1.8 STACK SAMPLING AND ANALYSIS OF PARTICULATE AND GASEOUS POLLUTANTS

Air sampling is the process of capturing contaminants in a known volume of air. The airborne contaminants are measured and compared against the volume of air and the results are stated as a concentration, usually as milligrams per cubic meter or parts per million.

- There are two main types of air sampling that can be conducted to estimate the levels of workers' exposure to a certain contaminants.

    1. Stationary or area monitoring
    2. Personal chemical exposure monitoring.

- Personal exposure monitoring measures an individual employee's exposure to a chemical or contaminant and area monitoring measures the concentration of a substance in a given area.

Levels of airborne contaminants can be compared with the following guidelines and standards:

The permissible exposure limit (PEL or OSHA PEL)

- It is a legal limit in the United States for exposure of an employee to a chemical substance or physical agent such as high level noise. Permissible exposure limits are established by the Occupational Safety and Health Administration (OSHA). Most of OSHA's PELs were issued shortly after adoption of the Occupational Safety and Health (OSH) Act in 1970.

Threshold limits value:

- The TLV for chemical substances is defined as a concentration in air, typically for inhalation or skin exposure. Its units are in parts per million (ppm) for gases and in milligrams per cubic meter (mg/m3) for particulates such as dust, smoke and mist. The basic formula for converting between ppm and mg/m3 for gases is ppm = (mg/m^3) * 24.45 / molecular weight. This formula is not applicable to airborne particles.

Three types of TLVs for chemical substances are defined:

- Threshold limit value − time-weighted average (TLV-TWA): average exposure on the basis of a 8h/day, 40h/week work schedule
- Threshold limit value − short-term exposure limit (TLV-STEL): A 15-minute TWA exposure that should not be exceeded at any time during a workday, even if the 8-hour TWA is within the TLV-TWA.
- Threshold limit value − ceiling limit (TLV-C): absolute exposure limit that should not be exceeded at any time
- There are TLVs for physical agents as well as chemical substances. TLVs for physical agents include those for noise exposure, vibration, ionizing and non-ionizing radiation exposure and heat and cold stress.

Recommended exposure limit (REL):

- It is an occupational exposure limit that has been recommended by the United States National Institute for Occupational Safety and Health
- These levels are the exposure that, in the judgment of NIOSH,will not cause adverse health effects in most workers.

Basic Principles of Sampling and Analysis

1. The components of the air pollution monitoring system includes the,
   - Collection or sampling of pollutants both from the ambient air and from specific sources.
   - The analysis or measurement of the pollutant concentration.
   - The reporting and use of the information collected.
2. Emissions data collected from point sources are used to determine compliance with air pollution regulations, determine the effectiveness of air pollution control technology, evaluate production efficiencies, and support scientific research.

3. The EPA has established ambient air monitoring methods for the criteria pollutants, as well as for Toxic Organic (TO) compounds and In-Organic (IO) compounds.
4. The methods specify precise procedures that must be followed for any monitoring activity related to the compliance provisions of the Clean Air Act.
5. The procedures regulate sampling, analysis, calibration of instruments and calculation of emissions.
6. The concentration is expressed in terms of mass per unit volume, usually micrograms per cubic meter ($\mu g/m^3$).

Sampling Guidelines

Survey for preliminary information

During ambient air pollutants sampling, it is also necessary to collect information on qualitative and quantitative data on the local sources of air pollution, topography, population distribution, land use pattern, climatology, etc., depending upon the objectives of the survey or measurement campaign.

Example:

An area map to locate pollution sources and monitoring, locations, sources of pollution situated at far distances, etc., and other relevant data that describe the behaviour of the atmosphere for a specific pollutant to be sampled may also be required.

- It includes:
  1. Selection of sampling procedures including procedures for analysis of sampler
  2. Sampling locations
  3. Period of sampling, frequency of sampling and duration
  4. Auxiliary measurements (including meteorological parameters)
  5. Processing of data.

Selection of Sampling Procedure

There are two types of sampling

- ❑ Continuous
- ❑ Time averaged insitu sampling

1. Continuous Sampling

Continuous sampling is carried out by automatic sensors, optical or electrochemical and spectroscopic methods which produce continuous records of concentration values.

2. Time Averaged in-Sampling

- The specific time-averaged concentration data can then be obtained from continuous records.
- Time-averaged data can also be obtained by sampling for a short time i.e., by sampling a known volume of air for the required averaging time.
- Samples are then analyzed by establishing physical, chemical, and biological methods for the concentration values which are the effective average over the period of sampling.

Sampling Locations

- Sampling locations are in general governed by factors like objectives, method of sampling and resources available.
- If the objective is to study health hazards and material damages, then locations should ne kept close to the objects.
  - ❑ Where the effects are being studied and should be kept at breathing level in the population centres, hospitals, schools, etc.
- For vegetation, it should be at foliage level.
- For background concentration, sampling location should be away from the sources of pollution.
- Fit can also be done by gridding the entire area to get statistically recommended values.
- The number of locations, however, depends upon the variability of concentration over the area under survey.
- A spot checking may be done to decide the location besides considering practical factors.

- Period of sampling, frequency and duration: Period,, frequency and duration of sampling should be appropriate to the objectives of the study.
- It should be such that the measured quantities are trapped in the sample at the end of the sampling.
- It is preferable to observe a sampling period consistent with the average times for which air quality standards of the given pollutants are specified.

Sources and Ambient sampling analysis:

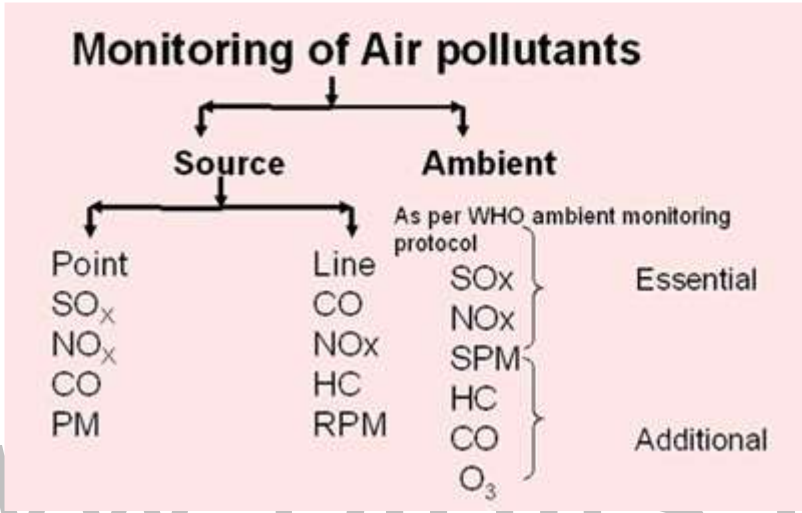


Figure 1.8.1 Sources and Ambient sampling analysis

[Source: https://images.app.goo.gl/GNYTY9nZER5McWYNA]

Most frequently occurring pollutants in an urban environment are particulate matters (suspended particulate matter i.e. SPM and respirable suspended particulate matter i.e. RSPM), carbon monoxide (CO), hydrocarbons (HC), sulfur dioxide (SO2), nitrogen dioxide (NO2), ozone (O3) and photochemical oxidants.

