trigger emissions of halogens that are subsequently transported back into urban areas by the sea breeze giving rise to ozone production
* Continental emissions, e.g., biomass burning, can also interact with urban emissions, altering how the urban emissions affect air quality and climate.
* Clearly, each urban area’s unique set of characteristics must be considered in the study of the impacts of urbanization on atmospheric chemistry.

Explain the atmospheric chemistry of air pollution

* People started to worry about the negative impacts of air pollution in urban areas when coal began to replace wood as a heating source.
* People died in the London Killer Smog Episode of 1952 when a dense fog containing sulphuric acid particles persisted for days.
* The same year in Los Angeles a researcher wrote a paper showing that this city was polluted by the release of large quantities of hydrocarbons and nitrogen oxides to the atmosphere that through a complex series of photochemical reactions create ozone and other harmful secondary pollutants
* These historical events motivated the scientific and policy communities to begin unraveling the atmospheric chemistry involved in air pollution and implementing regulations to improve air quality.
* Today, air pollution typically refers to a set of criteria pollutants typically referred to as lead (Pb), carbon monoxide (CO), sulphur dioxide (SO2), nitrogen dioxide (NO2), ozone (O3), and particulate matter (PM). These criteria pollutants were designated as such due to their impacts on human health and later to their impacts on ecosystems. The 4 pollutants (SO2, NO2, O3, and PM) all have an impact on air pollution and climate and are key active species in atmospheric chemistry.

Describe the environmental impact of SO2, NO2, O3, and PM.

Acid rain formation

* Both SO2 and NO2 were named criteria pollutants for their role in the formation of acid rain, a general term for wet and dry deposition of sulphuric and nitric acids (H2SO4 and HNO3, respectively) and for their direct and indirect human health impacts
* Acidic deposition lowers the pH of lakes, rivers, and stream causing harm to entire watersheds and ecosystems and also erosion of building and automotive parts.
* Sulphur dioxide is converted to sulphuric acid via aqueous phase

SO2(g) SO2.H2O

SO2.H2O HSO3- + H+

HSO3- + H2O2(aq) SO2OOH- + H2O

SO2OOH- +H+ H2SO4

* Sulphur dioxide is also converted to sulphuric acid via gas phase oxidation

SO2+OH+M HSO3+M

HSO3+O2 SO3+HO2

SO3+H2O+M H2SO4

* The aqueous phase pathway is believed to be responsible for more than 50% of the ambient sulphate concentration.
* The lifetime of SO2 in the aqueous phase pathway is very short whereas the lifetime of SO2 in the gas-phase oxidation pathway is on the order of 1-2 weeks, which explains why high concentrations of sulphate can be found both near and far downwind from SO2 sources.
* Nitrogen oxides are converted to nitric acid primarily by gas-phase oxidation during the daytime

OH+NO2+M HNO3+M

* Nitrogen oxides are converted to nitric acid by a nitrate radical (NO3) heterogeneous pathway during nighttime when NO3 cannot be photolyzed

NO2+O3 NO3+O2

NO3+NO2 N2O5

N2O5+H2O(aq) 2HNO3(aq)

* Although the gas-phase oxidation rate of NOX to nitric acid is approximately 10 times faster than the gas-phase oxidation rate of SO2 to sulphuric acid, high concentrations of nitric acid in the aqueous form are not generally found in most source regions. This is because sulphuric acid formed in the gas-phase immediately associates with water molecules to form sulphuric acid aerosol, which excludes nitric acid.
* Nitric acid will remain in the gas phase until deposited to surfaces or absorbed by a cloud or rain droplet with lower concentrations of sulphuric acid, which can occur downwind from the emission sources.
* It is also important to note that both sulphuric and nitric acid formation is dependent on OH formation or in more general terms, the oxidation capacity of the atmosphere.
* In industrialized regions, anthropogenic sources, i.e. energy production, industry and transportation, typically dominate emissions of SO2 and NO2 and their precursors. The use of mazut to heat the central heating which contains sulfur and the use of the fuel containing sulfur in industries. Blanco contains a lot of sulfur. NO2 is releasing from burning installation and during transport.
* It is difficult to predict the emission if you know the emission of NO2 from the fuel because the N2 is the dominating gas, most of NOx that is produced is from N2+O2

Tropospheric ozone

* Ozone near the surface in the troposphere is harmful to human health and ecosystems due to its ability to oxidize biological tissue.
* A common human health impact of tropospheric ozone is respiratory illnesses such as asthma in children.
* Tropospheric ozone is formed when volatile organic compounds (VOC) are oxidized in the atmosphere in the presence of nitrogen oxides (NO+ NO2 = NOX) and sunlight.
* In addition to chemical formation, ozone is transported from the stratosphere to the troposphere through stratospheric/tropospheric exchange.
* The major emission source of NOX in urban areas is fossil fuel combustion, typically utilized for transportation, electrical power generation and industrial processes.
* However, the major urban emission sources of VOCs are both anthropogenic and natural. Anthropogenic VOC emission sources are combustion, fuel evaporation, solvent use, and chemical manufacturing.
* The primary natural VOC source is emissions from terrestrial vegetation, such as from forests .Therefore, the natural emissions of VOCs have an impact on the effectiveness of either NOX or VOC controls to reduce O3 concentrations.
* Tropospheric ozone production occurs when the hydroxyl radical oxidizes VOCs, carbon monoxide (CO), and methane (CH4) in the presence of nitrogen oxides (NOX)
* precursors from large urban areas can be transported on hemispheric scales in the free troposphere and increase background levels of surface ozone such that the hemispheric transport may offset local mitigation strategies to reduce ozone levels
* Due to the large number of different VOC species, their complex oxidation pathways and their numerous emission sources, the formation of tropospheric O3 is extremely complex.
* Below is the simplest pathway, the formation of O3 during the oxidation of CO:
* Ozone photolysis produce oxygen radical:

O3 + h.v → O2 + O(1D) ,

* The oxygen radical produced from ozone photolysis can react with water and 2 times OH radicals are formed, can also react with VOCs and OH radicals are produced.
* The hydroxyl radical formed react with CO to produce CO2 and H radical.

OH+CO CO2+H

* The hydrogen radical is surrounded by oxygen and react with oxygen to give HO2 radical

H+O2+M HO2+M

* If NOx is present, the HO2 radical react with the NOx to produce OH and the OH radical is recycled

HO2+NO OH+NO2

* If the NOx is present there is rate accelerating. The reaction CO+OH to give CO2 is catalyzed and goes much faster because the OH radical is recycled back. If the OH is recycled means the H, HO2 are also recycled
* The NO2 photolysis produce NO and oxygen , this oxygen radical react with oxygen to give ozone:

NO2+ hv NO+O

O+O2+M O3+M

* The overall reaction :

OH+CO CO2+H

H+O2+M HO2+M

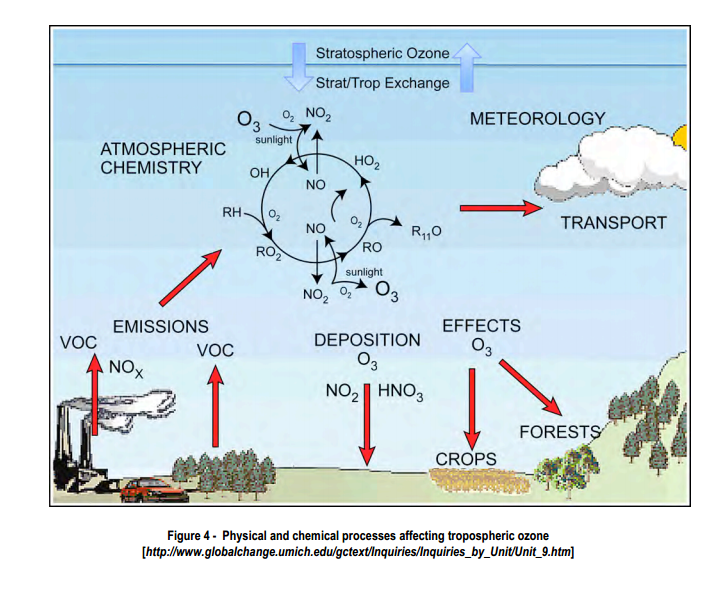
HO2+NO OH+NO2

NO2+ hv NO+O

O+O2+M O3+M

CO+2O2 CO2+O3

* Below the diagram shows when VOCs are present :



* When VOCs are present, the hydroxyl radical can react with RH from VOCs to give R radical and water
* The R radical react with oxygen to give RO2 radical
* When NO is present, RO is formed from the reaction of RO2 and NO which gives NO2 and RO
* The new radical RO react with oxygen to give HO2 radical and the R11O
* The HO2 radical is recycled and HO2 with NO produce OH and NO2, the OH is also recycled

Particulate matter

* An aerosol is technically defined as a suspension of particulate matter (fine solid or liquid particles) in gas.
* Aerosols and PM have a variety of impacts including causing respiratory illnesses, decreasing visibility, and impacting climate through both direct (the particles themselves absorbing or scattering radiation) and indirect (the particles serving as a cloud condensation nuclei) effects.
* Different terminology used for particulate matter:
* **Aerosols, aerocolloids, aerodisperse system**: Tiny particles dispersed in gases
* **Dust:** Suspension of solid particles produced by mechanical disintegration of material such as crunching, grinding, and blasting.
* **Fog**: a loose term applied to visible aerosols in which the dispersed phase is liquid. Usually a dispersion of water or ice close to the ground.
* **Fume**: The solid particles generated by condensation from the vapor state, generally after volatilization from melted substances, and often accompanied by a chemical reaction such as oxidation.
* **Haze:** an aerosol that impedes vision and may consist of a combination of water droplets, pollutants and dust.
* **Mist:** Liquid, usually water in the form of particles suspended in the atmosphere at or near the surface of the Earth; small water droplets floating or falling, approaching the form of rain, and sometimes distinguished from fog as being more transparent or as having particles perceptibility moving downward.
* **Particle:** An aerosol particle may consist of a single continuous unit of solid or liquid containing many molecules held together by intermolecular forces. A particle may also be considered to consist of two or more such unit structures held together by inter-particle adhesive forces such that it behaves as a single unit in suspension or upon deposit.
* **Smog**: a term derived from smoke and fog, applied to extensive contamination by aerosols. Now sometimes used loosely for any contamination of the air.
* **Smoke:** Small gas-borne particles resulting from incomplete combustion, consisting predominately of carbon and other combustible material, and present in sufficient quantity to be observable independently of the presence of other solids.
* **Soot:** Agglomerations of particles of carbon impregnated with tar, formed in the incomplete combustion of carbonaceous material.

The main sources of atmospheric aerosols.

* Particles may be directly emitted from a source (primary aerosol) or formed in the atmosphere through a gas-to particle conversion process (secondary aerosol).
* Aerosols have both natural and anthropogenic sources. Natural sources include dust, sea spray, forest fires, volcanoes and vegetation.
* Anthropogenic sources include transportation, industry, fires, mechanical sources, and human induced changes in vegetation.
* Particles change their size and composition in the time between emission and their removal from the atmosphere by dry or wet deposition.
* The size of aerosol determine how much is inhaled and where they are deposited
* The composition of aerosols varies greatly across urban areas due to different emission sources and meteorological conditions. The composition of aerosol and meteorological conditions can be used to trace the origin of particles
* Organic aerosols (OA) are of particular importance since they make up between 20 to 90% of the submicron particle mass.
* Organic aerosols exist in the atmosphere as both primary and secondary aerosol.
* Primary organic aerosol (POA) is directly emitted from emission sources such as fossil fuel combustion and biomass burning.
* Secondary organic aerosols (SOA) result from the oxidation of gas-phase species. It is believed that SOA accounts for a large portion of total OA and hence aerosol in general.

Formation mechanism of aerosol

Coarse mode: Mechanically generated aerosol and a**re from:** wind brown dust**,** mechanical generated particles from crashing of stones**,** sea spray particles formed after evaporation of water **and** particles emitted by volcanoes. Coarse particles have higher mass and are settling down easily from atmosphere and are removed by sedimentation.Because particles have high speed, bind to each other, stick to each other and become bigger and can be removed easily. The residence time is very small. Coarse mode forms the PM10 and fine particles(less than 2.5 μm)

Accumulation mode has 2 modes: droplet mode and condensation mode**,** Droplet mode: chemical conversion to low volatility vapor, low volatility vapor takes water to form droplet and coagulation reactions take place in the droplet. Particles are removed by rainout and washout. Condensation mode: hot vapor is condensed and primary particles are formed, coagulated and form chain aggregates. Particles are removed by rainout and washout. Accumulation mode forms the ultrafine particles (less than 100nm).

