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**Environmental Science Education Title: Measuring Tropospheric Ozone**

**Overview:** Ozone is a form of elemental oxygen (O3), a molecule of three oxygen atoms bonded in a structure that is highly reactive as an oxidizing agent. Ozone occurs in both the stratosphere and the troposphere levels of the atmosphere. When in the stratosphere (located approximately 10-50 km from earth’s surface), ozone molecules form to the ozone layer and help prevent harmful UV rays from reaching Earth’s surface. In lower altitudes of the troposphere (surface - approximately 17 km), ozone is harmful to human health and is considered an air pollutant contributing to photochemical smog (figure 1). Ozone molecules can cause damage directly by harming respiratory tissue when inhaled, or indirectly by harming plant tissues (figure 2) and softer materials (figure 3) including tires on automobiles.

Outdoor tropospheric ozone is formed at ground level when nitrogen oxides (NOx) and volatile organic compounds (VOCs) from automobile emissions are exposed to sunlight. Consequently, health concerns over ozone concentrations escalate in sunny conditions or when and where automobile use is increased.

Indoor tropospheric ozone is formed when electrical discharges from equipment using high voltages (e.g. ionic air purifiers, laser printers, photocopiers) break down the chemical bonds of the atmospheric oxygen (O2) in the air surrounding the equipment:

O2 → 2O

The free radicals of oxygen in and around electrical discharge recombine to create ozone (O3).

2O + 2O2→ 2O3

**Principles:** Tropospheric ozone can be monitored by using a mixture of starch, potassium iodide, and water spread on filter paper. Once dried, the paper, called

Schönbein paper, changes color when ozone is present.

The method is based on the oxidation capability of ozone. Ozone in the air will oxidize the potassium iodide on the test paper to produce iodine:

2Kl + O3 + H2O--> 2KOH + O2 + I2

The iodine then reacts with the starch, staining the paper a shade of violet. The intensity of the color depends on the amount of ozone present in the air. The darker the color, the more ozone is present:

 + starch → violet color

Ozone concentration is sampled at different sites of higher risk including parking lots, garages, parkways, and corners of heavily trafficked streets. Indoor sites include room and spaces with equipment involving ink printing such as copiers.

**Procedure:**

1. **Schönbein Paper Preparation**
   1. Place 100 ml of distilled water in a 250 ml beaker.
   2. Add 1 1/4 teaspoon of cornstarch.
   3. Place a stir bar in the beaker and place the beaker on a hot/stir plate. Heat and stir the mixture slowly until it gels. The mixture is gelled when it thickens and becomes somewhat translucent.
   4. Remove the beaker from the heat source, add 1/4 teaspoon of potassium iodide, and stir well.
   5. Cool the solution before applying to the filter paper.
   6. Lay a piece of filter paper on a glass plate, or hold it in the air, and carefully brush the paste onto the filter paper. Turn the filter paper over and do the same on the other side. Try to apply the paste as uniformly as possible.
   7. Set the paper out overnight and away from sunlight or place in a low temperature (20° C) drying oven to dry.
   8. Once paper is dry, use scissors to cut the filter paper into 1-inch wide strips. If storing the paper for later use, place the strips in a sealable plastic bag or glass jar out of direct sunlight.
2. **Measuring Ozone**
   1. Spray a strip of test paper with distilled water and hang it at a data collection site out of direct sunlight. Ensure the strip hangs freely and unobstructed.
   2. Expose the paper for approximately eight hours. Note where each strip was hung.
   3. After exposure, seal the strip in an airtight container if the results will not be recorded immediately.
   4. To observe and record test results, spray the paper with distilled water.
   5. Observe the color by comparing it to the provided color scale and recording the corresponding Schönbein number.

**Representative Results**

Use the Schönbein number scale (figure 4) for quantitative analysis of ozone. The chart is used to compare with sample papers after 8 hours of exposure at sample locations. Score increases with increasing color intensity, with the darkest violet on the right side of the scale. Results should vary based on where collection site was (figure 5).

**Applications:** Tropospheric ozone exposure is harmful to human health, known to cause chest pain, coughing, throat irritation, and congestion. Ozone also interferes with lung function, exacerbating symptoms of bronchitis, emphysema, and asthma, and can permanently damage lung tissue.

Outdoor locations of increased amounts of sunlight and urban areas experience higher levels of tropospheric ozone due to increased amount and density of nitrate emissions. Indoor locations where copy machines and ink printers are used are also high-risk areas for ozone exposure.

**Legend:**  
Figure 1: Golden Gate Bridge panorama

Characteristic coloration for smog in California in the beige cloud bank behind the Golden Gate Bridge. The brown coloration is due to the NOx in the photochemical smog.   
By Aaron Logan - <http://www.lightmatter.net/gallery/Travel/ggb>

Figure 2: Plants damaged by ozone. Top row is normal, bottom row has been exposed to ozone.

Figure 3: Ozone cracks in natural rubber tubing.

Figure 4: Schönbein Number Scale

Figure 5. Graph of sample ozone concentrations.Outdoor and indoor tropospheric ozone concentrations shown by site and Schönbein score.