Source Monitoring Instruments:

- Pollutants
- Velocity
- Temperature
- Pressure

- The recommended criteria for siting the monitoring stations :

- The site is dependent upon the use/purpose of the results of the monitoring programs.
- The monitoring should be carried out with a purpose of compliance of air quality standards.
- Monitoring must be able to evaluate impacts of new/existing air pollution sources.
- Monitoring must be able to evaluate impacts of hazards due to accidental release of chemicals.
- Monitoring data may be used for research purpose.

Types of ambient monitoring stations:

Station type	**Description**
Type A	Downtown pedestrian exposure station- In central business districts, in congested areas, surrounding by buildings, many pedestrians, average traffic flow > vehicles per day. Location of station- 0.5 m from curve; height 2.5 to 3.5 m from the ground.
Type B	Downtown neighborhood exposure stations- In central business districts but not congested areas, less high rise buildings, average vehicles < 500 vehicles per day. Typical locations like parks, malls, landscapes areas etc.Location of station- 0.5 m from curve; height 2.5 to 3.5 m from the ground.
Type C	Residential population exposure station – In the midst of the residential areas or sub-urban areas but not in central business districts. The station should be more than 100 m away from any street.
Type D	Mesoscale stations – At appropriate height to collect meteorological and air quality data at upper elevation;

	main purpose to collect the trend of data variations not human exposure.Location – roof top of tall buildings or broadcasting towers.
Type E	Non-urban stations – In remote non-urban areas, no traffic, no industrial activity. Main purpose to monitor trend analysis.
Type F	Specialized source survey stations – to determine the impact on air quality at specified location by an air pollution source under scrutiny.

Table1.8.1Types of ambient monitoring stations

Frequency of data collection:

Gaseous pollutants: continuous monitoring

Particulates: once every three day

Number of stations:

- Minimum number is three.
- The location is dependent upon the wind rose diagram that gives predominant wind directions and speed.
- One station must be at upstream of predominant wind direction and other two must at downstream pre dominant wind direction.
- More than three stations can also be established depending upon the area of coverage.

Components of ambient air sampling systems:

Four main components are:

1.Inlet manifold

2.Air mover

3.Collection medium

4. Flow measurement device

Characteristics for ambient air sampling systems:

Five main characteristics are:

1.Collection efficiency

2.Sample stability

3.Recovery

4. Minimal interference

5. Understanding the mechanism of collection

Basic considerations for sampling:

- Sample must be representative in terms of time, location, and conditions to be studied.
- Sample must be large enough for accurate analysis.
- The sampling rate must be such as to provide maximum efficiency of collection.
- Duration of sampling must accurately reflect the fluctuations in pollution levels i.e. whether 1-hourly, 4-hourly, 6-hourly, 8-hourly, 24-hourly sampling.
- Continuous sampling is preferred.
- Pollutants must not be altered or modified during collection.

Errors in sampling by HVS:

- Particulates may be lost in sampling manifold – so not too long or too twisted manifold must be used.
- If 'isokinetic' conditioned are not maintained, biased results may be obtained for particulate matters.

Advantages of HVS:

- High flow rate at low pressure drop

- High particulate storage capacity
- No moisture regain
- High collection efficiency
- Low cost
- Not appreciable increase in air flow resistance
- Filter is 99% efficient and can collect the particles as fine as 0.3 µm
- Absorption principle is 99% efficient in collecting the gases.

1.2 AIR POLLUTION

Definition of Air Pollution:

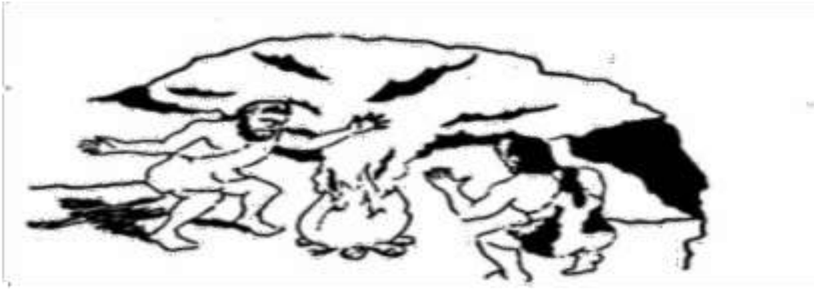
Air pollution is defined as the presence of any solids, liquid or gaseous matter present in the atmosphere in such concentrations that may or tend to be injurious to human beings or other living creatures, plants, vegetation.

An average human being requires 12KG of air / day

This is equal to 15 times greater than food / day

SCOPE OR HISTORY OF AIR POLLUTIONS:

- Air pollution has been a public health problem since the discovery of fire. In fact, incidents and episodes of air pollution have been documented throughout history.
- In ancient times, people used fire inside their caves and huts, often filling the air with harmful smoke.
- The Roman philosopher Seneca noted the “heavy air of Rome” in 61 A.D., and King Edward I strictly prohibited coal burning in London in 1273.
- The origin of modern air pollution problems can be traced to eighteenth century England and the birth of the Industrial Revolution.
- As manufacturing replaced predominantly agricultural activities, populations shifted from the countryside to the city. What resulted was disastrous, as burgeoning population strained rudimentary public utilities and services.



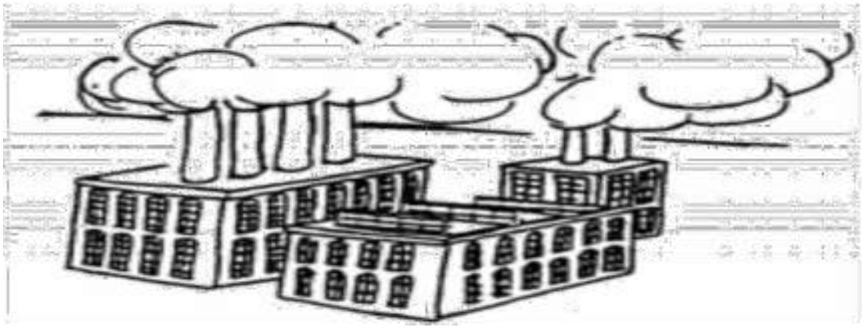


Figure 1.2.1 Smoke, produced by burning coal and wood, was the earliest form of air pollution. Smoke and ash produced by power plants contributed significantly to the problem of air pollution in the late 19th and early 20th centuries.

