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Chemical smog

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Abstract
This article deals with urban air pollution, commonly called smog, and its impacts on ecosystems, agriculture, material substances, and human health. This should be in reference of brief description of the two types of smog (London or sulfurous smog and Los Angeles or EOLSS* smog). The chemistry of smog is reviewed with a focus on the Los Angeles or photochemical type, which is the dominant type impacting urban, regional, and global environment today. The chemical processes that form photochemical smog from the hydrocarbon and nitrogen oxide emissions of combustion processes are briefly reviewed. The importance of the formation of secondary oxidants (e.g., ozone [O3], peroxyacylnitrates [PANs]) and inorganic acids (sulfuric and nitric) in photochemical smog is stressed. These secondary oxidants and acids play important roles in the effects of smog on ecosystems and human health, as well as in agriculture and materials damage on urban, regional, and global scales. The effects of the air pollutants produced in smog formation are also reviewed. The urban-, regional-, and global-scale impacts discussed include human health effects; damage to buildings, plants, and tree foliage; crop yield reduction; visibility loss; precipitation pollution (acid rain); and radiative balance effects including urban heat islands, weather, and climate. The concept of urban climate impacts is introduced and discussed in light of the radiative properties of the gases and aerosols present in urban atmospheres due to smog formation.

Keywords: Chemical smog, Ecosystems, Angeles, hydrocarbon

Introduction

The term smog was first coined in 1905 in a paper by Dr. Henry Antoine Des Voeux to derive from the merging of two words; smoke and fog. Smog is also used to describe the type of fog which has smoke or soot in it. Smog is a yellowish or blackish fog formed mainly by a mixture of pollutants in the atmosphere which consists of fine particles and ground-level ozone. Smog which occurs mainly because of air pollution can also be defined as a mixture of various gases with dust and water vapor. Smog also refers to hazy air that makes breathing difficult.

Smog is a type of intense air pollution. The word "smog" was coined in the early 20th century, and is a contraction (portmanteau) of the words smoke and fog to refer to smoky fog; its opacity, and odor. The word was then intended to refer to what was sometimes known as pea soup fog, a familiar and serious problem in London from the 19th century to the mid-20th century. This kind of visible air pollution is composed of nitrogen oxides, sulphur oxides, ozone, smoke and other particulates. Man-made smog is derived from coal combustion emissions, vehicular emissions, industrial emissions, forest and agricultural fires and photochemical reactions of these emissions.

Smog is often categorized as being either summer smog or winter smog. Summer smog is primarily associated with the photochemical formation of ozone. During the summer season when the temperatures are warmer and there is more sunlight present, photochemical smog is the dominant type of smog formation. During the winter months when the temperatures are colder, and atmospheric inversions are common, there is an increase in coal and other fossil fuel usage to heat homes and buildings. These combustion emissions, together with the lack of pollutant dispersion under inversions, characterize winter smog formation. While photochemical smog is the main smog formation mechanism during summer months, winter smog episodes are still common. Smog formation in general relies on both primary and secondary pollutants. Primary pollutants are emitted directly from a source, such as emissions of sulfur dioxide from coal combustion. Secondary pollutants, such as ozone, are formed when primary pollutants undergo chemical reactions in the atmosphere

- **How Smog is formed?**

The atmospheric pollutants or gases that form smog are released in the air when fuels are burnt. When sunlight and its heat react with these gases and fine particles in the atmosphere, smog is formed. It is purely caused by air pollution. Ground level ozone and fine particles are released in the air due to complex photochemical reactions between volatile organic compounds (VOC), sulfur dioxide (SO_2) and nitrogen oxides (NO_x).

These VOC, SO_2, and NO_x are called precursors. The main sources of these precursors are pollutants released directly into the air by gasoline and diesel-run vehicles, industrial plants and activities, and heating due to human activities.

Smog is often caused by heavy traffic, high temperatures, sunshine, and calm winds. These are a few of the factors behind an increasing level of air pollution in the atmosphere. During the winter months when the wind speeds are low, it helps the smoke and fog to become stagnate at a place forming smog and increasing pollution levels near the ground closer to where people are respiring. It hampers visibility and disturbs the environment.