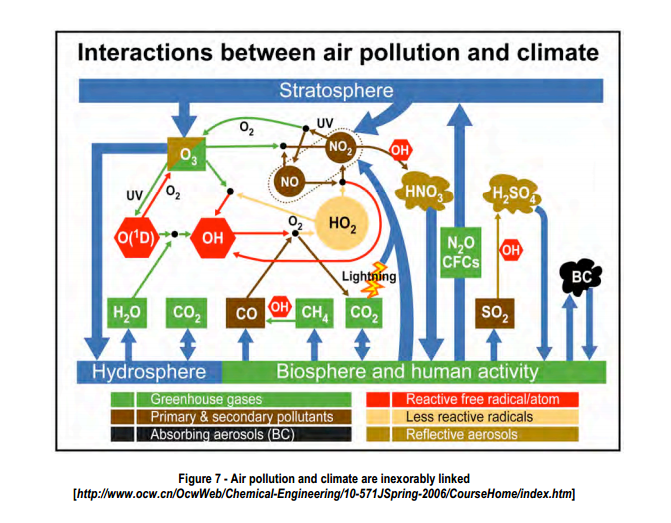
Transient nuclei mode has 2 modes: condensation mode and homogeneous nucleation mode, Condensation mode: hot vapor is condensed and primary particles are formed, coagulated and form chain aggregates. Particles are removed by rainout and washout. Homogeneous nucleation mode: chemical conversion to low volatility vapor, homogeneous nucleation takes place in low volatility vapor and then coagulation reactions take place. The transient nuclei mode forms nanoparticles(less than 50nm)

Sinks mechanism of atmospheric aerosol

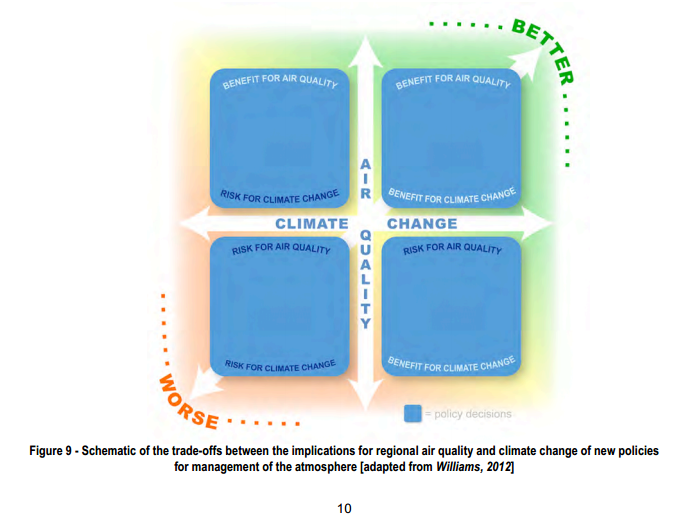
* **Dry deposition** by direct contact with leaves or building materials. linked to gravitation, mass of particle is important, particle diameter is important, the small particle diameter means the small velocity and the big particle means the high velocity
* **Wet deposition** by wash out with rain, fog or snow. Wet deposition consists ofdissolving and scavenging: the molecules are dissolved in the water droplet and fall at the same speed with the water droplet.
* In cloud scavenging by: nucleation, Brownian diffusion and phoresis
* Precipitation scavenging : impaction , Brownian diffusion and phoresis

Climate change

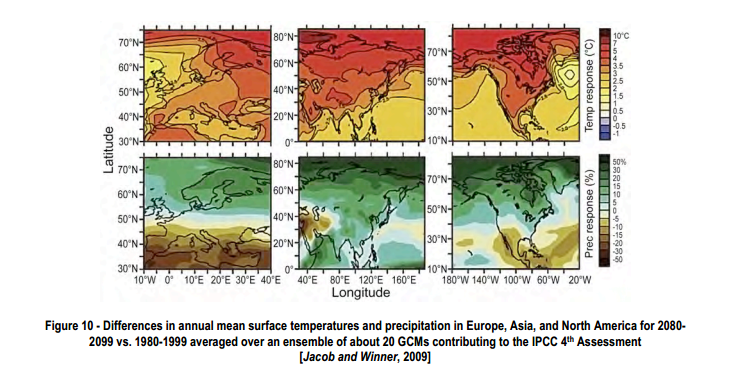
* Air pollution and climate change have largely been kept separate in both the scientific and policy communities.
* This was primarily due to the temporal and spatial differences between air pollution and climate with air pollutants being short-lived reactive species that have impacts on the local and regional scale and climate forcing agents being longer-lived radiatively active species that have impacts on the global scale.
* However, more recently and into the future, it is clear that air pollution and climate change are inexorably linked.



* The air pollutants include:
* Green houses gases: CH4; CO2; N2O; CFCs (e.g.freon) and water vapor.
* Primary and secondary pollutants: CO; NO; NO2 and SO2 these pollutants are both primary and secondary. Primary pollutants chemicals are pollutants that are released directly into the air in a harmful form while the secondary pollutants are chemicals released into air that become hazardous after reacting with substances in the air.
* absorbing aerosols: black carbon and the reflecting aerosols: H2SO4; HNO3 and O3
* Reactive free radical atoms like OH and O (1D) and the less reactive radicals HO2.
* Air pollutants that typically were researched and regulated for their air quality impacts are now being recognized as important drivers of climate change:
* Green houses gases (CH4, CO2, N2O, CFCs and troposphere ozone) contribute to global warming. The 2 most important pollutants contributing to the climate change is CH4 and CO2. Water vapor is not considered as a pollutant because it is natural. These chemicals listed above absorb the IR and contribute to the global warming.
* Absorbing aerosols: black carbon contributes to the increasing temperature and the reflective aerosols have cooling effects.
* In addition, the scientific community has begun to provide information on the regional impacts of climate change and how these changes may impact air pollution.
* It is clear that air pollution and climate change are issues that now have overlapping temporal and spatial scales and should be addressed in an integrated manner.
* Species that typically were considered solely air pollutants in the past include troposphere ozone and now is a green house gas and contribute to increase in temperature and black carbon which is an absorbing aerosols and contribute to the increase in temperature.
* Mitigation of aerosols from an air quality standpoint is clearly a win strategy for human health and wellbeing. However, from a climate standpoint, mitigating aerosols would eliminate a cooling effect from the reflecting aerosols , thus increasing the overall net global radiative forcing, a net loss for climate
* The decision makers has to put measure that protect the air quality and the climate at the same time



* In addition to air pollution having an impact on radiative forcing, climate change has an impact on air pollution meteorology and chemical process.
* Changes in surface temperature and precipitation due to radiative forcing caused by both long and short-lived climate forcers will impact regional air pollution.
* A strong warming occurs over the northern mid-latitude continents



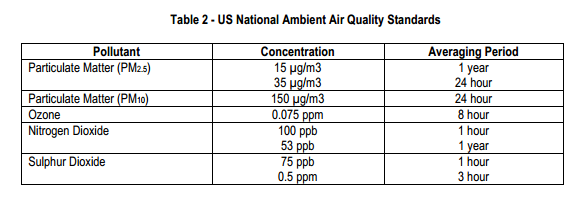
* The increase in temperature leads to an increased frequency of heat waves, which are strongly associated with high pollution episodes, e.g., the 2003 heat wave in Europe.
* Precipitation is expected to increase due to increased evaporation from the oceans. However, the frequency and intensity of the increased precipitation varies considerably at a regional scale.
* Less frequent but heavier precipitation events could lead to more pollution episodes by reducing wet deposition of aerosol and other pollutants.
* Models also indicate a warming climate could impact large-scale atmospheric dynamic patterns. A significant long term decline in the number of summertime mid-latitude cyclones across the northeastern United States will be observed which in turn strongly correlates with the number of high ozone episodes due to decreased pollutant ventilation.
* It is now widely recognized that air pollution and climate change can no longer be considered as separate issues in the scientific and policy communities

Health impact of air pollution

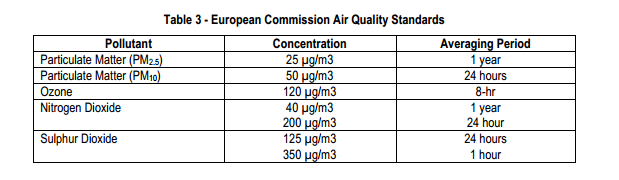
* There is great evidence linking air pollution with mortality and morbidity in the general population
* Public health damage is consistently found with adverse effects concentrated in urban areas both in developed and developing countries.
* The range of adverse health effects is broad, affecting both the respiratory and the cardiovascular system.
* Children, women, and older adults are the most susceptible to these adverse health effects in the general population
* The risk increases with intensity of exposure. Little information supports the presence of a threshold level for these effects.
* In fact, effects were found at very low levels of particulate matter.
* The adverse health effects of air pollution are observed both in short-term exposures and for long-term exposures.
* These problems are exacerbated by indoor air pollution typically caused by the burning of solid fuels.
* Low-income population in general, and women and young children in particular are subject to a higher exposure since they spend the most time near the domestic hearth
* One of the main sources of pollution and health damage is traffic*.*
* The World Health Organization conducted a study of the burden of disease caused by environmental problems attributed to air pollution effects on respiratory diseases, perinatal conditions and birth defects, cancer, cardiovascular diseases, bronchial obstructive disease, and asthma. The study estimated that in developing countries 42% of all respiratory diseases are attributable to air pollution
* Exposure to complex mixtures of air pollutants, mainly particulate matter and ozone, causes structural lung changes that are induced by sustained inflammation, leading to vascular reconstruction of the lung airways and impairing the repair process.
* Children are particularly vulnerable to respiratory problems because of their physical characteristics and behavior.
* In children under 5 years of age it has been estimated globally that acute lower respiratory infections (pneumonia, bronchiolitis and bronchitis) are responsible for about 20% of the 10.6 million deaths annually worldwide. About 90% of these deaths are due to pneumonia.
* Over the last decade research shows an increased risk of cardiovascular disease due to both particulate matter and ozone exposure
* Many cardiovascular indexes show cardiovascular injury induced by increased levels of ambient particles (changes in the heart rate, or heart rate variability, blood pressure, vascular tone, and blood coagulability).
* In addition, chronic exposure to increased concentrations of particulate air pollutants accelerates the progression of atherosclerosis
* The evidence suggests that stroke mortality and hospital admissions are higher in areas with elevated levels of outdoor air pollution because of the combined acute and chronic effects of air pollution on stroke risk.

Air quality regulation

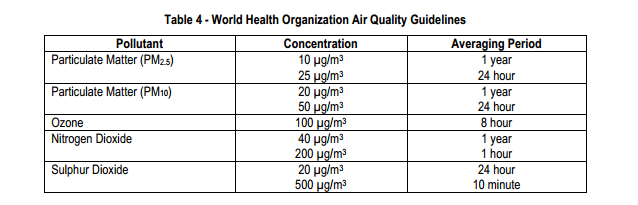
* The impacts of air pollution on human health are the main driver toward implementing air quality regulations.
* Vector-borne diseases, impacts on maternal and newborn health, nutrition of general public and heat related stress are among the health problems that have been linked with climate change
* Following the major pollution episodes in Los Angeles USA and London UK in the 1950s, governments began to implement legislation to first fund research on air pollution and then to control air pollution.
* This effort culminated in the US with enaction of the 1970 Clean Air Act, which authorized the development of comprehensive federal and state regulations to limit emissions from both stationary and mobile sources and initiated the National Ambient Air Quality Standards (NAAQS) amongst other regulatory programmes.
* The Clean Air Act was amended in 1977 and again in 1990, with the latter implementing the Acid Rain programmes and significantly increasing the authority and responsibility of the federal government to protect human health and the environment from the impacts of air pollution



* In Europe, air quality management began with the signing of the United Nations Economic Commission for Europe (UNECE) in 1979 Geneva Convention on Long-Range Transboundary Air Pollution (LRTAP), which has been extended by eight protocols, the 1999 Gothenburg Protocol being the last one.
* LRTAP aims to limit and gradually reduce and prevent air pollution by developing policies and strategies across its 51 parties.
* In parallel to LRTAP, in 2001 the European Commission established National Emissions Ceilings (NEC), which set national emissions limits for four pollutants that are responsible for acidification, eutrophication, and ground-level ozone pollution.
* The NECs are largely based on the Gothenburg Protocol.
* In 2005, the European Commission also launched the Thematic Strategy on Air Pollution (TSAP), the first of its seven Thematic Strategies in the European Union’s Sixth Environment Action Programme (EAP).
* TSAP established interim objectives for air pollution in the EU and proposes appropriate measures for achieving them, e.g. setting air quality standards and rules for monitoring.
* Air quality management in the European Union is thus interplay between the Air Quality Directives defined under TSAP, the NEC directives, and LRTAP.



* In 1987, the World Health Organization (WHO) published *Air Quality Guidelines for Europe*. The aim of the guidelines was to provide a basis for protecting public health from adverse effects of air pollutants, to eliminate or reduce exposure to those pollutants, and to guide national and local authorities in risk management decisions.
* In 2005, following important new research from low- and middle-income countries, the WHO released new *Air Quality Guidelines* for four common pollutants (PM, O3, NO2, and SO2) that are intended to inform policy-makers from different parts of the world on appropriate targets for policy related to air quality management.



* It must be pointed out that air quality improvements throughout the world do not merely follow from the dictation of air quality standards similar to those designed by US EPA, the European Commission, or the WHO. Each country’s national air quality standards should and will likely vary according to the approach adopted for balancing health risks, technological feasibility, economic considerations, and various other political and social factors.
* Determining national air quality standards and enforcing them depends greatly on the level of development and national capability in air quality management.

Scientific tools to study air pollution in megacities

* Ground-based, ship, and aircraft observations
* Satellite observations
* Emission inventories
* Modeling

Ground based, ship and aircraft observations

* Ground-based observation networks are crucial for studying atmospheric chemistry in megacities.
* Continuous ground-based meteorological networks are essential in order to characterize meteorological processes that control air pollution transport and stagnation events.
* Ground-based observation networks of atmospheric pollutants can detect exceedances of air quality standards, identify trends, detect or quantify emission sources, and determine the effects of air pollution control measures.
* Several examples of long-term ground based observation databases of different spatial coverage are:
* The AIRBASE database through EIONET,
* The EBAS database hosted by NILU Norway
* The AirParif database for Paris.
* many regulatory agencies in developed and developing countries have air pollution monitoring networks that provide hourly concentrations of important air pollutants such as O3, SO2, NOX, PM10
* The number of air pollution monitors within a city and the air pollutants measured vary greatly. A more globally consistent air pollution monitoring network would provide a robust dataset to study atmospheric chemistry in megacities and the environmental and human health impacts of air pollutants.
* More recently, surface super-sites have been incorporated into megacity field campaigns to complement and extend observations from aircraft and satellites.
* Super-sites provide simultaneous measurements of a variety of chemical and meteorological parameters and tend to have more specific scientific purposes than long-term ground-based observation networks.
* For example, a series of super-sites may be used to study the chemical composition of air parcels or of particles as a function of time and location.
* Some examples of data from super-sites are the recent MEGAPOLI and MILAGRO campaigns that focused on Paris and Mexico City respectively.
* In addition to surface super-sites, field campaigns in megacities often include aircraft and ships that provide highly sophisticated platforms for studying atmospheric chemistry.
* Such platforms include in-situ and/or remote sensing instrumentation that provide observations of primary pollutants, secondary species, meteorological conditions, vertical profiles, and a wide range of other parameters.
* An airborne research platform provides a unique way to study the source region, vertical and horizontal dispersion, and chemical and physical transformation of atmospheric pollutants. Meanwhile, ship platforms provide the means to study meteorological and chemical processes at the surface ocean-atmosphere interface and in the marine boundary layer, which are regions difficult to measure using ground-based and aircraft observations.
* The type of platform and instrumentation used to study atmospheric chemistry is dependent on the unique characteristics of the megacity of interest.
* Ground based, aircraft, and ship observations often provide a very detailed local to regional view of air pollution.
* Therefore, there is a need to integrate observations from field campaigns and monitoring networks in order to bridge scales from a local to regional to global level. Such integration would enhance the global perspective of the impacts of air pollution from megacities while still maintaining the critical detailed local and regional information.