[source:https://images.app.goo.gl/nFbgJBTQvq3kQ5jy7]

- By 1940, air pollution in the United States and emerging public opinion pressured government regulators to act. Smog formed around Los Angeles, while other metropolitan areas around the country began to report degradations in air quality and visibility. Growing familiarity with environmental issues and increased public pressure hastened federal and state action.
- California was the first state to pass air pollution regulations. Shortly after California acted in 1947, the federal government convened the first National Air Pollution Symposium composed of the leading environmental specialists and government representatives of the day. This landmark symposium marked the introduction of federal government involvement in environmental regulation.

In 1955, upheld by strong public support and improved science, Congress passed its first environmental legislation. From these meager beginnings the U.S.

Environmental Protection Agency and an effective public policy toward the environment were instituted.

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Scales of Air Pollution:

Air pollution problems may occur on three scales:

i. Micro scale

Micro-scale problems range from those covering less than a centimeter to those the size of a house or slightly larger (few meters to 100s of meter).

ii. Meso-scale

Meso-scale air pollution problems are those of a few hectares up to the size of a city or county (local-to-regional).

iii. Macro scale.

Macro-scale problems extend from counties to states, nations, and in the broadest sense, the globe (regional-to continental scale)

1.5 EFFECTS OF AIR POLLUTION ON HUMANS

People experience a wide range of health effects from being exposed to air pollution. Effects can be broken down into short-term effects and long-term effects.

Short-term effects, which are temporary, include illnesses such as pneumonia or bronchitis. They also include discomfort such as irritation to the nose, throat, eyes, or skin. Air pollution can also cause headaches, dizziness, and nausea. Bad smells made by factories, garbage, or sewer systems are considered air pollution, too these odors are less serious but still unpleasant.

Long-term effects of air pollution can last for years or for an entire lifetime. They can even lead to a person's death. Long-term health effects from air pollution include heart, lung cancer, disease and respiratory diseases such as emphysema. Air pollution can also cause long-term damage to people's nerves, brain, kidneys, liver, and other organs. Some scientists suspect air pollutants cause birth defects. Nearly 2.5 million people die worldwide each year from the effects of outdoor or indoor air pollution.

Health Effects of Sulfur Dioxide:

Sulfur dioxide irritates the skin and mucous membranes of the eyes, nose, throat, and lungs. High concentrations of SO_2 can cause inflammation and irritation of the respiratory system, especially during heavy physical activity. The resulting symptoms can include pain when taking a deep breath, coughing, throat irritation, and breathing difficulties. High concentrations of SO_2 can affect lung function, worsen asthma attacks, and worsen existing heart disease in sensitive groups. This gas can also react with other chemicals in the air and change to a small particle that can get into the lungs and cause similar health effects.

Health Effects of Nitrogen Dioxide:

Breathing air with a high concentration of NO_2 can irritate airways in the human respiratory system. Such exposures over short periods can aggravate respiratory diseases, particularly asthma, leading to respiratory symptoms (such as coughing, wheezing or difficulty breathing), hospital admissions and visits to emergency rooms

Longer exposures to elevated concentrations of NO_2 may contribute to the development of asthma and potentially increase susceptibility to respiratory infections. People with asthma, as well as children and the elderly are generally at greater risk for the health effects of NO_2.

NO_2 along with other NO_x reacts with other chemicals in the air to form both particulate matter and ozone. Both of these are also harmful when inhaled due to effects on the respiratory system.

Health Effects of Particulate Matter:

The size of particles is directly linked to their potential for causing health problems. Small particles less than 10 micrometers in diameter pose the greatest problems, because they can get deep into your lungs, and some may even get into your bloodstream.

Exposure to such particles can affect both your lungs and your heart. Numerous scientific studies have linked particle pollution exposure to a variety of problems, including:

- Premature death in people with heart or lung disease
- Nonfatal heart attacks
- Irregular heartbeat
- Aggravated asthma
- Decreased lung function
- Increased respiratory symptoms, such as irritation of the airways, coughing or difficulty breathing.
- People with heart or lung diseases, children, and older adults are the most likely to be affected by particle pollution exposure.

Health Effects of Carbon monoxide:

It is a colorless, odorless, tasteless, and toxic air pollutant; The largest anthropogenic source of CO is vehicle emissions, Breathing high concentrations of carbon monoxide leads to reduced oxygen (O2) transport by hemoglobin and has health effects that include headaches, increased risk of chest pain for the persons with heart diseases.

Carbon monoxide is a toxic gas that you cannot see or smell, CO is given off whenever fuel or other carbon-based materials are burned, vehicle emissions increase unhealthful ambient CO concentrations, but with the introduction of emissions controls, particularly automotive catalysts, estimated CO emissions from all sources decreased by 21%, The locations that continue to have high concentrations of CO contain high pollution.

When the engines and vehicle emissions-control equipment operate less efficiently, The combustion is less complete, and catalysts take longer to become fully operational, So, The products of incomplete combustion are formed in higher concentrations. Carbon monoxide is a dangerous, poisonous substance if the people are exposed to it in high quantities, The industrial processes where carbon monoxide may be produced include metal manufacturing, the electricity supply, mining metal ore and coal, food manufacturing, extracting oil and gas from land or sea, The production of chemicals, cement lime, plaster and concrete manufacturing, and petroleum refining.

Health Effects of Ozone:

- Cause coughing and sore or scratchy throat.
- Make it more difficult to breathe deeply and vigorously and cause pain when taking a deep breath.
- Inflame and damage the airways.
- Make the lungs more susceptible to infection.
- Aggravate lung diseases such as asthma, emphysema, and chronic bronchitis.
- Increase the frequency of asthma attacks.

Health Effects of Lead:

Depending on the level of exposure, lead can adversely affect the nervous system, kidney function, immune system, reproductive and developmental systems and the cardiovascular system. Lead exposure also affects the oxygen carrying capacity of the blood. The lead effects most likely to be encountered in current populations are neurological effects in children.