The time that smog takes to form depends directly on the temperature. Temperature inversions are situations when warm air does not rise instead stays near the ground. During situations of temperature inversions, if the wind is calm,

smog may get trapped and remain over a place for days.
But it is also true that smog is more severe when it occurs farther away from the sources of release of pollutants. This is because the photochemical reactions that causes smog to take place in the air when the released pollutants from heavy traffic drift due to the wind. Smog can thus affect and prove to be dangerous for suburbs, rural areas as well as urban areas or large cities.

- **Type of Smog**

Smog is of two types: (1) Photochemical smog (2) Sulfur smog (London smog)

1. Photochemical smog – commonly formed in urban areas and originates from elevated levels of hydrocarbon vapors and nitrogen oxides in the presence of sunlight,
2. Sulfur smog (London smog) – formed when there is an increased level of sulfur oxides in the atmosphere.

- **Photochemical Smog**

Photochemical smog, as commonly seen in the Los Angeles Basin, is mainly composed of ozone and nitrogen dioxide. During the formation of ozone, nitrogen dioxide from vehicle exhaust is photolyzed by incoming solar radiation to produce nitrogen oxide and an unpaired oxygen atom. The lone oxygen atom then combines with an oxygen molecule to produce ozone. Under normal conditions, the majority of ozone molecules oxidize nitrogen oxide back into nitrogen dioxide, creating a virtual cycle that leads to only a very slight buildup of ozone near ground level. However, when volatile organic compounds (VOCs) are present in the atmosphere, the equation changes entirely. Highly reactive VOCs oxidize nitrogen oxide into nitrogen dioxide without breaking down any ozone molecules in the process. This leads to a proliferation of ozone near ground level and dense smog formation. Although photochemical smog in the United States is mainly associated with the Los Angeles Basin, photochemical smog episodes have been reported in Denver, Philadelphia and New York.

- ***Composition of Photochemical Smog***

The following substances are identified in photochemical smog:

1. Nitrogen Dioxide (NO2) from vehicle exhaust is photolyzed by ultraviolet (UV) radiation (hν) from the sun and decomposes into Nitrogen Oxide (NO) and oxygen radical:

$NO_2+h\nu \rightarrow NO+O$

2. The oxygen radical then reacts with an atmospheric oxygen molecule to create ozone, O3:

$O+O_2 \rightarrow O_3$

3. Under normal conditions, O3 reacts with NO, to produce NO2 and an oxygen molecule:

$O_3+NO \rightarrow O_2+NO_2$

This is a continual cycle that leads only to a temporary increase in net ozone production. To create photochemical smog on the scale observed in Los Angeles, the process must include Volatile organic compounds (VOC's).

4. VOC's react with hydroxide in the atmosphere to create water and a reactive VOC molecule:

$RH+OH. \rightarrow R+H_2O$

5. The reactive VOC can then bind with an oxygen molecule to create an oxidized VOC:

$R+O_2 \rightarrow RO_2$

6. The oxidized VOC can now bond with the nitrogen oxide produced in the earlier set of equations to form nitrogen dioxide and a reactive VOC molecule:

$RO_2+NO \rightarrow RO+NO_2$

In the second set of equations, it is apparent that nitrogen oxide, produced in equation 1, is oxidized in equation 6 without the destruction of any ozone. This means that in the presence of VOCs, equation 3 is essentially eliminated, leading to a large and rapid buildup in the photochemical smog in the lower atmosphere.
In the morning, NO and VOC concentrations are high, as people fill their cars with gas and drive to work. By midmorning, VOC's begin to oxidize NO into NO2, thus reducing their respective concentrations. At midday, NO2 concentrations peak just before solar radiation becomes intense enough to photolyze the NO2 bond, releasing an oxygen atom that quickly gets converted into O3. By late afternoon, peak concentrations of photochemical smog are present.

