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ENVIS NEWSLETTER

Acid Rain and Atmospheric Pollution

Indian Institute of Tropical Meteorology, Pune

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Editors Desk:

The science of air pollution is quite complex and evolving. Furnishing information to public is a key to transform the thinking of public and make them active in becoming effective players in preventing air pollution. In this newsletter we have attempted to provide some knowledge on understanding the basics of air pollution science. In this regards we have emphasized on the most important and toxic pollutant "OZONE" (a form of SMOG) which is found at the height of 0-15 km. This tropospheric ozone is very harmful because in addition to be an air pollutant it also acts as green house gas which contributes to global warming. The issue includes the basic understanding regarding tropospheric ozone formation, and its effect on our atmosphere and health as well. In addition, for the enthusiastic individuals, details' regarding a simple experiment on how ground level ozone testing can be done at home is also provided which is also quite interesting. Further we appreciate the views of the reader/user groups about this newsletter, so that we can enrich it further. We also encourage and invite relevant articles, news, events on pollution related topic for publication in newsletter in future.

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Ozone: Some Basics

Ozone is a form of elemental oxygen. In its most stable form, elemental oxygen exists as diatomic molecules (O_2) however, the molecule of ozone consists of three oxygen atoms bound together (**O_3**). It is unstable and highly reactive gas. At low concentrations it is irritating and toxic as well.

It is found naturally in small concentrations in the **stratosphere**, a layer of Earth's upper atmosphere. In this upper atmosphere, ozone is made when ultraviolet light from the sun splits an oxygen molecule (**O_2**), forming two single oxygen atoms. If a freed atom collides with an oxygen molecule, it becomes ozone. **Stratospheric ozone** has been called "good" ozone because it protects the Earth's surface from dangerous ultraviolet light.

Ozone can also be found in the **troposphere** i.e. the lowest layer of the atmosphere. **Tropospheric ozone** (often termed "bad" ozone) is formed after a lightening storm or it is man-made, a result of air pollution from internal combustion engines and power plants. Contribution of tropospheric ozone is just 10 - 15 % of total atmospheric ozone and it has a very serious consequence on our environment. At room temperature, ozone is a pale blue gas with a sharp odor, characteristic of the air after a thunderstorm or near an old electric motor. It condenses to a dark blue liquid at -112°C and freezes at -193°C.

Ozone is much more reactive than O_2. It is a very powerful oxidizing agent. It can oxidize many organic compounds and is used commercially as bleach for waxes, oils, and textiles, and as a deodorizing agent. Because it is a powerful germicide, it is also used to sterilize air and drinking water. Ozone is usually manufactured by passing an electrical discharge through O_2 gas or through dry air. The resulting mixture of ozone and O_2 or air is usually suitable for most industrial applications of ozone. Because ozone is very unstable and reactive, the preparation of pure ozone is both difficult and hazardous and is seldom attempted.

Automobile exhaust and industrial emissions release a family of **nitrogen oxide gases** (NOx) and **volatile organic compounds** (VOC), by-products of burning gasoline and coal. NOx and VOC combine chemically with oxygen to form ozone during sunny, high-temperature conditions of late spring, summer and early fall. High levels of ozone are usually formed in the heat of the afternoon and early evening, dissipating during the cooler nights.

In brief, ozone can be formed when a mixture of O_2 and NO_2 is exposed to bright light. Such mixtures occur in the polluted air of large cities. The concentration of NO_2 in air is usually very low, because N_2 and O_2 do not react at normal temperatures. However, in the hot, reacting gases inside the cylinders of internal combustion engines, nitrogen and oxygen can react.

$$N_2\,(g) + O_2\,(g) \xrightarrow{\text{heat}} 2NO(g)$$

The NO formed inside automobile engines reacts spontaneously with O_2 in air to form NO_2.

$$2NO(g) + O_2\,(g) \longrightarrow 2NO_2(g)$$

Nitrogen dioxide is a red-brown gas that dissociates when it is irradiated with bright light.

$$NO_2\,(g) \xrightarrow{\text{light}} NO(g) + O(g)$$

The oxygen atom formed in this process is extremely reactive and readily attaches to a molecule of O_2, forming ozone.

$$O\,(g) + O_2(g) \longrightarrow O_3(g)$$

As discussed above these reaction sequences are applicable for inside the cylinder for combustion engine. The process of formation of tropospheric ozone by different sources are quite elaborate and out of scope of this article and hence not discussed in detail here.

On sunny days where NO_2 pollution from traffic is high, the concentration of ozone in the air can reach levels that are dangerous for plants and animals. Although ozone pollution is formed mainly in urban and suburban areas, it ends up in rural areas as well, carried by prevailing winds or resulting from cars and trucks that travel into rural areas. Significant levels of ozone pollution can be detected in rural areas as far as 250 miles (402 kilometers) downwind from urban industrial zones.