EFFECTS OF AIR POLLUTIONS ON MATERIALS:

- The damage due to air pollution on materials is really a serious concern since the service life of buildings is remarkably reduced. It is true that the intensity of manmade pollutants on building degradation is more than the impact of natural pollutants.
- Most importantly the affects of soiling, degradation, corrosion and erosion caused by sulphur dioxide are very much serious.
- The effect of air pollution on materials may be seen in terms of discoloration, material loss, structural failing and soiling.
- Both discoloration and structural failure due to air pollution on buildings may be insignificant and that may not involve huge coasts. But the effect of corrosion due to acidic deposition costs a lot.
- Especially the effect of sulphur dioxide and nitrogen dioxide emissions is very much significant.
- The effect of calcium sulphate has been very significant and may be continued for fairly long time.
- When calcium carbonate dissolves in sulphuric acid leads to the formation of calcium sulphate. The calcium sulphate when it falls on stone breaks the surface of the building blocks.
- The acid rain and photochemical smog affect metals and buildings .Acid rain pollutes the soil and water sources.
- Acidic products of the air pollutant cause disintegration of textile, paper. Many small industrial units and sources of locomotive pollutants have been sifted to save the famous marble structure, Taj Mahal at Agra.
- Hydrogen sulphide decolorizes silver and lead paints. Ozone oxidizes rubber goods.

1.6 THE EFFECTS OF AIR POLLUTION ON PLANT

Pollution enters the environment from diffuse sources. The causes can be outright, such as the emissions from a coal-burning power plant. Other times, the source may be hard to identify, such as nonpoint source pollution (NSP), where there can be several contributors contaminating surface water. Pollutants can be substances, like pesticides, that do not naturally occur in the environment. Naturally occurring substances also carry risks by disrupting the chemical balance in the air or water. A pollutant, therefore, is any substance that can cause harm. The effects of pollutants can easily be detected on plant structure.

Leaf Structure

Pollutants such as ground-level ozone physically damage leaves by causing chlorosis, or an abnormal yellowing of the leaves, resulting from a deficiency of chlorophyll. Chlorophyll is vital for photosynthesis. This molecule fuels the food-making process by capturing energy from the sun. Without chlorophyll, a plant cannot manufacture food or energy. In areas with high concentrations of ozone, parts of the leaf will die as a result of exposure.

Delayed Flowering

Exposure to vehicle exhaust impacts plant structure by delaying the flowering of exposed plants, as reported in a study published in the journal "Environmental Pollution." A stressed plant will not flower but, rather, will use its resources to survive the threat. The study also noted an increase in senescence or plant aging. Because of the concentration of emissions, plants in urban environments were identified to be at the greatest risk.

Root Damage

Whether the source is acid rain caused by sulfur dioxide emissions or acidic mine drainage from abandoned mines, acidic soils create a complex scenario that results in plants' failure to thrive. Acidic conditions mobilize aluminum ions, normally present in a non-harmful form in the soil. The mobilized aluminum damages root systems and prevents calcium uptake. The result is an overall slowing of plant growth from a lack of nutrients. Aluminum and other heavy metals can further impact plant structure by reducing soil bacteria. A reduction in soil micro-organisms prevents the breakdown of organic matter, resulting in a reduction of available nutrients.

Stomata Damage

Stomata are the tiny pores found on leaves. Their function is to act as sites of gas exchange between the plant and the atmosphere. Carbon dioxide is taken up through the stomata and oxygen released during photosynthesis. Pollution negatively impacts this plant structure by reducing the size of the stomata, as reported in a 2005 study published in the journal "Cellular and Molecular Life Sciences." When gas exchange is compromised, photosynthesis slows.

EEFECTS OF AIR POLLUTION ON ANIMALS:

- Animals, or wildlife, are vulnerable to harm from air pollution. Pollutant issues of concern include acid rain, heavy metals, persistent organic pollutants (POPs) and other toxic substances.
- Insects, worms, clams, fish, birds and mammals, all interact with their environment in different ways. As a result, each animal's exposure and vulnerability to the impacts of air pollution can be equally different.
- Air pollution can harm wildlife in two main ways.
- It affects the quality of the environment or habitat in which they live
- It affects the availability and quality of the food supply

Air pollution harms habitat:

- Habitat is the place in which animals live, including in and on the soil, as well as in water.

- Acid rain can change the chemistry and quality of soils and water. For example, water bodies can become too acidic for some animals to survive or have normal physiological functions.
- Alternatively, acid rain can increase the release of heavy metals, such as aluminum, from soils into water habitats.
- The result is higher availability of heavy metals in the water column, which are very toxic to many animals including fish.
- Some heavy metals, such as mercury, can be transported in the air long distances away from emission sources.

Although not as well understood, other forms of air pollution, such as smog, particulate matter, and ground-level ozone, to mention a few, likely affect wildlife health in similar ways to human health including harming the lungs and cardiovascular systems. An animal's vulnerability to air pollution is influenced by how it breathes - whether it uses lungs, gills or some other form of gas exchange, such as passive diffusion across the surface of the skin.

Air pollution harms food supply and quality :

- Many heavy metals, toxics, persistent organic pollutants (POPs) and other air pollutants affect wildlife by entering the food chain and damaging the supply and quality of food.
- Once consumed, many of these pollutants collect and are stored within the animal's tissues.
- As animals are eaten by other animals along the food chain, these pollutants continue to collect and increase in concentration. This process is called bioaccumulation.
- Top level predators such as bears and eagles, among many others, are particularly susceptible to the bioaccumulation of these types of air pollutants.

For example, mercury is of great enough concern that it is recommended we limit how often we eat certain types of fish that may contain high levels of heavy metal.

- Air pollutants can poison wildlife through the disruption of endocrine function, organ injury, increased vulnerability to stresses and diseases, lower reproductive success, and possible death.
- Changes in the abundance of any species because of air pollution can dramatically influence the abundance and health of dependent species.

For example, the loss of some species of fish because of higher levels of aluminum may allow insect populations to increase, which may benefit certain types of ducks that feed on insects. But the same loss of fish could be detrimental to eagles, ospreys and many other animals that depend on fish as a source of food.

- It is very difficult to fully understand and appreciate how far and in what ways such changes will affect other species throughout the ecosystem, including humans.

EFFECTS OF AIR POLLUTION ON AESTHETIC VALUE AND VISIBILITY:

- Air pollution can create a white or brown haze that affects how far we can see.
- It also affects how well we are able to see the colors, forms, and textures of natural and historic vistas.
- Haze is caused when sunlight encounters tiny particles in the air.
- The particles scatter light into and out of the sight path and absorb some light before it reaches your eyes.
- The more particles in the air, the more scattering and absorption of light to reduce the clarity and colors of what you see. Some types of particles scatter more light, especially when it is humid.
- Haze is mostly caused by air pollution from human activity including industry, power generation, transportation, and agriculture.