Satellite-based observations

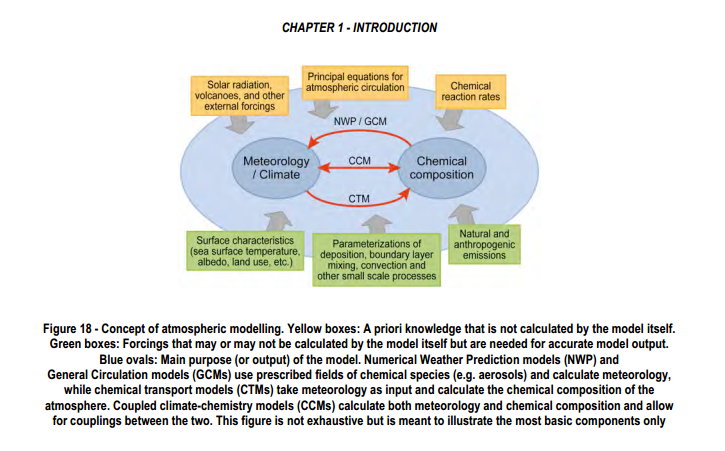
* Ground, ship, and aircraft observations provide a detailed snapshot of atmospheric composition. Satellite-based observations provide a complementary global, continuous perspective, overcoming some of the temporal and spatial limitations of surface and aircraft measurements.
* Historically, satellites were most readily used to determine stratospheric atmospheric composition, largely because the presence of clouds and the overhead stratosphere make tropospheric measurement challenging.
* However, in recent decades, new instruments targeting tropospheric composition have been developed and deployed on satellites, rapidly enhancing our ability to track global tropospheric composition.
* These observations can provide critical information for monitoring and forecasting of air quality, studying long-range transport of pollution, and monitoring emissions of air pollutants and climate forcers.
* The majority of tropospheric measurements from space have employed nadir (downward looking) geometry. Occultation measurements offer much better sensitivity to trace species in the atmosphere; however detection is limited to the upper troposphere, which is generally less informative for air quality applications
* Solar backscatter measurements observe reflected and backscattered solar radiation in the ultraviolet (UV), visible (VIS), and near infrared (NIR) spectral region and are typically sensitive down to the lowest layers of the atmosphere, except in the case of significant cloud cover.
* This near surface sensitivity and the narrow field of view obtained with nadir observations are important pre-requisites for obtaining information about air pollutants.
* A number of key atmospheric trace gases absorb in the UV-visible range: O3, NO2, HCHO, SO2, BrO, and Glyoxal (CHOCHO).
* A disadvantage of solar backscatter sounders such as , GOME and SCIAMACHY is that the measurements require solar light, i.e., they can only be performed on the Earth’s sunlit side. In contrast, TOMs use thermal emission and permit measurements during night as well as day.
* Thermal emission measurements use the thermal infrared (TIR) spectral region to measure tropospheric trace gases, including tropospheric O3, CO, CH4, H2O, HDO and volcanic SO2.
* Several experimental retrievals for species with weaker emission features, such as NH3 and CH3OH, have been recently demonstrated with the TES and IASI instruments
* Tropospheric aerosols are challenging to characterize due to the variety and variability of aerosol sources as well as the short residence time of aerosols in the atmosphere.
* The presence of clouds is an additional challenge for passive remote sensing observations of aerosols. Active sensors, such as lidars, can profile aerosol and cloud extinction at high vertical resolution.
* In recent years, CALIOP observations have provided detailed observations of aerosol plumes, and overlaying vertical layers. The drawback of these observations for air quality applications is their limited coverage and long repeat times.
* All current satellites relevant for air pollution research are in polar low Earth orbit (LEO). This limits the number of passes over a given area to twice per day, but observations can be limited further by cloud cover and by the swath width of satellites dictating a longer time between repeat visits.
* For air quality monitoring, more frequent observations would be highly desirable. This can be achieved with several LEO satellites or, for the tropics and mid-latitudes, with a geostationary satellite such as the proposed GeoTROPE mission.

Emission inventories

* A critical step in improving our understanding of the impact of megacities on air quality, atmospheric composition, and climate is the development of high-quality emission inventories of relevant gases, aerosols, and their precursors.
* An emissions inventory is a current, comprehensive listing by source of air pollutant emissions associated with a specific geographical area for a specific time interval.
* Therefore, emissions inventories are developed for local, regional, and global applications as well as scientific and policy applications (chemical transport models, global climate models, trend analysis, regional and local scale air quality modeling, regulatory impact assessments, and human exposure modeling).
* Global emission inventories typically have resolutions of about half a degree or very recently one tenth of a degree (EDGAR V4).
* Regional inventories often have scales from 5 to 100 km whereas local inventories have resolutions of 1 to 10 km.
* Two fundamental tools for developing emission estimates of air pollutants are **emission factors** and **emission estimation models**.
* Emission factors relate the quantity of a pollutant released to the atmosphere as a function of activity level for a given source. E=A\*EF (1-ER/100) where E is the emissions; *A* is the activity rate; *EF* is the emissions factor, and *ER* is the overall emission reduction efficiency using capture or control techniques (given in %).
* Emission factor uncertainty is dependent on the kind of emissions released, the number of tests used to determine the emissions factor, using the appropriate percentile within the distribution range, and the number of similar emissions units within a specific area
* Determining emission factors for every source and every pollutant under a variety of operating conditions throughout the world is a daunting task. Therefore, most emission factors are developed from only a limited sampling of the emissions source population for any given category, i.e. source population average.
* The limited number of samples likely results in emission factors not statistically representative of the actual emissions of a source category
* Emission estimation models use empirically developed process equations to estimate emissions from a given source. In general, an emission estimation model is used rather than an emission factor when a large number of equations, interactions, and parameters impact the emissions estimate.
* In many cases, emission estimation models are used to develop inventories for mobile and non-road source categories since it is difficult to directly measure activity for numerous individual sources operating under a wide variety of conditions.
* Emission estimates derived using emission factors or emission estimation models are then developed into an emission inventory.
* There are two approaches to emission inventory development: down-scaled and bottom-up.
* The down-scaled approach develops emission inventories based on global, national, or regional data by down scaling the larger scale data using some measure of activity data or proxy (e.g. population density) related to the emissions in the area of study.
* The bottom-up approach estimates emissions for individual sources and then aggregates all sources in the area of study to derive regional, national, or global emission estimates.
* The down-scaled approach is typically used when local emissions are unknown, cost prohibitive to obtain, or not publically available.
* In addition, aircraft and satellite observations can be used to derive top-down emission estimates using a-priori information from a bottom-up emissions inventory.
* However, discrepancies often exist between emission inventories developed by downscaled versus bottom-up approaches
* Emission inventories are critical in order to understand atmospheric chemistry in general, but especially for megacities. It is clear that discrepancies exist between down-scaled versus bottom-up methodologies as well as between national and regional emission inventory development.
* In order to understand atmospheric chemistry in megacities, an integrated emissions approach that transcends methodologies and political boundaries is needed. Such an approach would allow for scale-bridging of emission inventories that would provide consistent local, regional, and global emissions inventories.

Modeling

* Along with laboratory studies and field measurements, modeling represents one of the main pillars of atmospheric chemistry research.
* Atmospheric models can be thought of as mathematical representations of the chemical and physical behavior of the atmosphere. Most commonly, models are used to simulate the state of the atmosphere on computers.
* For this purpose the atmosphere is divided into a large number of small compartments, so-called grid boxes, for each of which the chemical and physical parameters are calculated based on initial conditions, internal tendencies, and external forcing.
* For instance, the concentration of a chemical component after some short amount of time usually referred to as *time step*, can be calculated from its initial value and the rate of change during the time step.
* The rate of change will be a result of chemical reactions, emissions, transport through winds, wet removal by precipitation, and many other physico-chemical processes. The new calculated concentration will then serve as initial value for the calculation of the next time step, and so forth.
* In such calculations, atmospheric models have to rely on various kinds of input, for instance values for chemical reaction rates, the radiation from the sun, and spatially and temporally resolved emission data.
* By using all available input information as well as our basic understanding of the processes occurring in the atmosphere, a model calculates the chemical state for each of its grid boxes and for each time step, thus yielding the distribution and evolution of chemical components in space and time.
* An atmospheric model can be used in two fundamental ways, either as a *diagnostic* tool, or as a *prognostic* tool. In the diagnostic tool case the model aims to answer the question why things are the way they are. For example, what are the physical and chemical processes that contribute to observed air pollution?
* In contrast to the real atmosphere, processes can be switched on and off in a model in order to assess their importance.
* The impact of different types of emissions, e.g. anthropogenic vs. natural sources, can thus be investigated.
* Concentrations of species that cannot easily be measured can be calculated even for remote or inaccessible regions of the atmosphere, thus allowing gap-free distributions for all chemical components included in the model.
* As prognostic tools, models are used to calculate future distributions of chemical components. In this way, the future evolution of atmospheric composition responding to natural and anthropogenic influences can be predicted.
* Different emission scenarios can be simulated, and the effectiveness of different emission reduction scenarios can be assessed.
* However, in order to gain confidence in a model it is important to carefully evaluate it against measurements. Only when it is established that the model succeeds in simulating past and present states of the atmosphere with reasonable accuracy, can be used to predict future behavior.
* Below are the basic components of atmospheric models, summarizing the basic input and output components of atmospheric models.



* Yellow boxes: A prior knowledge that is not calculated by the model itself include: solar radiation, volcanoes, other external forcing, principle equation for atmospheric calculation and chemical reaction rate.
* Green boxes: Forcings that may or may not be calculated by the model itself but are needed for accurate model output include: Surface characteristics(sea surface temperature, albedo, land use) , parameterization of deposition, boundary layer mixing, convection and other scale small process, natural and anthropogenic emissions
* Blue ovals: Main purpose (or output) of the model: meteorology/climate and chemical composition
* Numerical Weather Prediction models (NWP) and General Circulation models (GCMs) use prescribed fields of chemical species (e.g. aerosols) and calculate meteorology, while chemical transport models (CTMs) take meteorology as input and calculate the chemical composition of the atmosphere. Coupled climate-chemistry models (CCMs) calculate both meteorology and chemical composition and allow for couplings between the two.
* There are various types of atmospheric models: Chemical transport models take meteorological parameters (temperature, wind, precipitation, etc.) as input and calculate the chemical composition of the atmosphere.
* Other models, e.g. numerical weather prediction models and climate models calculate meteorological parameters themselves and take chemical distributions (e.g. ozone and aerosols) as input.
* A more advanced group of models calculates both meteorology and chemistry in a coupled way, allowing for interactions between chemistry and climate, but are computationally expensive so that simplifications have to be made, or the *model resolution* has to be coarse.
* Resolution is one of the most fundamental features of a model. As a model usually calculates only one value per parameter for each grid box, assuming that the value is constant all over the grid box, many patterns that vary on finer spatial scales than the grid box dimension cannot be resolved.
* For example, some air pollutants have very short lifetimes compared to atmospheric transport timescales, and thus have rather uneven distributions, which reflect point sources of emissions. Also, topography and land use vary in general on smaller scales than can be resolved in a regional let alone global model.
* In order to resolve fine scale patterns in a model it is necessary to run the model on a higher resolution (i.e. to use a smaller grid box size).
* When a large domain has to be investigated this necessarily leads to a large number of grid boxes in the model, and often exceeds the limitations with respect to computer power.
* Megacities affect their environment on very local scales; down to street level, but as strong emission sources they also have global environmental impacts.
* Conversely, global change will influence megacities related to both climate change and long-range transport of air pollution.
* Given the multi-scale character of the effects *of* and *upon* megacities, trade-offs have to be made in modeling.
* Models having a sufficiently fine resolution for local air pollution studies cannot be run globally, but only for a confined region of the atmosphere (so-called regional or local models).
* On the other hand, global models that address changes in large-scale meteorological parameters and changes in the background concentrations of long-lived air pollutants have too coarse a resolution to be applied to local studies.
* Observations of the atmosphere are typically unevenly distributed in space and time and with differing precision and accuracy. Models, on the other hand, provide a self-consistent framework but are subject to multiple errors due to uncertain estimates of parameters, inadequate representation of processes, and lacking of process understanding.
* However, the combination of measurements and models provides complementary information that leads to a better description of the system and its evolution. To achieve this, the combination must be made in an optimum sense, which either minimizes the distance between model and observations (variational approach) or minimizes the error variance of the system’s predictor (statistical approach).

Projects intended to decrease air pollution

* These projects are intended to improve our understanding of air pollution and its impacts, including policy relevant aspects:
* ADAPTE: Adaptation to health impacts of air pollution and climate extremes in Latin American cities
* CalNex 2010: Air Quality and Climate Change Field Study in California in 2010
* CAREBeijing: Campaigns of Air Quality Research in Beijing and Surrounding Regions
* CityZen: megaCITY–Zoom for the Environment;
* ICARTT: The International Consortium for Atmospheric Research on Transport and Transformation
* IMPACT: Integrated Measurement Programme for Aerosol and oxidant Chemistry in Tokyo
* MILAGRO: Megacity Initiative: Local and Global Research Observations, Mexico City
* MEGAPOLI: Megacities: Emissions, urban, regional and Global Atmospheric Pollution and climate effects and Integrated tools for assessment and mitigation
* PRIDE-PRD: Programme of Regional Integrated Experiments of Air Quality over Pear River Delta;
* SAEMC: the South American Emissions Megacities and Climate

Indoor air pollution part

Why do we learn this course?

