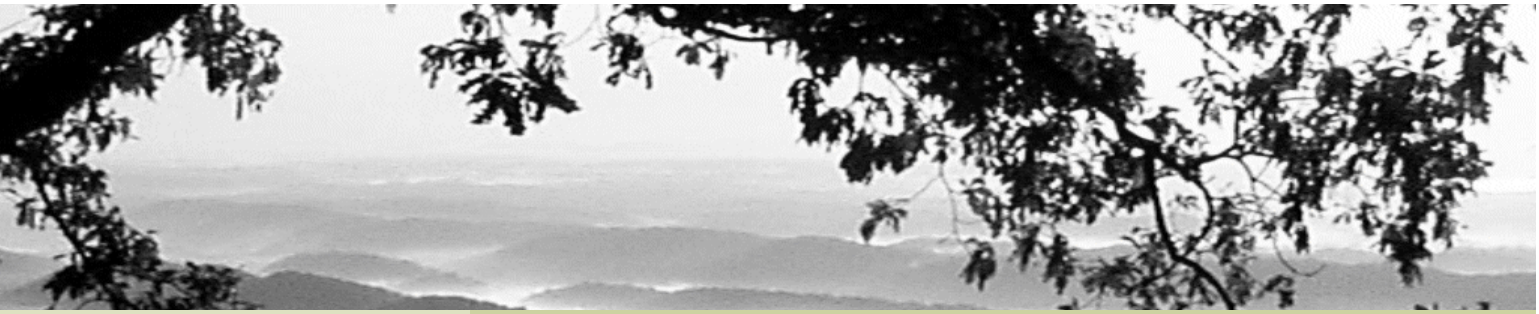

On the Air

Technical Notes on Important Air Quality Issues

August 2003

Outdoor Ozone Monitors Over-Estimate Actual Human Ozone Exposure

Science: Continuous outdoor monitoring of ozone levels is useful for many purposes, but indoor air monitoring and personal measurements are the best ways to estimate actual day-to-day human ozone exposure. The study described here indicates that actual personal exposures are only 7 to 31 percent of the ozone levels measured by conventional outdoor monitors. During ozone season, the amount of time spent outdoors and time spent with windows open are major determinants to personal exposure.

Policy: Much effort is expended by the U.S. EPA and state and local regulatory programs to inform the public when outdoor ozone levels are unacceptably high. However, indoor air monitoring and personal ozone exposure measurements suggest that most of us are not exposed to unhealthy doses of ozone. From a public health perspective, when ozone levels are in the unhealthy range (Orange Air Quality Index or higher), most people--especially sensitive individuals--should limit prolonged outdoor exertion and reduce their ozone exposure by staying indoors.

Background

Ozone (O_3) is one of the criteria air pollutants for which the U.S. EPA has set national ambient air quality standards. Ozone is produced by a series of solar-powered chemical reactions between reactive volatile organic compounds (VOCs) and nitrogen oxides (NO_x). Given the many human-caused VOC and NO_x sources in urban/industrial areas, it is not surprising to find peak short-term O_3 levels downwind of these areas during warm, sunny and stagnant summer weather.

Exposure to high levels of O_3 can injure lungs, impair respiration and sensitize respiratory systems. People with respiratory diseases such as asthma and those involved in vigorous or lengthy outdoor activities such as children, workers, and athletes are particularly susceptible to more serious effects from ozone exposure. Short-term health effects such as coughing, throat irritation, chest discomfort, and difficulty in normal deep breathing may be experienced by healthy persons exposed to particularly elevated levels of O_3. There is legitimate debate over the level at which these effects become a serious concern.

Health effect studies seek to establish relationships between outdoor air

quality and various measures of health or infirmity. While outdoor O_3 measurements can estimate exposures for those involved in outdoor work or play, the evidence suggests that outdoor measurements do a poor job of estimating actual typical human exposure. Until the 1970s, very little was known about O_3 concentrations inside buildings; and even today, the database on this subject is not large. Invariably these studies indicate that in the absence of indoor sources, indoor O_3 concentrations are almost always lower than outdoor levels. A wide range of indoor/outdoor O_3 concentration ratios can be found in the literature with indoor O_3 at 10 to 70 percent of outdoor levels.

Outdoor, Indoor and Personal Ozone Exposure

Researchers from Harvard University, working as part of the Southern Oxidants Study, sought to better understand the relationship between outdoor, indoor and personal O_3 levels and to identify factors associated with exposure. Inexpensive passive samplers were used to estimate week-long O_3 exposures for a small group of grade-school children for six weeks during the summer of 1994. To insure a wide range of potential outdoor exposures, two Nashville communities were included: Inglewood, an urban residential area about 7 km northeast of downtown, and Hendersonville, a suburban "bedroom" community 22 km northeast of downtown. Historically, outdoor O_3 levels obtained by the suburban "downwind" Hendersonville continuous monitoring station are substantially higher than at the more urban Inglewood station. These continuous monitoring stations provided a baseline record of hourly outdoor O_3 levels throughout the study.