- Natural haze from dust, wildfires, and more also occurs in many parks.
- On hazy days, air pollution can be visible as a plume, layered haze, or uniform haze. A plume is a column-shaped layer of air pollution coming from a point source (such as a smoke stack).
- Layered haze is any confined layer of pollutants that creates a contrast between that layer and either the sky or landscape behind it.
- Plumes and layers can mix with the surrounding atmosphere, creating a uniform haze or overall decline in air clarity.
- Plumes and layered haze are more common during cold winter months when the atmosphere moves less.
- Uniform haze occurs most often when warm air causes atmospheric pollutants to become well mixed.

1.4 SOURCES AND EFFECTS OF AIR POLLUTANTS

Air pollution is a growing problem around the world, with individuals and nations like pumping enormous volumes of harmful pollutants into the atmosphere every day. These pollutants are not only dangerous to the health and wellbeing of plants, animals, and people, but they are also a major contributor to recent climate shifts observed across the globe.

Cutting down on the volume of pollutants produced is a crucial step in managing our negative effects on the climate. How can this be achieved? One of the first and most important steps is identifying some of the most common and prevalent pollutants, understanding where they come from, and recognizing their effects. This knowledge will help you to identify the key ways in which you can cut down on air pollution and contribute to a global decline in the volume of pollutants found in the air.

1.Carbon Monoxide (CO)

Carbon Monoxide is a highly toxic and dangerous pollutant, infamous for its lack of identifying color and smell. At one point, this gas was extremely prevalent in homes for use in domestic heating before it was found to be unsuitable, and it has since been replaced by much safer solutions such as natural gas and electricity. However, this gas is far from extinct in human use.

Sources: Most commonly, Carbon Monoxide is produced by combustion engines running without modern catalytic converters. Other common sources of Carbon Monoxide are old gas and fuel appliances, incinerators, and even cigarettes.

Effects: Carbon Monoxide can have a profound effect on the environment as it is extremely poisonous and can contribute to very dangerous ground-level air and ozone conditions.

2.Lead (Pb)

Lead has long been known to be a dangerous substance. Once common place in nearly all gas and aviation fuels, there has since been a tremendous effort to reduce the amount of lead found in these substances. Since the introduction of lead-free gasoline, the volume of lead in the atmosphere has dropped enormously.

Sources: While efforts have been made to remove lead from fuel, it continues to be present in some aircraft fuel. Similarly, the outpouring of lead from metal processing plants and the release of lead from waste processes such as incineration and battery acid production means that there is still enough lead in the air to recognize it as dangerous pollution.

Effects: Lead can not only poison humans, but it also has a profound effect on natural ecosystems. Contaminating air, soil, and water, lead can cause damage to flora and fauna alike.

3. Ozone (O3)

Ozone is not inherently bad. After all, the ozone layer is one of the major protections mankind has against harmful solar radiation. However, ground-level Ozone has become a major problem in recent years.

Sources: Ground-level Ozone is formed by chemical reactions between multiple different oxides found in the air, which – when exposed to sunlight – can form new compounds and leave Ozone as a by-product. The majority of the emissions which make up Ozone come from the usual suspects, such as car exhausts, factory processing, electric utilities and power plants, and even some chemical solvents.

Effects: Ozone is a dangerous substance for most living organisms, and as such, an increase in ground-level Ozone has a notable effect on human health as well as the overall health of multiple ecosystems on land and in the seas.

4. Nitrogen Dioxide (NO2)

Nitrogen Dioxide is one of the oxides which can react to produce Ozone, but that is far from its only negative effect. Nitrogen Dioxide is one of the gases that one most commonly thinks of when considering air pollution: thick, brown, and choking, it is one of the more visibly harmful pollutants.

Sources: Nitrogen Dioxide, like many other pollutants, is most often released into the atmosphere by the burning of fossil fuels in car engines, airplane engines, factories, and power plants.

Effects: In addition to being a choking and obstructive gas in the air, Nitrogen Dioxide also has the propensity to react with other agents to form nitric acid and organic nitrates, contributing to the formation of acid rain.

Needless to say, Nitrogen Oxide has a huge effect on humans, increasing the likelihood of respiratory problems, cancers, and other lung problems. Acid rains produced by Nitrogen Dioxide are extremely harmful to plants and animals across the world and can lead to further problems in water systems.

5.Sulfur Dioxide (SO2)

Sulfur Dioxide is a substance most closely associated with the steam age and locomotives, as the biggest culprit in its production is coal combustion. However, these days are not so far gone as you may have thought.

Sources: To this day, locomotives, ships, planes, and other equipment still produce huge volumes of Sulfur Dioxide. Industrial processes, particularly ore extraction and purification, are also producers of the gas.

Effects: Sulfur Dioxide, like Nitrogen Dioxide, is a compound that often mixes with other pollutants in the air to form harmful acids, but it is also harmful on its own. Common effects of Sulfur Dioxide poisoning are respiratory problems, eye problems, and even heart and circulatory problems. Importantly, Sulfuric Acid, created by the mixing of sulfur with water, is a potent acid that is not only destructive to human property but also to trees, soils, and water systems.

6.Particulate Matter (PM)

Particulate Matter is something a lot more visible and tangible than the components listed above but is no less dangerous or harmful. The matter generally consists of soot, dirt, and chemical by-products produced through combustion or chemical mixing.

Sources: Particle matter is produced by nearly every single process involving chemicals and fuels, as well as more innocuous processes such as farming and road construction. Any process which produces a physical by-product will generally result in particulate matter.

Effects: Particle Matter ranges from annoying to extremely dangerous, often hampering visibility on roads and causing respiratory problems. Particulate Matter is associated with a range of heart, lung, and eye conditions in humans and is also linked to an increased likelihood of developing cancers later in life.

7.Carbon Dioxide

This greenhouse gas is a natural by-product of respiration. It is also associated with the burning of fossil fuel.

Sources: Carbon dioxide is added to the atmosphere naturally when organisms respire or decompose (decay), carbonate rocks are weathered, forest fires occur, and volcanoes erupt. Carbon dioxide is also added to the atmosphere through human activities, such as the burning of fossil fuels and forests and the production of cement.