* We spend more time in indoor environment ( trains , breakfast, rooms)
* To know hazards of indoor air pollution
* To know different toxicants in indoor air, according to sources, settings and activities
* To characteristics and issues relating to indoor air pollution in industrialized and developing countries
* And to know how to prevent exposure to indoor air contaminants

What are things influencing the indoor air pollution? Or what are the sources of pollutants in indoor air

* Indoor air quality is influenced by concentrations of outdoor air pollutants: vehicles and industrial plants
* Characteristics of the building: building materials such as asbestos and cement, wood preservatives and others. Volatile organic compounds may be released by various sources including paints, glues, resins, polishing materials, perfumes, spray propellants and cleaning agents. Formaldehyde is a component of some household products and can irritate the eyes, nose and airways.
* Customs, habits, traditions of the residents like Second hand tobacco smoke, use of incense smoke and repellant for mosquitoes. The concentration in indoor are higher than outdoor because some people are smoking inside the building and also there is emission of VOCs like benzene
* Fuels used for heating and cooking: use of open fires, unsafe fuels or combustion of biomass fuels, coal and kerosene.
* Confined and poorly ventilated spaces: Gas stoves or badly installed wood-burning units with poor ventilation and maintenance can increase the indoor levels of carbon monoxide, nitrogen dioxide and particles. The solid fuel which are not drying don’t burn completely and emits particulate and VOCs
* Overcrowded homes and insufficient living space, these places are painted and paints emit VOCs, the solution can be to substitute the solvent based paints with water based paints.
* Level of economic development: Industrialized ≠ developing countries, in developing country they focuses on something else than air quality, air quality is not the priority

What are the adverse health effects of air pollutants ?

**Acute: characterized by short time disease**

* Irritation of the mucous membranes (eyes, nose, throat)
* Cough, wheeze, chest tightness
* Increased airway responsiveness to allergens: increased response to allergens
* Increased incidence of acute respiratory illness: cold, pneumonia, otitis media
* Tracheobronchitis: inflammation of the lung
* Exacerbation of asthma: a more severe form of asthma

**Chronic: long time disease coming when you spend long time to the air pollution**

* Long-term exposure decreases lung growth
* Impairment of pulmonary function
* Increased susceptibility to chronic obstructive lung diseases, including asthma
* Other
* These are symptoms and it is difficult to always correlate them with air pollution. They are called sick building syndrome

What are the sick building syndrome and solutions?

* **Sick building syndrome** (**SBS**) is used to describe situations in which building occupants experience acute health and comfort effects that appear to be linked to time spent in a building, but no specific illness or cause can be identified. They are related to poor indoor air quality

|  |  |
| --- | --- |
| Symptoms | Solutions |
| Headache | Remove the source of pollution |
| Irritation of nose, eye or throat | Increase ventilation |
| Dry cough | Air cleaning filters |
| Dry or itchy skin | Education and communication |
| Difficulty in concentrating | Remove the source of pollution |
| Fatigue | Remove the source of pollution |
| Sensitivity to odors | Remove the source of pollution |

What are the building occupants and susceptible people?

* Building occupants are people living or working in particular indoor environments and react to pollutants in different ways:
* Some groups of people are particularly susceptible to indoor air pollution problems.
* The symptoms reported by people in a particular environment with the same pollution can vary.
* In some cases, the symptoms reported can be resulted from factors other than air pollution.
* A person’s susceptibility to a particular air pollutant also depends on genetic factors, lifestyle, and age.
* Sometimes it is a matter of concentration rather than susceptibility.
* Older people and children are generally more sensitive.
* People suffering from chronic lung or respiratory diseases are more susceptible.
* Individuals who have suppressed immune systems.
* Some people, when exposed to chemicals, develop multiple chemical sensitivity (MCS).

Which outdoor activities that causes indoor air pollution

* Industrial or agricultural activities: Outdoor pollution primarily results from the combustion of fossil fuels by industrial plants and machines used in agriculture. This releases carbon monoxide, sulfur dioxide, particulate matter, nitrogen oxides, hydrocarbons and other pollutants.
* Treatment of industrial effluents and domestic residues
* Traffic: vehicles, motors and tracks, trains
* Solid waste management: The characteristics of emissions and solid waste disposal may vary for each specific industry (e.g. smelting, paper production, refining and others).
* Cottage industries: creation of products and services is home-based, rather than factory-based
* Chemical incidents and spills
* Smoke from cooking: One village and they use solid fuel inside home and emit a lot of particulate matter and smoke outside the houses and pollute the outdoor air. This outdoor air can enter the indoor air of other villages.

In which way the indoor air can mixed with outdoor air

* Infiltration: natural air exchange that occurs between a building & its environment when doors & windows are closed. leakage through holes or openings in the building due to:
* pressure differentials inside & outside the building
* Temperature differentials inside & outside of buildings. in winter, warm air inside wants to rise and exits through cracks in ceiling & draws in outside air
* how fast wind is blowing
* natural ventilation: air exchange that occurs when windows or doors are opened to increase air circulation
* forced ventilation: mechanical air handling systems used to induce air exchange using fans & blowers

What are the global burdens of disease attributable to selective major risk factors?

* In high-mortality developing countries, indoor smoke due to solid fuel is responsible for 3.7% of the overall disease burden, making it the most important risk factor after malnutrition (9%), unsafe sex (6%) and lack of safe water and adequate sanitation.
* In low-mortality developing countries, indoor smoke occupies the 8th rank and accounts for 1.9% of the disease burden.
* In contrast, in industrialized countries the impact of cooking and heating with solid fuels becomes negligible in relation to risk factors such as tobacco, high blood pressure and alcohol consumption.

What are the types of solid fuels that are used? Exposure and the maximum limit

* Solid fuel (Wood, dung, charcoal, coal): 3 billion people rely on solid fuels. Solid fuels comprise 10-15% of the total fuels used worldwide. Half of the world’s population) rely on solid fuels (e.g. dung, wood, agricultural residues, charcoal, coal) for their basic energy needs. Cooking and heating with solid fuels leads to high levels of indoor air pollution, a complex mix of health-damaging pollutants (e.g. particulate matter and carbon monoxide)
* Agricultural residues
* China , India and Africa are the countries that use too much solid fuel(red color on map)
* Women and young children, who spend most time at home, experience the largest exposures and health burdens.
* 150 µg/m3 PM10 is the 24-hour 99% percentile value, thus it should be exceeded only on 1% of occasions.
* The recommended annual mean limit is 50 µg/m3 PM10 (particles ≤ 10 micrometre (µm) in diameter).
* Numerous studies have shown that the levels of particulates are very high, with 24-hour. Can reach around 1000 µg/m3 PM10, and even exceeding 10 000 µg/m3 PM10 when sampling is carried out during use of an open fire.
* It is reasonable to compare the EPA recommended annual mean limit of 50 µg/m3 PM10 with the typical 24-hour mean for a home in which biomass fuel is used, of 1000 µg/m3 PM10. This comparison shows that average pollution levels are around 20 times the EPA recommended limit.
* Two important components are (a) the level in the home, and (b) the length of time for which each person in the home is exposed to that level.
* We know that typically women and young children (until they can walk), and girls (as they learn kitchen skills) are often exposed for at least 3*–*5 hours a day, often more.
* In some communities, and where it is cold, exposure will be for a much longer period each day.

What are interventions available to reduce indoor air pollution from solid fuel?

* look first on the sources of pollution
* Improved stoves configuration by using optimal combustion temperature to complete combustion by properly mixing with air.
* Replace the wood with other kind of Cleaner fuels (kerosene, gas, electricity)
* Works with a safe home environment by :
* Install Hoods and chimneys to evacuate the pollutants
* Open windows, ventilation holes, eaves spaces
* Separate kitchen
* Change some behavior
* Drying the solid Fuel
* Use of pot lids
* Good maintenance of stoves
* Keeping children away from smoke

What are the combustible products and their sources?

|  |  |
| --- | --- |
| Sources | Combustible products |
| Gas stoves and appliances  Wood and coal stoves  Gas and propane engines  Fireplaces  Tobacco smoke  Candles and incense  Mosquito coils | -Carbon monoxide (CO), from incomplete combustion  -Nitrogen dioxide (NO2) from engine of high temperature  -Sulfur dioxide (SO2) from fuel containing sulfur  -Nitrogen compounds (NOx)  -Particulate matter (PM) |

What are different areas and pollutants for indoor air pollution?

Carbon monoxide

* Carbon monoxide: the silent killer, a common cause of acute and lethal poisoning. carbon monoxide is from combustion process
* Colourless, odourless gas formed by incomplete burning of carbon-based fuels
* CO’s affinity for Hb is 240*–*270 times greater than oxygen, it replaces oxygen and tissues cannot use this gas, instead of oxygen the CO is transported in the body.
* Fetal Hb( baby hemoglobin) has higher affinity for CO: it decreases the capacity of Hb for carrying oxygen.
* CO causes a leftward shift of the oxyhaemoglobin (OHb) dissociation curve: it decreases oxygen delivery to tissues.
* Intoxication results in tissue hypoxia
* Multiple organ systems are affected
* Breed more pure oxygen and not if you are affected by CO pollution, the pure high concentration of oxygen push away the CO
* The sources of CO are:
* Gas, kerosene, wood stoves and coal
* Fires, fireplaces, furnaces
* Leaking chimneys and vents
* Room and water heaters
* Vehicle exhaust in closed garage
* Tobacco smoke
* Any place where combustion is incomplete
* Symptoms of CO
* Headache, dizziness, fatigue, dyspnoea
* Nausea, vomiting
* Irritability
* Sleepiness, confusion, disorientation
* Unconsciousness, coma
* Death
* Delayed neuropsychological sequelae (in survivors)
* Prevention of exposure to CO
* Keep fuel-burning appliances in good working condition
* Check heating systems, chimneys and vents regularly
* Never burn charcoal indoors
* Never leave a car running in a closed garage
* Consider CO detectors

Nitrogen oxide from combustion process

* Nitrogen monoxide (NO) and nitrogen dioxide (NO2) are gases produced by high temperature combustion through reactions between nitrogen and oxygen.
* Both nitrogen in fuel and nitrogen in the air can participate in the reactions.
* Formation of NO can be followed by further oxidation into NO2 in the atmosphere. NO2 is the most toxic of the nitrogen oxides (grouped generically as NOx) and it is very important from the health point of view.
* Emissions of nitrogen oxides have generally increased, a fact which has resulted in a lot of studies dealing with nitrogen oxides exposure, particularly over the last 15 years.
* Measurements of NO2 were carried out in residential and industrial premises over 2-day periods both in winter and summer. Personal exposures were found to vary substantially among the 43 respondents, ranging from 10.2 - 87.5 ppb with a mean of 43.7 ± 16 ppb in winter and 23.6 ± 7.8 ppb in summer.
* The results also showed that the season of the year, house size and outdoor occupation could significantly influence exposure as well as factors such as the type of fuel used and the ambient air quality level.
* Personal exposure to NO2 was significantly greater in winter than in summer, and respondents living in smaller houses and/or having outdoor occupations were exposed to higher NO2 levels.
* During the colder months( January and February), there is increase of NOx because of the use of fuel in heating

Volatile organic compounds

* The most diverse group of indoor air pollutants: Alkanes, aromatic hydrocarbons, alcohols, aldehydes, ketones .
* Sources: Released by everything from:
* Solvents, fabric softeners, deodorizers and cleaning products
* Paints, glues, resins, waxes and polishing materials: particle of wood embedded in resin has monomers and can emitted after a certain time
* Spray propellants, dry cleaning fluids, detergents: limonene is from the detergents used to clean the floor
* Pens and markers,
* Binders and plasticizers
* Cosmetics: hair sprays, perfumes
* Hot showers emit VOC when organic compounds are in water and chloroform can be formed
* Home garage and exhaust from cars emit benzene, toluene.
* Plants :limonene, isoprene and α-pinene are emitted from plants
* Cigarette smoking: this can emit benzene but the benzene indoor has decreased nowadays because it is not allowed to smoke in the room.
* Some examples of VOCs sources: Carpet made of glue emit VOC, Polyurethane in mattress, formaldehyde, which leaks from pressed wood and insulation, irritates mucous membranes and induces skin allergies and pesticides, which are found indoors more often than outdoors due to seepage
* Formaldehyde is an important chemical used widely by industry to manufacture building materials and numerous household products.
* It is also a by-product of combustion and certain other natural processes. Thus, it may be present in substantial concentrations both indoors and outdoors.
* Sources of formaldehyde in the home include building materials, smoking, household products, and the use of unvented, fuel-burning appliances, like gas stoves or kerosene space heaters.
* Formaldehyde, by itself or in combination with other chemicals, serves a number of purposes in manufactured products. For example, it is used to add permanent-press qualities to clothing and draperies, as a component of glues and adhesives, and as a preservative in some paints and coating products.
* In homes, the most significant sources of formaldehyde are likely to be pressed wood products made using adhesives that contain urea-formaldehyde (UF) resins.
* Pressed wood products made for indoor use include: particleboard (used as subflooring and shelving and in cabinetry and furniture); hardwood plywood paneling (used for decorative wall covering and used in cabinets and furniture); and medium density fiberboard (used for drawer fronts, cabinets, and furniture tops).
* Medium density fiberboard contains a higher resin-to-wood ratio than any other UF pressed wood product and is generally recognized as being the highest formaldehyde-emitting pressed wood product.
* Other pressed wood products, such as softwood plywood and flake or oriented strandboard, are produced for exterior construction use and contain the dark, or red/black-colored phenol-formaldehyde (PF) resin.
* Although formaldehyde is present in both types of resins, pressed woods that contain PF resin generally emit formaldehyde at considerably lower rates than those containing UF resin.
* The rate at which products like pressed wood or textiles release formaldehyde can change. Formaldehyde emissions will generally decrease as products age. When the products are new, high indoor temperatures or humidity can cause increased release of formaldehyde from these products.
* During the 1970s, many homeowners had urea-formaldehyde foam insulation (UFFI) installed in the wall cavities of their homes as an energy conservation measure. However, many of these homes were found to have relatively high indoor concentrations of formaldehyde soon after the UFFI installation. Few homes are now being insulated with this product.
* Studies show that formaldehyde emissions from UFFI decline with time; therefore, homes in which UFFI was installed many years ago are unlikely to have high levels of formaldehyde now.
* The source of formaldehyde differ according to the country:
* Developing countries: Use of solid fuels indoors, Mosquito coils, Furniture (pressed wood)
* Industrialized countries: Household cleaners and deodorizers, Glues and resins, Tobacco smoke, Carpeting, Furniture and dyed materials, Pressed wood products, Urea formaldehyde insulating foam (UFFI), Others
* Most VOCs are released in very small amounts. Unclear health effects due to low concentrations
* The health effect of VOCs include acute and chronic