Effect of Ozone on health and Plants

When you inhale ozone, it travels throughout your respiratory tract. Because ozone is very corrosive, it damages the bronchioles and alveoli in your lungs, air sacs that are important for gas exchange. Repeated exposure to ozone can inflame lung tissues and cause respiratory infections.

Ozone exposure can aggravate existing respiratory conditions such as asthma, reduce your lung function and capacity for exercise and cause chest pains and coughing. Young children, adults who are active outdoors and people with respiratory diseases are most susceptible to the high levels of ozone encountered during the summer.

In addition to effects on humans, the corrosive nature of ozone can damage plants and trees. High levels of ozone can destroy agricultural crops and forest vegetation. Ozone effects on plants are more pronounced when soil moisture and nutrients are adequate and ozone concentration is high. Under good soil moisture and nutrient conditions the ozone from air will enter through openings into the leaf and damage the cells that produce the food for plants. Once the ozone is absorbed in the leaf some plants spend energy to produce bio-chemicals that can neutralize a toxic effect from the ozone. Other plants will suffer the toxic effect, and growth loss and/or visible symptoms may occur. The presence of ozone in an area can be detected when consistent and known symptoms are observed on the upper leaf-surface of a sensitive plant species such as "**black-berry**" plant which is considered as a "**bio-indicator**" of ground level ozone by specialists.

The effect of ozone on plants is very well illustrated from the below photograph of white pine plant. The needle tips of this white pine have turned pale, revealing burns caused by ozone.

Photograph by Andrew Boone / courtesy www.forestryimages.org

Overexposure to ozone not only causes discoloration; it can also reduce tree growth. Ozone diminishes a plant's ability to produce and store food, making it vulnerable to disease, pests, and inclement weather.

Air Quality Index

To protect yourself from ozone exposure, you should be aware of the Air Quality Index (AQI). The AQI measures concentrations of five air pollutants: ozone, sulfur dioxide, particulate matter, carbon monoxide and nitrogen dioxide. One should also be familiar with the Environmental Protection Agency (EPA) guide for ozone-alert values. The EPA has chosen the above pollutants as criteria pollutants, but these are not all of the pollutants in the air. These concentrations are compared to a standard set out in federal law. An index value of 100 means that all of the criteria pollutants are at the maximum level that is considered safe for the majority of the population. Numbers above 100 indicate higher concentrations and therefore a greater risk to most individuals. The EPA Chart is shown in the table.

EPA Air Quality Guide for Ozone

Air Quality Index	Color	Air Quality	Prediction
0 to 50	Green	Good	No health impacts are expected.
51 to 100	Yellow	Moderate	Unusually sensitive people should limit prolonged outdoor activity.
101 to 150	Orange	Unhealthy for sensitive groups	Active people and those with respiratory disease should limit prolonged outdoor activity.
151 to 200	Red	Unhealthy	Active people and those with respiratory disease should avoid prolonged outdoor activity; all others should limit prolonged outdoor activity.
201 to 300	Purple	Very unhealthy	Active people and those with respiratory disease should avoid all outdoor activity; all others should limit outdoor activity.

Ground Level Ozone Testing

Ground level ozone testing is done by a test method called Schoenbien Color test which was developed by Dr. Schoenbein in the early 1800's. The test paper he developed contains Potassium Iodide, Corn Starch and water. This test is based on the oxidation capability of ozone. Schoenbein's paper is placed in an area away from light for eight hours to allow for a reaction. Ozone in the air will oxidize the potassium iodide on the Schoenbein paper to produce iodine. The iodine reacts with starch and produces a purple color. The exact shade of purple correlates to the amount of ozone present in the air. The two reactions involved are:

$$2KI + O_3 + H_2O \xrightarrow{\text{sunlight}} 2KOH + O_2 + I_2$$

$$I_2 + \text{starch} \longrightarrow \text{Blue or Purple color}$$

Schoenbein Paper Preparation. . . . . . .

1. Place 100 ml of water in a 250ml beaker then add 5g of corn starch.
2. Heat and stir mixture until it gels. The mixture is gelled when it thickens and becomes somewhat translucent.
3. Remove the beaker from the heat and add 1g of potassium iodide and stir well. Cool the solution.
4. Lay a piece of filter paper on a glass plate and carefully brush the paste onto the filter paper. Turn the filter paper over and do the same on the other side. Apply

the paste as uniformly as possible.

5. Allow the paper to dry. Do not set in direct sunlight. Cut the filter paper into 1inch wide strips, place them in a zipper-lock plastic bag or glass jar out of direct sunlight.

Testing Procedure. . . . .

1. Dip a strip of test paper in distilled water and hang it at a data collection site out of direct sunlight. Make sure the strip can hang freely.
2. Expose the paper for approximately eight hours. Seal it in an airtight container if the results will not be recorded immediately.
3. To observe and record test results, dip the paper in distilled water. Observe the color and determine the Schoenbein Number using the Schoenbein color scale.

Schoenbien Color Scale table:

Scale	Color
0-3	Little or no Change
4-6	Lavender Hue
7-10	Blue or Purple

Schoenbien Color Scale:

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