Effects: Carbon dioxide and its role in the greenhouse effect contribute to air pollution, which causes climate change. Scientists of NOAA believe carbon dioxide pollution is the primary culprit. When the CO2 Emissions released from fossil fuel-burning energy plants combine with moisture in the air, the result is precipitation with high acid content. Carbon dioxide emissions impact human health by displacing oxygen in the atmosphere. Breathing becomes more difficult as carbon dioxide levels rise.

8.Methane

Comes from the gas emitted by livestock and swamps.

Sources: Since the Industrial Revolution, human sources of methane emissions have been growing. The current increase in methane levels has been caused by fossil fuel production and intensive livestock farming. Together these two sources are responsible for 60% of all human methane emissions. Other sources include landfills and waste (16%), biomass burning (11%), rice agriculture (9%) as well as biofuels (4%).

Effects: Methane, when released into the atmosphere before it is burned, is harmful to the environment. It is able to trap heat in the atmosphere, therefore, contributes to climate change. High levels of methane concentrations in the air can reduce the amount of oxygen breathed from the air. It is very dangerous to the human body and can result in suffocation, mood changes, slurred speech, vision problems, memory loss, nausea, vomiting, facial flushing and headache.

9. Chlorofluorocarbons

Once used as propellants in aerosol items and in refrigerants, CFCs have been outlawed due to the hazardous effect on the ozone layer.

Sources: Chlorofluorocarbons, also known as CFCs, consist of chemical compounds made up of chlorine, fluorine and carbon. CFCs have no significant natural sources. CFCs have been used as refrigerants in air conditioners and refrigerators, Halon in aircraft, in aerosol spray cans, in manufacturing foams as industrial solvents, and as cleaning agents in the manufacture of electronics.

Effects: CFCs contribute to the loss of the protective ozone layer, which blocks ultraviolet rays from the sun. This exposes more people to UV radiation, which can cause skin cancer. According to the American Cancer Society, one in five Americans will develop skin cancer in their lifetime.

10. Volatile Organic Compounds (VOCs)

VOCs are emitted into the air from products or processes. For example, Benzene, 1,3-Butadiene are volatile organic compounds.

Sources: The main source of atmospheric benzene in Europe is petrol vehicles, which account for about 70% of emissions. Another 10% comes from the distillation, refining and evaporation of petrol from vehicles. The main source of 1,3-Butadiene is also principally from road traffic, in the combustion process of petrol and diesel vehicles. Unlike benzene it is not a constituent of fuel but is produced through the combustion of olefins. An additional source is from industrial processes such as synthetic rubber manufacture. VOCs can also come from personal care products such as perfume and hair spray, cleaning agents, dry cleaning fluid, paints, lacquers, varnishes, hobby supplies and from copying and printing machines.

Effects: Some VOCs are harmful by themselves, including some that cause cancer. VOCs play a significant role in the formation of ozone and fine particulates in the atmosphere. Under sunlight, VOCs react with nitrogen oxides emitted mainly from vehicles, power plants and industrial activities to form ozone, which in turn helps the formation of fine particulates.

Remedies to Avoid Air Pollution:

- Raise awareness. Whether it be through joining non-profits, activist groups, or even just posting about the matter online, raising people's awareness about air pollution and its causes is an important step in reducing the problem around the world.
- Try to minimize travel in cars and airplanes. While driving is often unavoidable, there are many who could quite easily cut down on their fuel consumption by making use of public transportation or even bikes. Similarly, making use of a more fuel-efficient vehicle is a good way to make the car travel you do undertake much less harmful. Keeping a car serviced and safe will dramatically improve its fuel-efficiency and reduce the volume of emissions it releases. Airplanes are among the worst contributors to air pollution, so consider staying in the country when vacationing.
- Conserve energy where possible. Since electricity production releases a huge number of air pollutants, using as little energy as possible can help minimize the amount produced in any one day. If you spread the message too, you can have a noticeable impact on electricity production. Simply changing light bulbs to energy-efficient alternatives, turning off appliances when not in use,

and reducing the amount of time spent in front of the television or on the computer are good starts.

- Make use of 3 R's. Who wouldn't have heard of 3 words Reduce, Reuse and Recycle Reduce simple means reducing the consumption of goods like plastic bags that can hurt the environment. Reuse means reusing the same thing for some different purposes; like reusing the old jar for storing cereals or pulses. Recycling stands for recycling old items so that they can be made into some useful products again.
- Get your car's engine tune-up. Keeping your car's engine tune-up will make sure that it does not consume more fuel and gives you better mileage.
- Keep tires properly inflated. Cars consume more gasoline when tires are not properly inflated. Keep the air pressure to the optimum level will reduce your impact on the environment.
- Make use of renewable electricity where possible. Installing your own solar panels for even small tasks can help to conserve electricity which would otherwise be provided by power plants.
- Get an energy audit done for your home. Get an energy audit done and ask the auditor about changes that you can make in order to ensure that your home is as energy-efficient as possible. They can give you recommendations that will help you out and even save you money in the long run.
- Consider going green. There are various ways to go green without even spending an extra penny. For e.g.: use the public mode of transportation instead of a car, opt for eco-friendly hotels when going out on a holiday, buy items with less packaging, buy energy-efficient appliances, use daylight as much as possible, avoid buying plastic water bottles, and many more.
- Plant trees and plants, as they can help to increase the amount of breathable air available, and reduce levels of certain pollutants that cause harm to the environment.

1.1 STRUCTURE AND COMPOSITION OF ATMOSPHERE

The Atmosphere

The Earth is enveloped by a deep blanket of gases extending several thousands of kilometers (about 9600kms) above its surface. This gaseous cover of the Earth is known as the atmosphere. It is an integral part of the Earth. It is only a very thin layer of gases. Because of force of Gravity it is inseparable from the Earth.

Significance of the Atmosphere:

- All life forms owe their existence to the atmosphere
- Animals need oxygen and plants need carbon dioxide.
- It is the atmosphere that provides oxygen and carbon dioxide.
- The atmosphere maintains the level of water and radiation in the earth system. In the absence of atmosphere there would have been extremes of temperature at about 260°C between day and night.
- The atmosphere maintains the temperature that suits us.
- It shields us from the sun's ultra violet radiation which is injurious to both plants and animals.
- It acts as a protective wall against the bombardment of meteors.
- The currents, motions, and various other activities on the atmosphere combine together to produce weather.

Structure of the Atmosphere:

- The atmosphere consists of zones or layers arranged like spherical shells divided vertically into five layers based on temperature and altitude above the Earth's surface.