Acute:

* Irritation of eyes and respiratory tract
* General: headache, dizziness, loss of coordination, nausea, visual disorders
* Allergic reactions, including asthma and rhinitis

Chronic:

* Damage to liver, kidney, blood system and central nervous system (CNS)
* Some may cause cancer in humans (formaldehyde)

Pesticides

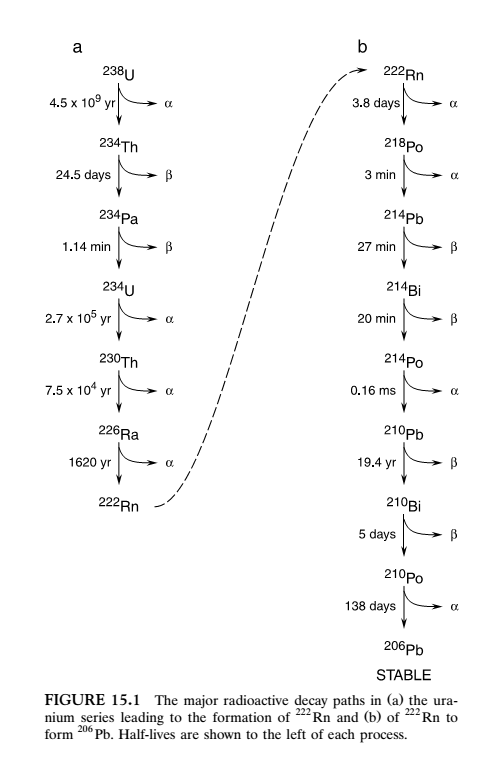
* Spraying pesticides in the home results in increased risks to children because of higher concentrations near the floor and persistence of insecticides in carpets and soft toys and overuse and misuse
* The typical activities of young children also contribute to their higher exposure. Children’s behavior and inhalation of pesticides by: Crawling, Playing close to the floor, Plush toys, Hand-to-mouth , Object-to-mouth
* Classes commonly used for insect control indoors:
* Pyrethroids: allergenic, CNS toxicity at high levels
* Cholinesterase inhibitors: neurotoxicants, neurodevelopmental toxicants
* Insect repellents (DEET)
* Mosquito coils
* Burning mosquito coils indoors generates smoke that can control mosquitoes effectively. This practice is currently used in numerous households in Africa, Asia and South America
* Mosquito coils may represent a serious potential threat to children’s health. Prolonged use has been associated with increased incidences of asthma and persistent wheezing in children.
* Although the active ingredient is usually small amounts of pyrethrins (considered a low-toxicity insecticide), over 99% of the mass of the coil is so-called “inert” ingredients.
* When analysed, the smoke from coils was found to be entirely composed of respirable-sized particles, some quite small. The particles contain numerous polycyclic aromatic hydrocarbons (PAH) and carbonyl compounds including formaldehyde.
* One recent analysis found that the burning of one mosquito coil for 2 hours allowed a steady state of particulate matter to develop, and that the PM2.5 produced was the equivalent of that from burning 75–137 cigarettes (the formaldehyde produced was the equivalent of 51 cigarettes).
* The effects on health of exposure to these insecticides include:
* acute poisoning usually related to accidental ingestion in children;
* Allergic and general symptoms: headache, nausea, vomiting; cough, rhinitis, bronchitis, asthma and other allergic symptoms.

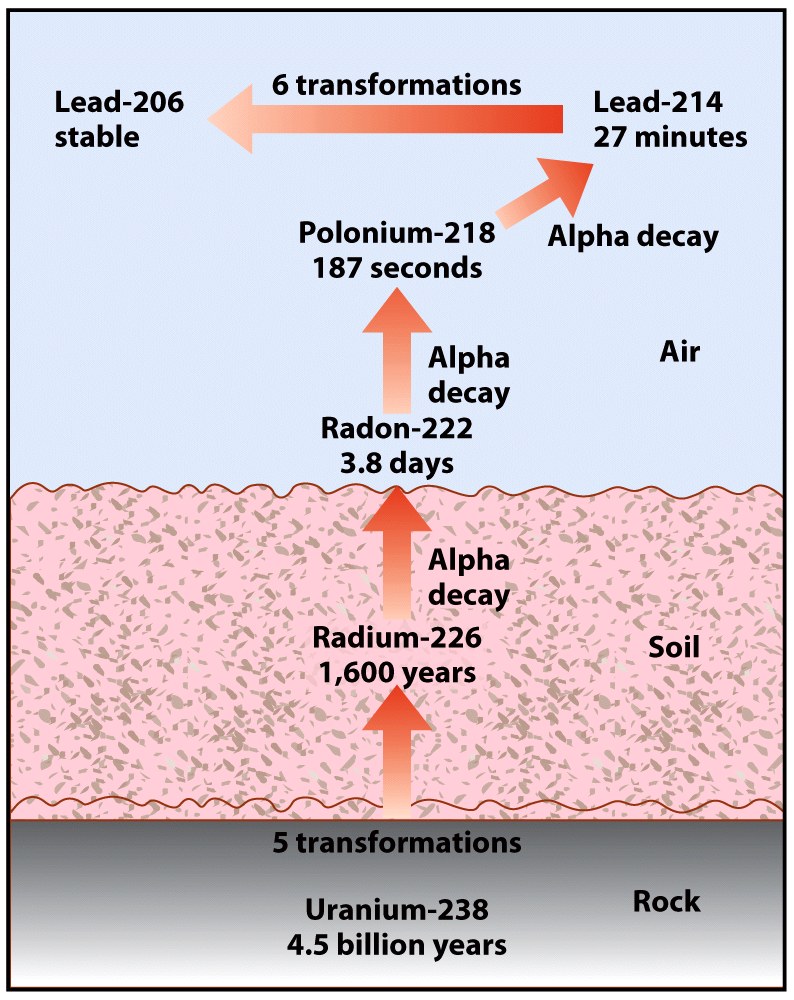
Environmental tobacco smoke

* The Mainstream smoke is the exhaled smoke
* The side stream smoke is emitted smoke from burning cigarette.
* Environmental tobacco smoke (ETS) is also called second-hand smoke and is a combination of mainstream and side stream smoke.
* This combination contains more than 4000 particle components and gases, over 50 of which are known carcinogens.
* ETS may cause 17% of lung cancers of nonsmokers.
* Concentrations one pack of cigarettes ≈ 20 mg m-3 of particles in room over 24 hours.
* Near smoker, concentrations 500-1000 mg m-3.
* Flying waffles is less harmful than smoking.
* The cigarette smoking increases the particulate matter concentration.
* The concentration of particulate matter can be the same but the effect can be different. The mass concentration of particulate matter on the coast mainly made of salt is different from the same mass concentration having harmful organic compounds

Radon

* Radon 222 is a radioactive gas that comes from the soil. Exposure to radon gas is the second leading cause of lung cancer (after smoking). It may enhance the risk of cancer in smokers
* Scientific evidence suggests that 3-14% of lung cancers are due to exposure to indoor radon.
* Radon is produced from the natural breakdown of the uranium found in most rocks and soils. Uranium is not volatile but radon is a gas and is volatile
* As it further breaks down, radon emits atomic particles. These particles are in the air we breathe. Once inhaled, they can be deposited in our lungs.
* The energy associated with these particles can alter cell DNA, thus increasing the risk of lung cancer.
* Radon usually does not present a health risk outdoors because it is diluted in the open air. Radon can, however, build up to dangerous levels inside a house.
* Radon concentrations indoors depend on construction aspects: building materials; cracks or pores in concrete floor and walls; floor-wall joints; loose pipe penetration; air pressure of a house lower than the surrounding soil, and others. Highest level in basements and ground floor. Exposure can also be from water vapor during showering, cooking
* Radon can enter your new house through cracks or openings in the foundation. The differences in air pressure between the inside of a building and the soil around it also play an important role in radon entry.
* If the air pressure of a house is greater than the soil beneath it, radon will remain outside. However, if the air pressure of a house is lower than the surrounding soil (which is usually the case), the house will act as a vacuum, sucking radon gas inside.
* Because radon comes from the soil, the geology of an area can help to predict the potential high level in soil, water as well as for elevated indoor radon levels.





* During the decay of ionizing radiation are formed. Ionizing radiation is radiation with enough energy so that during an interaction with an atom, it can remove tightly bound electrons from the orbit of an atom, causing the atom to become charged or ionized.
* There are two basic types of ionizing radiation: electromagnetic and particulated radiation.
* Electromagnetic ionizing radiation such as X-rays and gamma rays has discrete packets of energy called photons that have neither mass nor electric charge. X-rays come from the electronic part of the atom; gamma radiation originates in the nucleus.
* Electromagnetic ionizing radiation is used in pediatric healthcare for both imaging and cancer treatment.
* Particulate radiation involves tiny fast-moving particles that have both energy and mass. Particulate radiation is primarily produced by disintegration of an unstable atom and the energy is carried by sub-atomic particles such as electrons, protons and neutrons.
* Neutron, Beta and alpha radiation are examples of particulate radiation. Alpha radiation has two protons and two neutrons and a positive charge, beta radiation is essentially electrons and has a negative charge and neutrons are not electrically charged.
* The alpha will stop and B will pass through pieces of paper, B will be blocked by a block of wood and gamma will pass in the block of wood. Gamma rays are stopped by the concrete.
* Ionizing radiation is a known carcinogen to which children are particularly vulnerable.
* Relevant exposures include pre- and postnatal irradiation for medical reasons, radon in the home, and accidental radiation releases. In some cases, children may receive higher doses than adults because of higher intake and accumulation.
* Furthermore, sensitivity to radiation is highest early in life. Although the mechanism of greater susceptibility is not well understood, it is likely to be linked to greater cell division in growing and developing tissues.
* Fetuses might be particularly sensitive to ionizing radiation, since their tissue cells are not only undergoing high rates of division, but are also differentiating into mature functional cells.
* A breath of radium when happens and it decays gives the other elements like polonium, bismuth, these elements they attract water molecules and form water droplet and deposited in the lung. These elements they can further decay and give ionizing radiation that ionize tissue cell and cause lung disease.
* Protection from ionizing radiation include:
* decreasing exposure time
* Increasing distance from source
* Introducing shielding.
* Inspection and enforcement of standards that have been developed for industrial and medical applications.
* The concentration of radon gas that reaches the surface of the Earth and thus can enter our dwellings is related to the concentration of radon in the rocks (generally granitic rock) and soil. Some regions in the United States contain bedrock with an above-average natural concentration of uranium.
* Radon gas enters homes and other buildings in three main ways:
* It migrates up from soil and rock into basements and lower floors. Basement are the one with high concentration of radium
* Dissolved in groundwater, it is pumped into wells and then into homes. Use the water in the shower and radon evaporate and the concentration of radon vapor increases.
* Radon-contaminated materials, such as building blocks that are used in construction.
* Radon concentration is measured in Becquerel/m3 or disintegration/s.m3
* You can solve the problem of radium pollution by:
* you can use other sources which is not ground water if the water has contaminated with radium
* build a house on the polar structure material like a layer of sand with a gas permeable layer that allow the soil gas to move freely underneath the house and on the top put the plastic sheeting to prevent the soil gas from entering home and seal the openings in the concrete foundation floor to reduce soil gas entry into home. Radon enter polar layer but cannot enter plastic foil.

Biological pollutants

* Biological pollutants are/were living organisms: Animal dander, dust mites, moulds, infectious agents, pollen
* Dust mites, fungi and bacteria require moisture to proliferate. Permeation of rain or groundwater into a building and condensation on cold interior surfaces can promote proliferation of microbes.
* Water vapor is produced by people and pets, cooking and showering and requires sufficient air exchange to prevent moisture problems. Mattresses, upholstered furniture and carpets are reservoirs for dust mites.
* Moulds have been associated with three types of effects: infections, allergic reactions and toxic effects. Toxic effects may be caused by inhalation of mycotoxins.
* You have to make sure the water vapor coming from cooking, showering is escaping away and not condenses on the surface to avoid mold development
* Sources of biological agents:
* Water-damaged surfaces and materials
* Humidifiers and stagnant water
* Water vapor from cooking and showering
* Air conditioning systems
* Mattresses, upholstered furniture and carpets
* Dirt
* Dust mites are acarians; Feed on human dander, Prefer warm, humid environments, the sources is bedding, carpets, upholstery, soft toys. The fecal of dust mites cause allergies and difficulties in breathing.
* Prevention of the dust mites is by:
* Encasing mattress and pillows
* Washing bedding in hot water
* Frequent vacuuming / damp mopping
* Decreasing clutter
* Removing carpets
* Moulds are a frequently undetected environmental problem, occur in damp indoor areas, allergies and nonspecific symptoms are common, but infections are rare.
* Chemical agents produced by moulds includes: mycotoxins, glucans and VOCs. Mycotoxins are associated with human disease and cause acute and chronic effects. Mycotoxins include: Aflatoxins , tricothecenes, ochratoxins and citrinin and hundreds of others. Glucans are the cell wall components and VOCs can cause irritation.
* Mycotoxins are associated with human disease. Tricothecenes inhibit protein synthesis and have many acute effects, including anemia and infant pulmonary haemorrhage. Ochratoxins and citrinin cause nephropathy and immunosuppression. Aflatoxins are hepatotoxins and are carcinogenic.

Asbestos

* **Asbestos** is a set of six naturally occurring silicate minerals used commercially for their desirable physical properties: Long (ca. 1:20 aspect ratio), thin fibrous crystals. Asbestos cannot burn and was good to use them as the isolation material
* The prolonged inhalation of asbestos fibers can cause serious illnesses including malignant lung cancer, mesothelioma, and asbestosis.
* The trade and use of asbestos have been restricted or banned in many jurisdictions.
* Pure asbestos material belongs to fiber class material and can be inhaled and cause cancer. Fiber class include: serpentine class (chrysotile is white), ammpibole class ( amosite is brown, crocidolite is blue, [tremolite](http://en.wikipedia.org/wiki/Tremolite), [anthophyllite](http://en.wikipedia.org/wiki/Anthophyllite) and [actinolite](http://en.wikipedia.org/wiki/Actinolite)) .
* they are applied in the walls of other types, in pipe insulation, attic insulation, fire branket, ship insulation, lamp wicks, locomotive insulation, brake pads, roofing products
* where they are used and they are no longer useful, it require to remove them and make sure no fiber is escaping

What are approaches to reduce the indoor air pollution?