- ***Controlling Photochemical Smog***

Every new vehicle sold must include a catalytic converter to reduce photochemical emissions. Catalytic converters force CO and incompletely combusted hydrocarbons to react with a metal catalyst, typically platinum, to produce CO2 and H2O. Additionally, catalytic converters reduce nitrogen oxides from exhaust gases into O2 and N2, eliminating the cycle of ozone formation. Many scientists have suggested that pumping gas at night could reduce photochemical ozone formation by limiting the amount of exposure VOCs have with sunlight.

- **Sulfur smog (London Smog):**

Sulfurous smog is also called "London smog," (first formed in London). London-type smog is mainly a product of burning large amounts of high sulfur coal. Clean air laws passed in 1956 have greatly reduced smog formation in the United Kingdom; however, in other parts of the world London-type smog is still very prevalent. The main constituent of London-type smog is soot; however, this smog also contains large quantities of fly ash, sulfur dioxide, sodium chloride and calcium sulfate particles. If concentrations are high enough, sulfur dioxide can react with atmospheric hydroxide to produce sulfuric acid, which will precipitate as acid rain.

$SO_2+OH \rightarrow HOSO_2$
$HOSO_2+O_2 \rightarrow HO_2+SO_3$
$SO_3+H_2O \rightarrow H_2SO_4$

- **Terrible Effects of Smog**
- ***Effects on human health***

Smog is composed of a mixture of air pollutants which can endanger human health. Various human health problems such as emphysema, asthma, chronic bronchitis, lung infections, and cancers are caused or exacerbated by the effects of smog. The effects include:

- Coughing and irritation of the eyes, chest, nose and throat: High ozone levels can irritate the respiratory system leading to coughing and wheezing. These effects generally last for only a few days after exposure, but the particles in the smog can continue to damage the lungs even after the irritations disappear.
- Aggravation of asthma: Asthma conditions are severely worsened by smog and can trigger asthma attacks.
- Breathing difficulties and lung damage: Bronchitis, pneumonia and emphysema are some of the lung conditions linked to the effects of smog as it damages the lining of the lungs. Smog also makes it difficult for people to breathe properly.
- Premature deaths because of respiratory and cancer diseases: A 2013 WHO report indicated that cumulative exposure to smog heightens the chances of premature death from cancers and respiratory diseases. Thousands of premature deaths in the United States, Europe, and Asian countries are linked to inhalation of smog particles. Such chemical particles include benzene, formaldehyde, and butadiene which are all comprised of cancer-causing carcinogens.
- Birth defects and low birth weights: Smog is highly linked to birth defects and low birth weight. Pregnant women who have been exposed to smog have had babies with birth defects. Spina bifida – a condition depicting malformations of the spinal column, and anencephaly – underdevelopment or absence or only part of the brain are birth defects associated with smog exposure. Furthermore, studies suggest that even as low as 5 µg exposure to smog particulate matter can result in risks of very low birth weights at delivery.
- The risk of developing rickets: Heavy smog that lasts for prolonged periods blocks UV rays from reaching the earth surface. This results in low production of Vitamin D leading to rickets due to impaired metabolism of calcium and phosphorus in the bone marrow.
- Risks of road accidents or even plane crash: Smog interferes with natural visibility and irritates the eyes. On this basis, it may prevent the driver or flight controller from reading important signs or signals thereby increasing the probability of road accidents or even plane crash.

3. Implications for plants and animals

Smog inhibits the growth of plants and can lead to extensive damage to crops, trees, and vegetation. When crops and vegetables such as wheat, soybeans, tomatoes, peanuts, cotton and kales are exposed to smog, it interferes with their ability to fight infections thus increasing susceptibility to diseases.

The smog's impact of altering the natural environment makes it difficult for animals to adapt or survive in such toxic conditions, which can kill countless animal species or make them susceptible to illness. Photochemical smog caused when nitrogen oxides react in the presence of sunlight, is established to destroy plant life and irritate sensitive tissues of both plants and animals.

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