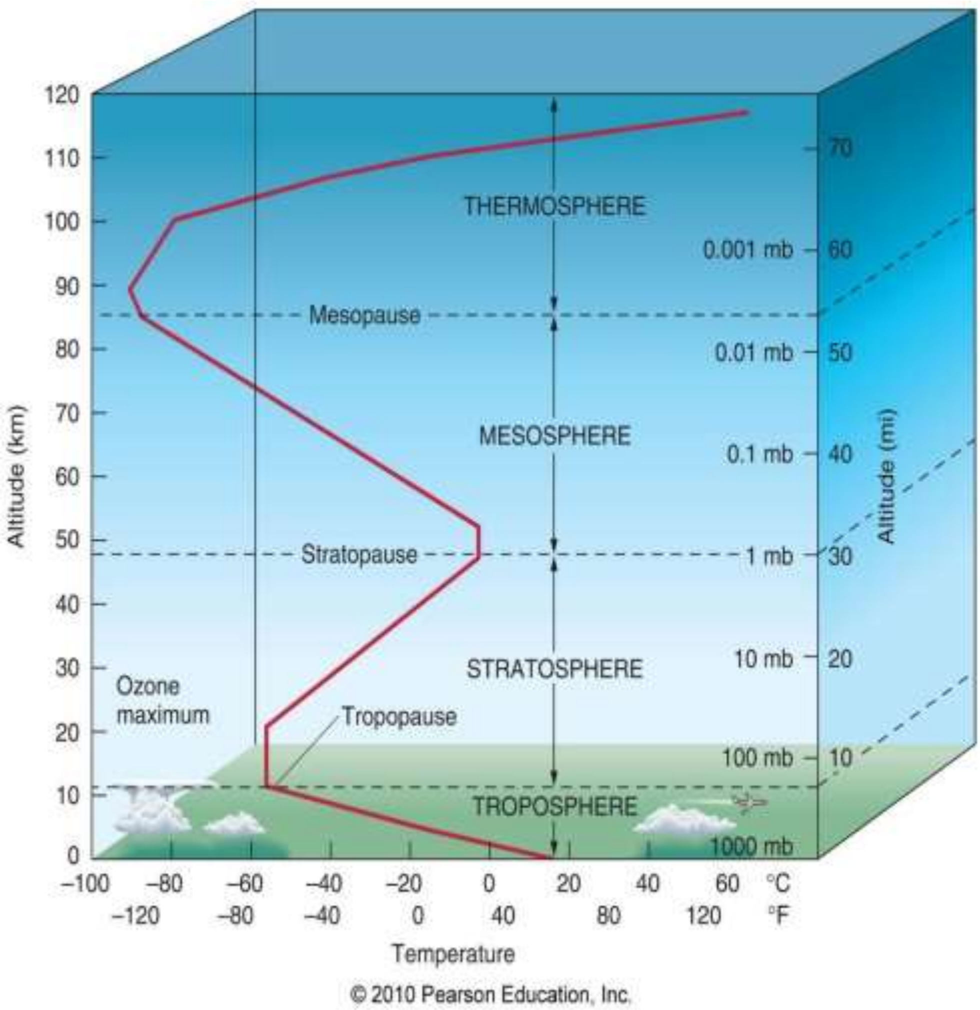

Figure1.1.1 Structure of the atmosphere

[Source: http://unilaggeography2012.blogspot.nl/p/gry-101-introduction-to-physical.html]

Each zone has its own physical and chemical characteristics and properties such as density, pressure, chemical and electrical and temperature properties .The five layers are:

- The Troposphere
- The Stratosphere
- The Mesosphere
- The Thermosphere and Ionosphere
- The Exosphere

The layers in the Atmosphere shown in the fig1.1.2

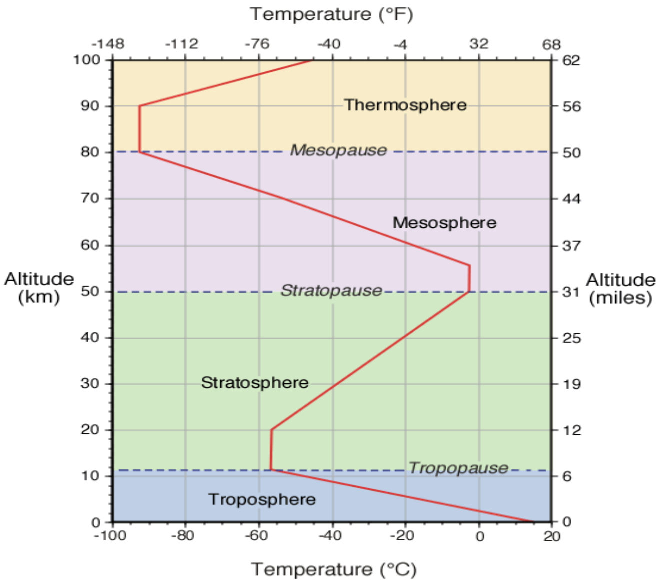

Figure 1.1.2 vertical structure of the atmosphere

[Source:https://www.assignmentpoint.com/wp-content/uploads/2016/09/Vertical-Structure-of-the-Atmosphere.jpg]

Gravity pulls gases toward the Earth's surface, and the whole column of gases exerts a pressure of 1000 hPa at sea level, 1013.25 mb or 29.92 n.Hg. Pressure and Density Decrease with Height.

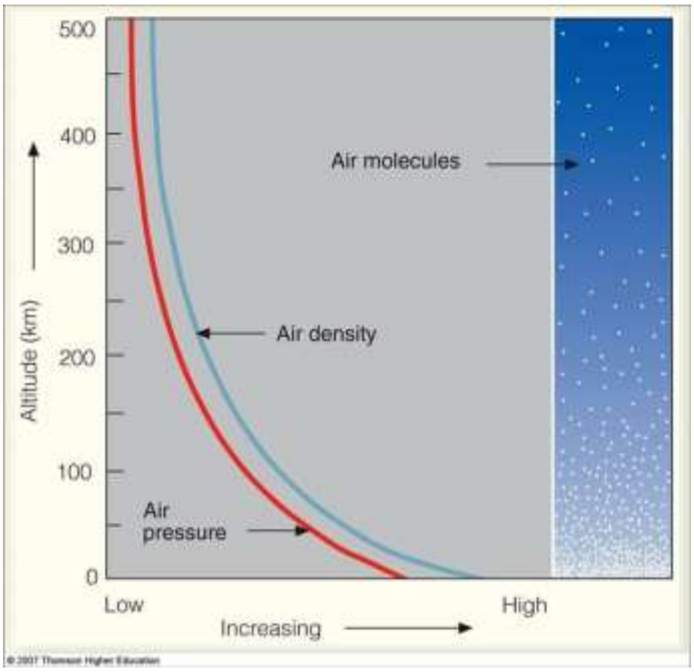

Figure1.1.3 Pressure and Density of Atmosphere

[Source :https://images.app.goo.gl/bYFKZ98YxmDtJv259]

The Troposphere

This is the lowest part of the atmosphere - the part we live in. It contains most of our weather - clouds, rain, snow. In this part of the atmosphere the temperature gets colder as the distance above the earth increases, by about 6.5°C per kilometer. The actual change of temperature with height varies from day to day, depending on the weather.