* It is always better to prevent rather than treat illness. To avoid problems due to indoor air quality, the first approach is source reduction and elimination, and the second, proper ventilation and maintenance of gas, oil and solid fuel cooking, heating and cooling systems. Air cleaning is the least effective, and most expensive. Air fresheners, which contain untested potentially harmful volatile organic compounds (VOCs), should not be used to cover up stale air or unpleasant smells.
* Eliminate or control the sources of pollution
* Improving stoves
* Clean fuels (kerosene, gas)
* Venting stoves for cooking and heating
* Regular maintenance of cooking, heating and cooling systems
* Choose non-volatile, non-toxic building materials
* Maintaining dry homes and schools
* Ventilation – building design by:
* Dilute and remove pollutants through ventilation with outdoor air
* Air cleaning(NOT air fresheners) by:
* Air filters and ionizers may remove some airborne particles
* Gas adsorbing material is used to remove gaseous contaminants
* The problem with these devices is that they can create the ozone in air.
* We can reduce indoor air pollution in developed countries by:
* Use low-toxicity material
* Monitor air quality
* Keep rooms clean
* Limit exposure to chemicals
* Allow for better mixing of indoor & outdoor air
* We can reduce the indoor air pollution in developing countries by:
* Dry wood before burning
* Cook outside
* Use less-polluting fuels (natural gas)

Explain how the analysis of VOCS in air is done

* They are present in low concentrations (μg/m³) compared to air constituents. Less than 10μg/m³ in Belgium
* We try to concentrate them by sorbent enrichment in order to quantify them( to be able to see the signal)
* Once are concentrated the Analysis is done in the laboratory by using gas chromatography –mass spectrometry (GC-MS)
* Interpretation of the results (chromatogram and mass spectra) to identify and quantify the compounds

Sorbent enrichment

* We use a stainless steel device which is a stainless steel tube filled with a polymer that sorbs organic compounds in the air (**Tenax**). All volatile present in air are retained on tenax and the tube is brought to the laboratory for the analysis. The sampling can be done in 2 ways: active sampling and passive sampling

Active sampling

* actively drawing air through a sorbent - filled tube
* The active sampling process is obviously a faster way to take an air sample
* Used in cases where a high sensitivity is needed
* Large sample volume is needed , The accuracy of the sample is determined by the sample volume
* Calibrated pumps, mass flow controllers or pumps in combination with appropriate air meters are often used
* Mass and the volume is known
* It is expensive method

Passive sampling

* Letting the compounds penetrate a well - defined sorbent bed simply through gradient - driven diffusion.
* Easy to use
* No pumps needed, no electricity
* Characterized by long sampling time, often exceed several days.
* Very volatile compounds may have the chance not only to enter the sampler, but also to leave it on the same way which can cause underestimation of the very volatile substances
* Passive samplers are not useful to monitor peak concentrations
* Difficult to know the volume of sampled air



m: mass of interested compound

D: diffusion coefficient

A: surface area of the tube

L: diffusion path length: length of stationary air phase

C: ambient concentration: concentration that you want to measure

C0: concentration at adsorbent surface =0

t: time

C-C0: driving force

The C is unknown and can be determined by using GC-MS

C=m.L/D.A.t; C=m/UTR.t; UTR: uptake rate= L/D.A

**Different types of passive sampling**

* Axial sampling
* One side is closed another side is open
* Based on diffusion, at a certain temperature compounds are moving
* Can take one week to take sample
* Radiello
* Compounds can diffuse along the side area of the white cylinder
* it can take one day or 8 hours for sampling

**Analysis of VOC is done in Gas chromatography**

* We have to first heat the sorbent tube by using thermal dissolution unit and pass helium in the tube.
* Sample is injected into inlet and it is volatilized, the portion is carried into the column by the carrier gas
* The components are separated by differential partitioning in the stationary phase and mobile phase
* The components elute from the column into the detector and the physical chemical parameter of the compound is detected and a signal is produced.
* The signal is amplified and sent to the data system where the chromatogram is electronically constructed
* Compounds are identified based on the retention time
* We inject both samples and the standards, we get peaks and we integrate the peaks to find the area under the curve and the area is proportional to the concentration.
* For MS, we bombard the compounds with electrons, the compounds are ionized and give fragments, these fragments are characteristics of the compound, we identify compounds based on these fragments

**Compounds of VOC analyzed by GC-MS?**

* Benzene(carcinogenic)
* Limonene
* Hexanol
* Ethyl acetate
* Toluene

Sources of pollution on this diagram slide 28

|  |  |  |
| --- | --- | --- |
| **Sources** | **Pollutants** | **Health effects** |
| **hot shower with chlorine treated water** | **Chloroform** | **Nervous system damage and cancer** |
| **Old paints** | **Lead** | **Nervous system, and organ damage** |
| **Fire places, wood stoves** | **Particulate matter** | **Lung Cancer, respiratory problems** |
| **Pipe insulation, ceilings, floor tiles** | **Asbestos** | **Lung Cancer and asbestosis** |
| **unvented stoves and heaters** | **Nitrogen oxides** | **Respiratory problems, headaches, irritated lungs** |
| **Pets** | **Animal dander** | **Allergies** |
| **Pesticides, paints, cleaning fluids** | **VOCs and others** | **neural, organ damage and cancer** |
| **Soil and rock near house foundation** | **Radon – 222** | **Lung cancer** |
| **Computer and office equipments** | **VOCs** | **Irritation, neural, organ damage and cancer** |
| **Tobacco Smoke** | Toxic or carcinogenic compounds | **Lung cancer and heart disease, respiratory problems** |
| **Gasoline** | VOCs | **Cancer** |
| **Leaky or unvented stoves, woodstoves, furnaces, car left running in garage** | **Carbon Monoxide** | **Neural impairment, Headache, heartbeat irregularities, death at high dose** |
| **Foam insulation, furniture, carpets, pressed woods** | **Formaldehyde** | **Respiratory irritation, Nausea, dizziness, irritation of throat, eyes, and lungs, cancer** |
| Heating and cooling ducts | Mold and bacteria | Allergies, asthma, respiratory problems |

Sources of pollution on this diagram slide 29

* Paints
* Cigarette :Marlboro
* Wall painted
* Plants emit VOCs
* Carpets emit VOCs
* Wood
* Plastic or foam insulation
* Perfumes
* Cleaning products
* Television

Extra notes from handout

What is indoor air pollution?

* The term indoors is used to refer to a variety of environments, including homes, work- places, and buildings used as offices or for recreational activities. In addition, a number of studies have been carried out to measure various compounds inside vehi­cles during commutes.
* Levels measured indoors are charac­teristic both of the particular sources present and to a significant extent of the outdoor concentrations of the species.

Radon

* Radon is formed by the radioactive decay of uranium. As a result, the highest concentrations tend to be associated with soils derived from rocks with high uranium content. Because radon is a gas that diffuses out of the soil, it can enter homes through cracks in the foundation, around loose-fitting pipes and wall joints, and through floor drains.
* The con­centrations found in a home depend on the type of soil (including the moisture content) on which it sits and the extent of Rn penetration into the house. They also depend on the house ventilation rate and the particular location in the house in which the measurement is made, with the basement typically having the highest concentration.
* Because homes are often warmer than the surroundings, the chimney effect occurs that draws gases including radon from the surroundings.
* Other sources include building materials such as concrete that are made from the earth crystal material and hence can contain a significant amount of uranium and radium.
* Radon dissolves in water and hence degassing from household water can also be the source
* The health concerns associated with radon are primarily associated with its radon daughters. As a noble gas radon is unreactive in air and is readily inhaled and exhaled. However a significant portion of its daughters are positively charged ions that are expected to attract water vapor and becomes hydrated; the formation of crystals with other ions is also likely. Uptake on existing aerosol particles also occurs readily and such particles can then be deposited in the respiratory tract providing a source of radioactive emissions directly to the lung. Effects such as lung cancer may then ensue.
* units used to express the concentration of Rn are picocuries per liter (pCi/L with pCi being the amount of substance that gives 2,2 radioactive decays per minute, or Becquerel per cubic meter (Bq/m3) where 1pCi/L=37Bq/m3
* the U.S. EPA recom­mends levels below 4 pCi/1 (150 Bq/m3)which is exceeded by about 7% of U.S. homes.

NOx

* Because of air exchange, indoor levels of NOx are gen­erally higher when outdoor levels increase; however, enhanced indoor levels are found when combustion sources are present. These include gas stoves, kerosene heaters, water heaters**,** and cigarette smoke
* While combustion generates primarily NO, the focus indoors has been on NO.2 because of its health impacts.
* Per­sonal exposures to NO2 are higher in homes having gas ranges as compared to those having electric ranges. The gas ranges with pilot lights have higher emissions as compared to gas ranges without pilot lights.
* The use of gas stoves is highly correlatedwith indoor NO2. The situation is even more severe for homes with a kerosene space heater
* High concentrations of NO2 is also found in **indoor skating rinks** where the use of ice resurfacing machines powered by propane, gasoline, or diesel fuel results in significant emissions
* The effect of the particular fuel used on the indoor NO2 concentrations is that Propane gave the highest values, followed by gasoline and diesel.
* In the **absence of** such sources of NOx; **indoor and outdoor concentrations are quite similar** since removal of NO and NO2 indoors on surfaces is relatively slow.
* although the surface reaction of NO, is relatively slow, it is still of interest since it generates nitrous acid (HONO)
* Different surfaces found inside homes have been found to have different removal ratesfor NO2. Large varia­tions in removal rate (and hence the formation of products such as NO and HONO) **are evi­dent,** varying **from negligible for plastic storm windows to quite large for wallboard.**
* In short, there is a variety of evidence that there are higher levels of NO2 indoors when combustion sources are present
* Significant concentra­tions of HONO are generated both by a heterogeneous reaction of NO2 on surfaces and by direct emissions from combustion sources.
* When the exhaust hood which is externally vented above the range **is turned** on, the NO2 and MONO decreased substantially. Similar production of HONO from kerosene and propane space heaters is decreased.

CO and SO2

* Combustion sources such as gas stoves and kerosene heaters are significant source of CO.
* **The** ratio of indoor to outdoor concentrations of CO in homes using gas stoves and the highest ratios found close to the source; higher CO levels indoors compared to outdoors are found for restaurants using **charcoal burners** as **well as gas giving much higher concentrations.**
* The use of charcoal increases extremely this ratio. In buildings where motor vehicle exhaust can he entrained from outdoors or attached parking garages, elevated indoor CO levels may also result.
* On the other hand, in homes and offices where there was no direct indoor source of CO, the indoor to outdoor ratio was about one, and sometimes less.
* Given that cars are major CO sources in urban areas, one might expect higher concentrations of CO during com­mutes and this is indeed the case.
* As is the case for CO, SO2 indoors and outdoors tend to be similar if there are no combustion sources indoors.
* On the other hand, quite high SO2 concentrations can result when there are indoor combustion sources, where unvented stoves using coal are used extensively for cooking and heating, average SO2 levels indoors are high during winter than during the summer.

Volatile organic compounds

* There are three sources/categories for VOC
* En­trainment of air from outside the building
* emis­sion from building materials
* Human activities inside buildings.
* As might be expected given the nature of the sources, a very large variety of organic compounds are identified indoors
* Hundreds of different compounds, with the particu­lar species can be found and their concentrations depending on the particular sources present as well as the air exchange retes
* Because of the VOC sources present indoors, the indoor-to-outdoor concentration ratios are quite laree for many compounds

En­trainment of air from outside the building

* Sources from Entrainment of outdoor air through ventilation systems brings with it the species found in ambient air. Some of them such as HNO3 and to a lesser extent O3 can be removed on surfaces such as those in air conditioning systems, and hence the indoor concentrations tend to be lower than those outdoors. Others such as NO tend to have similar concentrations indoors and outdoors if there are *no* significant combustion sources indoors. In the case of hydrocarbons the concentrations of compounds that do not have significant indoor source tend to be about the same as the outdoor concentrations.
* Some specific outdoors sources can lead to higher concentrations of certain VOCs indoors than in general outdoors air environment. Gases generated in a landfill or from petroleum contamination can migrate through the soil and groundwater to adjacent building and homes to give larger indoor concentrations particularly in the basement and crawl spaces than otherwise expected. The use of pesticides outside buildings can also lead to the enhanced concentrations of these compounds indoors by migration of pesticides into the house through cracks in the basement walls.
* Another source of VOCs is the motor vehicle emission which can be drawn into buildings from outdoors or parking garages.

Emis­sion from building materials

* Emission associated with building materials are major contributors to indoor level of VOCs. New buildings often have higher concentration of certain compounds compared to the older buildings.
* A number of VOCs are present at increased concentration in houses with complaints compared to the normal houses.
* Carpets are major sources of VOCs in homes. Emissions come not only from the carpet fibers but also from the backing materials and the adhesives used to bind the carpet to the backing. The emissions of VOC from carpets tend to decrease with time and increases with temperature.
* Emission rates from other building materials such as flooring, paints, varnishes and sealants also tend to increase not surprisingly with temperature.
* Direct emission of formaldehyde is from building materials, this formaldehyde has well known effects which include possible human carcinogenicity and eye, skin and respiratory tract irritation. it is emitted from urea formaldehyde foam insulation as well as from resins used in reconstituted wood products such as particleboard and plywood. High levels are found in mobile homes because of the reconstituted wood products used in their construction. Formaldehyde is not a constituent of natural gas combustion. Temperature is also an important determinant of formaldehyde levels.
* In addition to direct emissions, the reaction of hydrocarbons with ozone indoors is a potential source
* It should be noted that building materials are sources of a variety of VOCs; they can also adsorb organics as well. As a result building surfaces and contents may act as reservoirs of organics, slowly releasing compounds over a period of time.

Emission from human activities inside building

* Emission from liquid process copiers and plotters , dry process copiers emits a number of hydrocarbons, aldehydes and ketones
* Enhanced levels of acetaldehyde is attributed to the oxidation of ethanol used as a cleaning agent
* Volatilization from hydraulics fluids used in building elevators are sources for alkanes
* Enhanced levels of chlorinated compounds are from unvented dry cleaning units and volatilization of chlorinated organic such as chloroform treated tap water.
* Chloroform is emitted from washing machine when bleach containing hypochlorite is used.
* Smoking results in enhanced level of nicotine, and a variety of other gases associated with cigarette smoke.
* In addition there is also emission from personal care products such as deodorants and antiperspirants.
* The used pesticides indoors can lead to very large concentrations not only of pesticide but of the additional VOCs used as matrix for the pesticide. Pesticide is present as gases and as adsorbed to dust particles in the home particularly for the less volatile compounds. As a result of this reversible adsorption desorption process, levels of organics can be maintains indoors after initial exposure by slow degassing from surfaces.
* The concentrations of VOCs from automobile exhaust are higher in the indoor environment of automobile during commutes. The source is primarily from the exhausts of surrounding vehicles.

Ozone

* Because the ozone decomposes on surface, the indoor ozone levels are usually lower than those outdoors due to the decomposition that occurs at the air passes through air conditioning systems and impacts building surfaces. Buildings with low air exchange with outside air tend to have lower ratio of indoor to outdoor.
* Other sources of ozone indoors are dry process photocopying machines, laser printers and electrostatic precipitators. During operation of some copy machines and laser printers you can notice the odor of ozone.
* In the indoor environment in cars, ozone levels tend to be significant less than the surrounding area. This is because the NO concentrations are higher near roadways so that ozone is titrated to NO2 by its rapid reaction with NO+O3 NO2+O2 and that ozone can decompose on the surface of the automobile air conditioning system.

Particles

* The epidemiological study shows that there is an increase of mortality associated with particles.
* If there is no indoor sources of particles, the levels indoor tend to reflect those outdoors
* In the case of high outdoors levels of particles, the indoor concentrations tend to be somewhat lower than those outdoors and when the outdoors levels are lower, the indoors levels tend to be higher.
* Night time mass concentrations in indoors tend to be smaller than those during the day probably because of the decrease of activities.
* Carpets are reservoirs of dust particles that can be suspended when walking, vacuuming. This activity leads to resuspension of the larger particles preferentially.
* A major source of increased particles indoors is cigarette smoking. In addition to the contribution to the mass concentrations of indoor particles cigarette smoke is of concern because of the mutagens, carcinogens and toxic air contaminants that are emitted. In building with cigarette smoke a variety of both gaseous and particulate polycyclic aromatic hydrocarbons (PAH) and poly-aromatic compounds (PAC) can be identified.
* Other significant sources are cooking, use of kerosene heaters, wood burning and humidifiers. Those sources depend on the type of cooking, amount of cooking and the ventilation. A high value is found in the restaurants. Kerosene heaters can be a significant sources of particles under some circumstances, where it does not contribute to the mass concentration of particles, it may contributes to significant health effects due to the composition of the particles emitted which includes polycyclic aromatic compounds and mutagenic species. In assessing the health effects of indoors particles, not only the mass concentrations should be taken into account but also the nature of compounds emitted.
* Humidifiers can be a significant source of airborne particles if tap water is used because as the water evaporates from the aerosol, the solids that were in water are left as particles.
* Where indoors heating and cooking involves the use of coal or biomass, indoor particle concentrations can be extremely large. High concentrations associated with coal burning combined with the mutagenic nature of the emissions have been suggested to be responsible for the enhanced lung cancer.
* Indoor to outdoor ratio of particle mass vary depending on the ventilation and filtration systems in use.
* The indoor concentrations of particles depend on outdoor levels, ventilation system, exchange rates and presence of indoor sources such as cigarette smoke. In many nonresidential buildings deposition is of particular interest because of the potential for damage to materials in museum, offices, cultural objects and industrial sites.

Extra notes chapter 9

* People spend most of their time indoors, so the compo­sition and quality of indoor air has a significant impact on human health. Because people's time is often divided between home and work, it is important to examine air quality in both residences and workplaces.
* Sources of indoor air pollution include outdoor air that infiltrates indoors and indoor emissions. Outdoor air contains the constituents of smog, but some of these constituents dis­sipate quickly indoors
* Major indoor sources of pollution include stoves, heaters, carpets, fireplaces, tobacco smoke, motor vehicle exhaust from garages, building materials, and insulation.
* In developing coun­tries, major sources of indoor air pollution include the products of solid biofuel and coal combustion for home heating and cooking. Such pollution is responsible for significant premature mortality worldwide. Whereas indoor air pollution is often regulated in workplaces, it is not regulated in residences.
* Nearly 1.6 million people worldwide die each year prematurely from indoor air pollution (not includ­ing smoking), making it one of the leading causes of death worldwide (World Health Organization (WHO), 2005).
* Most of these deaths are due to indoor burning of solid bio-fuels and coal for home heating and cooking with inefficient cook stoves and heaters.

Pollutants in Indoor Air and Their Source

* Many of the pollutant gases in indoor air are also found in outdoor air. Outdoor pol­lutants enter indoor air by infiltration, natural ventila­tion, and forced ventilation.
* **Infiltration** is natural air exchange through cracks and leaks, such as through door and window frames, chimneys, exhaust vents, ducts, plumbing passages, and electrical outlets.
* **Natu­ral ventilation** is air exchange resulting from the open­ing or closing of windows or doors to enhance the cir­culation of air.
* **Forced ventilation** is the air exchange resulting from the use of whole house fans or blowers
* Table below identifies major pollutants in indoor air , their primary sources and health effects

|  |  |  |
| --- | --- | --- |
| Pollutants | Sources | Health effects |
| **Gases** | | |
| VOCs | Adhesives, solvents, building materials, combustion appliances, paints, varnishes, tobacco smoke, room deodorizers, cooking, carpets, furniture, draperies. |  |
| Sulfur dioxide | Outdoor air, kerosene space heaters, gas stoves, coal appliances |  |
| Ozone | Outdoor air, photocopy machines , electrostatic air cleaners |  |
| Carbon dioxide | Metabolic activity, combustion , tobacco smoke, garage exhaust | No effect |
| Carbon Monoxide | Boilers, gas or kerosene heaters, gas or wood stoves, fireplaces, tobacco smokes, garage exhaust, outdoor air | Headache, heartbeat irregularities, death, CO has 250x affinity for hemoglobin than O2 |
| Formaldehyde | Insulation, Paneling, particle board, furnishings, carpeting, plywood, ceiling tile, tobacco smoke, adhesives | Nausea, dizziness, irritation of throat, eyes, and lungs |
| Nitrogen dioxide | gas or kerosene heaters, gas or wood stoves, tobacco smokes, garage exhaust, outdoor air, furnaces, fireplaces and vents | Headaches, irritated lungs |
| Radon – 222 | Diffusion from soil and rock near house foundation, concrete | Lung cancer |
| Chloroform | Pulp and paper mills, water and wastewater plants | Cancer |
| 1, 1, 1-Trichloroethane | Aerosol sprays | Dizziness, breathing irregularities |
| Benzo-a-pyrene | Tobacco smoke, woodstoves | Lung Cancer |
| Para-dichlorobenzene | Air fresheners, mothballs | Cancer |
| Methylene chloride | Paint strippers and thinner – persistent | Nerve disorders, diabetes |
| Styrene | Carpets, plastics, | Kidney & liver damage |
| Tetrachlor-  Ethylene | Dry-cleaning fluid | Nerve disorders, damage to liver and kidneys, cancer |
| **Aerosol particles** | | |
| Allergens | House dust, domestic animals, insects, pollens | Allergies, coughs, sneezing, eye irritation, sore throats, difficulty breathing |
| Asbestos | Pipe insulation, ceilings, floor tiles, oven mitts, fire retardant materials | Lung Cancer and asbestosis |
| Fungal spores | Soil, plants, foodstuffs, internal surfaces | Allergies, coughs, sneezing, eye irritation, sore throats, difficulty breathing |
| Bacteria, viruses | People, animals, plants, air conditioner |  |
| Polycyclic aromatic hydrocarbons | Fuel combustion, tobacco smoke , |  |
| Other | Resuspension, tobacco smoke, wood stoves, fireplaces, outdoor air |  |

Carbon Dioxide

* **Carbon dioxide** [CO2(g)], which is present in back-   
  ground air, is also produced indoors from breathing and the burning of wood, coal, oil, and gas. It does not pose a health problem until its mixing ratio reaches 15,000 ppmv, much higher than its background mixing ratio of 393 ppmv in 2011.

Carbon Monoxide

* **Carbon monoxide** is produced outdoors by automobile and other fossil fuel and bio-fuel combustion sources is emitted indoors by boilers, heaters, stoves, fireplaces, cigarettes, and cars in garages.
* In the absence of indoor sources, mixing ratios of CO indoors are usually less than are those outdoors.
* In the presence of indoor sources, indoor mixing ratios of CO can reach a factor of 4 or more times those out­doors.

Nitrogen Dioxide

* **Nitrogen dioxide** is produced chemically   
  from the oxidation of nitric oxide and emit-   
  ted in small quantities indoors.
* Sources of NO and NO2 indoors include in-garage cars, kerosene and gas space heaters, wood stoves, gas stoves, and cigarettes.
* In the absence of indoor sources, indoor mixing ratios of NO2 are similar to those outdoors. High mixing ratios of NO2occur over short periods during the operation of NO2 producing appliances.
* Because UV sunlight does not penetrate indoors, the photolysis of NO2 and subsequent pro­duction of ozone is not a concern in indoor air.

Ozone

* **Ozone** is produced photo-chemically in urban air outdoors following photolysis of nitrogen dioxide, is rarely produced indoors because UV sunlight, required for its production is usually unavailable indoors.
* The major indoor source of ozone is outdoor air. Photo­copy machines and electrostatic air cleaners, which emit UV radiation, can also produce ozone indoors.
* In residences and most workplaces however, ozone mix­ing ratios indoors are almost always less than they are outdoors.
* Ozone is lost indoors by reaction with wall, floor, and ceiling surfaces; reac­tion with indoor gases; and deposition to floors.

Sulfur Dioxide

* **Sulfur dioxide** is emitted outdoors during gaso­line, diesel, and coal combustion, is emitted indoors during combustion of kerosene for space heaters or wood for heating and cooking.
* In the absence of indoor sources, indoor SO2 (g) mixing ratios are typically 10 to 60 percent those of outdoor air.
* indoors SO2 (g) does not chemically degrade quickly in the gas phase because the hydroxyl radi­cal OH required to initiate its breakdown is not produced indoors. Lifetime of the hydroxyl radical is about 1 second and OH brought indoors from the outside disappears quickly.
* Losses of SO2 include deposition to wall and floor sur­faces, dissolution into liquid water (e.g., in bathtubs and sinks), and dissolution into aerosol particles con­taining liquid water.

Formaldehyde

* **Formaldehyde** (HCHO) is produced during fossil fuel and solid and liquid bio-fuel burning and chemical reaction outdoors, it is also emitted from particleboard, insu­lation, furnishings, paneling, plywood, carpets, ceiling tile, tobacco smoke, and combustion indoors.
* Formalde­hyde mixing ratios indoors are usually greater than are those outdoors. In outdoor air, formaldehyde breaks down by photolysis and reactions with HO2 (g) and OH (g).
* UV sunlight and OH (g) are not present indoors, but HO2 (g) sometimes is, and it is the most likely indoor chemical breakdown source of formaldehyde.
* Formaldehyde is also removed by deposition to the ground and reaction with wall, floor, and ceiling sur­faces.

Radon

* **Radon** (Rn) is a radioactive but chemically un-reactive, colorless, tasteless, and odorless gas that forms naturally in soils.
* Its decay products are believed to be carcinogenic and have been measured in high con­centrations near uranium mines and in houses particularly in their basements overlying soils with uranium-rich rocks.
* Radon plays no role in acid deposition, stratospheric ozone, or outdoor air pollution problems. Because of its indoor effects, radon is considered a hazardous pollutant
* The ultimate source of radon gas is the radioactive decay of solid mineral **uranium-238**
* Radon formation from uranium involves a long sequence of radioactive decay processes. During radio­active decay of an element, the element spontaneously emits radiation in the form of an alpha particle, beta particle or gamma ray.
* An **alpha particle** is the nucleus of a helium atom, which is made of two neutrons and two protons. It is the least penetrating form of radiation and can be stopped by a thick piece of paper. Alpha particles are not dangerous unless the emitting substance is inhaled or ingested.
* A **beta particle** is a high-velocity electron. Beta particles penetrate deeper than do alpha particles, but less than do other forms of radiation, such as gamma rays.
* A **gamma ray** is a highly energized, deeply penetrating photon emitted from the nucleus of an atom not only during nuclear fusion (e.g., in the sun's core), but also sometimes during radioactive decay of an element.
* **Antoine Henri Becquerel** discovered radioactive decay.
* Becquerel placed a uranium-containing mineral on top of a pho­tographic plate wrapped by thin, black paper.
* After letting the experiment sit in a drawer for a few days, he developed the plate and found that it had become fogged by emissions that he traced to the uranium in the mineral. He referred to the emissions as **metallic phosphorescence.**
* What he had discov­ered was the emission of some type of particle due to radioactive decay.
* He repeated the experiment by placing coins under the paper and found that their out­lines were traced by the emissions.
* Two years later **Ernest Ruther­ford** found that uranium emit­ted two types of particles, which he named alpha and beta particles. And he discovered gamma ray later as well.
* The decaying of radon gives polonium-218 which decays to lead-214; polonium-218 and lead-214 are referred to as radon progeny and are electrically charged and can be inhaled or attach to particles that are inhaled.
* In the lungs or in ambient air, Pb decays to bismuth-214 which decays to polonium-214 and this polonium decays almost immediately to lead-210 which has a lifetime of 22 years and usually settles to the ground if it has not been inhaled.
* It decays to bismuth-210, then to polonium-210 and then to the stable isotope lead-206 which does not decay further.
* Outdoor radons concentrations are generally low and do not pose a human health risk. However, because of the lack of ventilation in many houses, indoor con­centrations can become thousands of times larger than outdoor concentration. Indoor concen­trations depend on the abundance of radon in soil and the porosity of floors.
* **Becquerel unit** is the num­ber of disintegrations of atomic nuclei per second to another isotope or element.
* Radon levels in homes can be reduced by installing check valves in drains, sealing basement walls and floors, and installing fans in crawl spaces to speed mixing of outside air with radon-laden air under the house.
* Radon-222 gas is not itself harmful, but its progeny, which enter the lungs directly or on the sur­faces of aerosol particles, are believed to be highly carcinogenic.
* Any activity increasing the inhalation of aerosol particles enhances the risk of inhaling radon progeny; thus, the combination of radon and cigarette smoking increases lung cancer risks above the normal risks associated with smoking.