The troposphere contains about 75% of all of the air in the atmosphere, and almost all of the water vapour (which forms clouds and rain). The decrease in temperature with height is a result of the decreasing pressure. If a parcel of air moves upwards it expands(because of the lower pressure). When air expands it cools. So air higher up is cooler than air lower down.

The lowest part of the troposphere is called the boundary layer. This is where the air motion is determined by the properties of the Earth's surface. Turbulence is generated as the wind blows over the Earth's surface, and by thermals rising from the land as it is heated by the sun. This turbulence redistributes heat and moisture within the boundary layer, as well as pollutants and other constituents of the atmosphere.

The top of the troposphere is called the tropopause. This is lowest at the poles, where it is about 7 - 10 km above the Earth's surface. It is highest (about 17 - 18 km) near the equator.

The Stratosphere

This extends upwards from the tropopause to about 50 km. It contains much of the ozone in the atmosphere. The increase in temperature with height occurs because of absorption of ultraviolet (UV) radiation from the sun by this ozone. Temperatures in the stratosphere are highest over the summer pole, and lowest over the winter pole.

By absorbing dangerous UV radiation, the ozone in the stratosphere protects us from skin cancer and other health damage. However chemicals (called CFCs or freons, and halons) which were once used in refrigerators, spray cans and fire extinguishers have reduced the amount of ozone in the stratosphere, particularly at polar latitudes, leading to the so-called "Antarctic ozone hole".

Now humans have stopped making most of the harmful CFCs we expect the ozone hole will eventually recover over the 21st century, but this is a slow process.

The Mesosphere

The region above the stratosphere is called the mesosphere. Here the temperature again decreases with height, reaching a minimum of about -90°C at the "mesopause".

The Thermosphere and Ionosphere

The thermosphere lies above the mesopause, and is a region in which temperatures again increase with height. This temperature increase is caused by the absorption of energetic ultraviolet and X-Ray radiation from the sun.

The region of the atmosphere above about 80 km is also caused the "ionosphere", since the energetic solar radiation knocks electrons off molecules and atoms, turning them into "ions" with a positive charge. The temperature of the thermosphere varies between night and day and between the seasons, as do the numbers of ions and electrons which are present. The ionosphere reflects and absorbs radio waves, allowing us to receive shortwave radio broadcasts in New Zealand from other parts of the world.

The Exosphere

The region above about 500 km is called the exosphere. It contains mainly oxygen and hydrogen atoms, but there are so few of them that they rarely collide - they follow "ballistic" trajectories under the influence of gravity, and some of them escape right out into space.

COMPOSITION OF ATMOSPHERE:

The three major constituents of Earth's atmosphere are nitrogen, oxygen, and argon.

- Water vapour accounts for roughly 0.25% of the atmosphere by mass.

- The concentration of water vapor (a greenhouse gas) varies significantly from around 10 ppm by volume in the coldest portions of the atmosphere to as much as 5% by volume in hot, humid air masses, and concentrations of other atmospheric gases are typically quoted in terms of dry air (without water vapor).
- The remaining gases are often referred to as trace gases, among which are the greenhouse gases principally carbon dioxide, methane, nitrous oxide, and ozone.
- Besides argon, already mentioned, other noble gases, neon, helium, krypton, and xenon are also present.
- Filtered air includes trace amounts of many other chemical compounds.
- Many substances of natural origin may be present in locally and seasonally variable small amounts as aerosols in an unfiltered air sample, including dust of mineral and organic composition, pollen and spores, sea spray, and volcanic ash.
- Various industrial pollutants also may be present as gases or aerosols, such as chlorine , fluorine compounds and elemental mercury vapor.
- Sulfur compounds such as hydrogen sulfide and sulfur dioxide (SO_2) may be derived from natural sources or from industrial air pollution.
- The atmosphere is composed of
    - Gases
    - Vapor
    - Particulates

The atmosphere is a mixture of many gases. In addition, it contains huge numbers of solid and liquid particles, collectively called aerosols.

The gases in the atmosphere are composed of neutral, uncharged particles. Except for the noble gases, atoms in the gas phase share electrons with other atoms in chemical bonds so that their electron count can approach the more stable filled-shell configuration. The Earth's atmosphere consists of a mixture of noble gas atoms and many kinds of molecules.

Major constituents of dry air, by volume			
Gas		**Volume**	
Name	**Formula**	**in ppm**	**in %**
Nitrogen	N_2	780,840	78.084
Oxygen	O_2	209,460	20.946
Argon	Ar	9,340	0.9340
Carbon dioxide (December, 2020)	CO2	415.00	0.041500
Neon	Ne	18.18	0.001818
Helium	He	5.24	0.000524
Methane	CH_4	1.87	0.000187
Krypton	Kr	1.14	0.000114
Not included in above dry atmosphere:			
Water vapor[(D)]	H_2O	0–30,000[(D)]	0–3%[(E)]

Changes in Composition:

Earth's primordial atmosphere was probably similar to the gas cloud that created the sun and planets. It consisted of hydrogen and helium, along with methane, ammonia, and water. This was a reducing atmosphere. There was no molecular oxygen or other reactive oxides. Over time, some of this first atmosphere, particularly the lighter gases, out gassed and was lost. More water may have arrived with comets colliding on the surface of the planet. Volcanic activity in the early, Earth created major changes with release of water vapor, carbon dioxide, and ammonia along with small quantities of SO_2, H_2S, HCl, N_2, NO_2, He, Ar, and other noble gases.

This produced the second atmosphere. Comet impacts may have increased the amount of water. Water vapor formed clouds. These produced rain. Over a period of thousands of years, the liquid water accumulated as rivers, lakes, and oceans on the Earth's surface. Bodies of liquid water acted as sinks for carbon dioxide. Chemical and biological processes transformed CO_2 gas to carbonate rocks. The nitrogen and argon accumulated in the atmosphere. They do not react with water or other atmospheric components. Oxygen existed in only trace quantities before life began.