**Volatile organic compounds**

* VOCs are organic compounds that have relatively low boiling points. Because of the low boiling points VOCs often evaporate from materials containing them.
* Sources of VOCs indoors include adhesives, solvents, building materials, combustion appliances, paints, var­nishes, tobacco smoke, room deodorizers, cooking, car­pets, furniture, and draperies.
* Some common VOCs in indoor air include propane, butane, pentane, hexane, n-decane, benzene, toluene, xylene, styrene, acetone, methylethylketone, and limonene, among many others.
* VOC mixing ratios indoors can easily exceed those outdoors by a fac­tor of 5. Many VOCs are hazardous.

Allergens

* **Allergens** are particles such as pollens, foods, or microorganisms that cause an allergy, which is an abnormally high sensitivity to a substance.
* Symp­toms of an allergy include sneezing, itching, and skin rashes. Indoor sources of allergens are dust mites, cats, dogs, rodents, cockroaches, and fungi. Pollens originate mostly from outdoor trees, plants, grasses, and weeds.
* Omni present indoor allergens are **dust mite feces**, allergens in airborne dust mite feces may exacerbate symptoms in 85 percent of asthmatics
* In cockroaches, the sources of allergens are body parts and feces. Cat allergens are present in the saliva, dan­der, and skin of the cat. Dog allergens are found in the saliva and dander of the dog. Allergens from cats, dogs, and cockroaches can trigger rapid asthmatic responses.

Coal Dust

* A major worldwide health problem directly linked to aerosol particles is coal workers pneumoconiosis, the name was changed to **black lung disease**.
* Coal workers develop black lung disease over many years of exposure to **coal dust.** The dust first builds up in air sacs in the lungs then scars the sacs, making breathing dif­ficult.
* Symptoms of the disease include chronic cough and shortness of breath. Black lung disease is the greatest occupational hazard worldwide.
* To decrease this disease there is a need for better ventilation and respiratory protection for coal miners, as well as a decrease in the number of miners.

Asbestos

* **Asbestos** is a class of natural impure hydrated silicate minerals that can be separated into flexible fibers. It is mined in open pits by blasting rock until asbestos is exposed and removed by machines.
* The raw asbestos mineral is waxy, greasy, and soft, but contains brittle fibers that easily fracture.
* Asbestos is chemically inert, does not conduct heat or electricity, and is fire resistant. As a result, it is has been widely used as an insulator and fire retardant.
* Once insulation containing asbestos has been installed, the asbestos is not expected to cause damage to humans unless the insulation is disturbed.
* When insulation is disturbed, fibers can be scattered into the air, where they can remain for minutes to days until they deposit to the ground or are inhaled. Thus, the only source of asbestos in indoor air is turbulent uplift, and the only sink is deposition.
* The primary health effects of asbestos exposure are lung cancer, mesothelioma, and asbestosis.
* **Mesothe­lioma** is a cancer of the mesothelial membrane lining the lungs and chest cavity.
* **Asbestosis** is a slow debilitating disease of the lungs, whereby bodily produced acids scar the lungs as they try to dissolve asbestos fibers in lung tis­sue.
* Significant scarring causes crackling of the lungs and inhibits oxygen from transferring from the airway to the blood, making it difficult to breathe.
* Cigarette smoking and exposure to asbestos are believed to amplify the rates of lung cancer in comparison with the rates of cancer associ­ated with just smoking or just exposure to asbestos.
* Short-term acute exposure to asbestos can lead to skin irritation and itching.

Fungal Spores, Bacteria, Viruses, and Pollen

* Fungal spores, bacteria, viruses, and pollen are com­mon indoor air contaminants. They can infiltrate indoors from outdoor air or grow indoors.
* **Fungal spores** are reproductive or resting organisms released by fungi and algae growing on leaf surfaces, soils, animals, and food­stuffs.
* **Bacteria and viruses** live in water, soil, plants, ani­mals, and foodstuffs, and they can be picked up read­ily by wind or turbulence.
* **Pollens** are large granules containing male genetic material released from flowers and blown by the wind to other flowers for fertilization.
* Some diseases associated with fungi, bacteria, and viruses include rhinitis (a respiratory illness), asthma, humidifier fever, extrinsic allergic alveolitis, and atopic dermatitis.
* Most human illnesses due to viral and bacte­rial infection are due to human-to-human transmission of microorganisms rather than to building-to-human transmission.

Environmental Tobacco Smoke

* When a person smokes a cigarette, some of the smoke is inhaled and swallowed, some is inhaled and exhaled **(mainstream smoke)** and the rest is emitted from the burning cigarette between puffs **(sidestream smoke)**.
* The mainstream plus sidestream smoke is called **environmental tobacco smoke** (ETS) which is a mix­ture of more than 4,000 aerosol particle components and gases, at least 50 of which are known carcinogens.
* because of the different conditions result­ing in mainstream versus sidestream smoke, the rela­tive gas and particle composition of the two types of smoke differ somewhat, with sidestream smoke possi­bly being more dangerous
* Also called **second-hand smoke,** ETS builds up in enclosed spaces, increasing danger to others in the vicinity. Even in well-ventilated indoor areas, particle and gas concentrations associated with ETS increase.
* Although the cumulative effect of ETS on outdoor air pollution is relatively small compared with the effects of other sources of pollution, such as automobiles, ETS concentrations can build up outdoors in the vicinity of smokers.
* The emission rate of a cigarette depends on the type of tobacco, density of its packaging, type of wrapping paper and puffing rate of the smoke.
* Emission rates of side stream smoke are greater than those of main stream smoke, thus a person standing a short dis­tance from a cigarette is often exposed to more pollution than is the smoker.
* ETS contributes to the buildup of gas and particle con­centrations indoors. Par­ticle concentrations in homes with a cigarette smoker are up to three times those in homes without a smoker.
* The health effects of smoking include the death from direct smoking related illness; most of the remaining direct smoking-related deaths are due to cancer of the pancreas, esophagus, urinary tract, and stomach.Health effects studies suggest that short-term expo­sure to ETS results in eye, nose, and throat irritation for most individuals, and allergic skin reactions for some
* ETS also elevates symptoms for people who have asthma and may induce asthma in some children. ETS exposure has also been linked to lower respiratory tract illness. Children exposed to ETS are hospitalized more often than children who are not exposed .ETS may cause up to 17 percent of lung cancers among nonsmokers. 30-percent increase in the cancer risk to women whose husbands smoked. The brain cancer tumors are also linked to ETS.
* Long-term exposure also results in cardiovascular disease and pulmonary malfunction, contributing to further mortality.

Indoor Solid Biofuel and Coal Burning

* One of the leading causes of death worldwide is the indoor burning of solid bio-fuels and coal for home heating and cooking. Such burning is carried out by large segments of the population in many developing countries.
* **Solid bio-fuels** used for home heating and cooking are generally wood, grass, agricultural waste, and dung. The use of solid bio-­fuels is often favored over the use of kerosene or other fossil fuels due to the lower price or better availability of bio-fuels, particularly in places such as sub-Saharan Africa.
* Indoor fuel burning kills about 1.6 million people prematurely each year, with 56 percent of the deaths population at risk of air pollution related disease or mortality.
* Indoor PM levels during burn­ing are ten to fifty times higher than recommended safe values. Women and children are disproportionately affected because they spend more time near the fires than do adult men.
* Whereas indoor air pollution mor­tality causes about 2.7 percent of all deaths worldwide annually, it is responsible for about 3.7 percent of such mortality in developing countries.
* Most deaths from indoor fuel burning are due to pneu­monia, chronic respiratory disease, and lung cancer.
* Indoor smoke significantly increases the risk of pneu­monia primarily among those 5 years old and younger.
* Exposure to smoke doubles the risk of pneumonia; Indoor smoke also strongly increases the risk of chronic respi­ratory disease and lung cancer, primarily among adults older than 30 years.
* In addition, women exposed to indoor smoke have three times the chance of contract­ing **chronic obstructive pulmonary disease (COPD),** such as chronic bronchitis, than do women who cook with cleaner fuels. Smoke exposure to men doubles their risk of COPD.
* The ultimate solution to the problems associated with indoor fuel burning is to replace wood- and coal-burning stoves and heaters with electric heaters and/or to ven­tilate smoke exhaust better. This is not a technological barrier to overcome, but an economic and social barrier, because many societies are resistant to change.

**Sick Building Syndrome**

* In some workplaces, employees experience an unusu­ally high rate of headaches, nausea, nasal and chest congestion, eye and throat problems, fatigue, fever, muscle pain, dizziness, and dry skin. These symptoms, present during working hours, often improve after a per­son leaves work. The situation described is called **sick building syndrome (SBS).**
* The cause of SBS is not certain, but it may be due to certain VOCs, inadequate building ventilation systems, or molds. SBS may also be caused by enhanced stress levels and heavy work­loads, or a combination of psychological and chemical factors.
* SBS may alternatively be caused by exposure to many pollutants in low doses simultaneously. This con­dition is referred to as **multiple chemical sensitivity (MCS).**
* People who are exposed over a long period of time to low levels of many chemicals due to poor ventilation in an office building can have reactions that people without MCS usually tolerate.
* Statistically, one-third of people working in a sealed building may be sen­sitive to one or more common chemicals.
* Triggers for MCS include tobacco smoke, perfume, traffic exhaust, nail polish remover, newspaper ink, hair spray, paint thinner, paint, insecticide, artificial colors and sweet­eners, carpeting, adhesive tape, flame retardant, felt-tip pens, and chlorine

**Personal Clouds**

* Concentrations of aerosol particles and gases measured in the vicinity of an individual who is indoors are often greater than are concentrations measured from a station­ary indoor monitor away from the individual.
* The rel­atively high concentration of pollution measured near an individual is called a **personal cloud**. A personal cloud may arise when a person's movement stirs up gases and particles on clothes and nearby sur­faces, increasing pollutant concentrations.
* People also release thermal-IR radiation, which rises and thus stirs and lifts pollutants.
* Personal cloud concen­trations increased to six and seventeen times, respec­tively, those of background values when activities such as dusting, folding clothes and blankets, and making a bed were performed.
* Personal clouds cause addi­tional health impacts not considered when stationary monitors are used to measure pollutant concentrations.

**Regulation of Indoor Air Pollution**

* Worldwide, many countries regulate indoor air pollutant concentrations in workplaces, public buildings, and schools; however, few enforceable regulations exist inresidences. In addition, indoor and some outdoor smok­ing regulations have been enacted in more than 100 countries.
* Aside from smoking regulations, regulatory stan­dards for individual pollutant concentrations in indoor workplaces are set by administrations. Indoor standards exist for more than 150 compounds.
* The rea­son is that outdoor standards are designed to protect the entire population, particularly infants and people afflicted with disease or illness. Indoor standards are designed to protect workers, who are assumed to be healthier than is the average person.
* Stringent outdoor standards for nitrogen dioxide are set because it is a precursor to photochemical smog. Because UV sunlight does not penetrate indoors, nitrogen dioxide does not produce ozone indoors, and indoor regulations of nitrogen diox­ide as a smog precursor are not necessary.
* Indoor stan­dards for nitrogen dioxide are based solely on health concerns.

Summary

* People spend most of their time indoors; thus, the qual­ity of indoor air has a significant impact on human health risk.
* Indoor air contains many of the same pollutants as outdoor air, but pollution concentrations in indoor and outdoor air usually differ.
* Although indoor mixing ratios of ozone and sulfur dioxide are usually less than are those outdoors, indoor mixing ratios of formalde­hyde are usually greater than are those outdoors.
* Indoor mixing ratios of carbon monoxide and nitrogen dioxide are generally the same as or less than are those outdoors, unless appliances or other indoor combustion sources are turned on.
* Indoor concentrations of radon, asbestos, and ETS, when present, are usually greater than are those outdoors, giving rise to potentially serious health problems for people exposed to these pollutants indoors.
* Indoor air also contains VOCs, allergens, fungi, bacte­ria, and viruses. A major source of human mortality and illness worldwide is the indoor burning of solid bio-fuels and coal for home heating and cooking. This problem could be mitigated with current technologies.
* Indoor air is regulated only in the workplace and in public buildings; residential air is not regulated.

Problems

* Why are ozone mixing ratios almost always lower indoors than outdoors?
* Why are workplace standards for pollutant con­centrations generally less stringent than standards for outdoor air?
* What would be the volume mixing ratio (ppmv) of carbon monoxide and the mass concentration (μg m-3) of particles if ten cigarettes were smoked in a 5 x 10 x 3-m room? How do these values compare with the U.S. federal primary 1-hour standard for CO (g) and 24-hour average standard for PM (Table 8.2)? Based on the results, which pollutant do you believe is more of a cause for concern with respect to indoor air qual­ity? Assume that the dry air partial pressure is 1,013 hPa and the temperature is 298 K, and use cigarette emission rates from Table 9.2.
* Why is radium less of a concern than radon?
* Why is removing asbestos from buildings often more dangerous than leaving it alone?
* Why does the gas-phase chemical decay of organic   
  compounds generally take longer indoors than outdoors?
* Identify three methods that could be used to reduce indoor pollution or its exposure due to the indoor burn­ing of solid bio-fuels and coal for home heating *and* cooking.
* Identify five indoor activities that could increase your personal cloud concentration of air pollution.

Topics

* Investigation of the air quality of the drinking places in Rwanda during night
* The emission from bricks fabrication in Rwanda ( the use of non dried wood contribute more to emission)