Thirty-six participants (10 to 12-year-old children) were recruited from elementary schools in Inglewood and Hendersonville. During each sampling week, each participant was given a set of three passive O_3 samplers: outdoor, indoor, and personal. The outdoor samplers were placed just outside their homes, but unlike the continuous outdoor station monitors, these provided only a weekly average of ozone levels. The indoor samplers were placed in the den/living room, and the personal samplers were attached to the participants' clothing during the day (Figure 1) and next to their beds at night. Each participant also recorded daily activities in diaries.

Results and Discussion

Figure 1. Passive Personal Ozone Sampler

The average and the range of O_3 levels obtained by continuous monitoring and passive sampling are shown in Figure 2. All the outdoor samples were above the minimum detection limit (MDL) of 1.2 parts-per-billion (ppb) for the passive sampler. In contrast, 64 percent of the indoor samples and 40 percent of the personal samples were below the MDL. Weekly average indoor O_3 levels were 3 to 15 percent of outdoor O_3, while average personal O_3 levels were about double indoor O_3 levels or 7 to 31 percent of outdoor O_3. The primary characteristic associated with personal O_3 exposure was the amount of time spent outdoors. When personal O_3 exposures were grouped into three categories based on outdoor time (<25th percentile, 25th-75th, >75th percentile), the children spending the greatest amount of time outdoors were subject to significantly higher O_3 exposures than those spending the least amount of time outdoors. Children with pets demonstrated higher personal O_3 exposures as well.

Personal O_3 exposures were not only affected by the total amount of outdoor

time, but also by the time of day they were outdoors. Children outdoors in middle to late afternoon experienced higher exposures than those outside at other times, corresponding to elevated outdoor O_3 concentrations in the afternoon. Figure 3 shows hourly average O_3 levels for the Hendersonville and Inglewood communities. While our study participants were not "couch potatoes" by any means, neither did they spend an inordinate amount of time outdoors. The amount of time our participants spent indoors was right in line with the national average of about 90 percent. On an average day participants spent 2.8 hours outdoors, 20.3 hours indoors and 0.9 hours in a vehicle.

The homes varied with regard to ventilation and climate control. When home characteristics were compared to indoor O_3 levels, four characteristics were significantly associated with indoor O_3 levels: air conditioning, carpeting, window fans, and frequency of window opening. Twenty-one homes had central air conditioning, eleven homes had window air conditioners, three had a combination of central and window air conditioners, and one had window fans only. Windows were opened frequently in five homes, occasionally in 22 homes and not opened in nine homes. "Tight" homes--those with air conditioning and closed windows--had lower air exchange with the outside and, consequently, lower O_3 levels. At the other end of the spectrum, those homes with window fans and open windows had higher air exchange rates and higher O_3 levels.

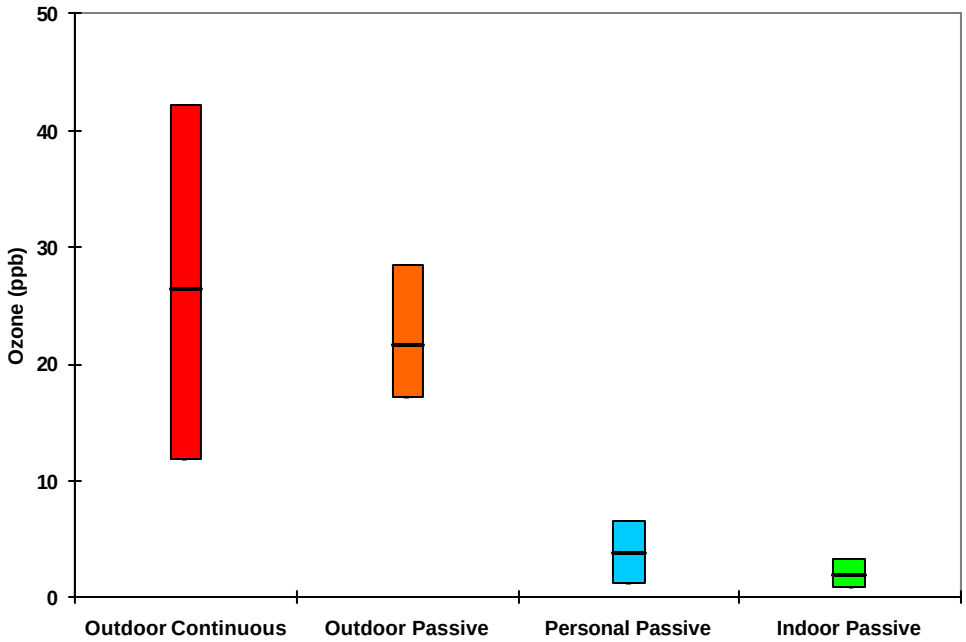

Figure 2. Weekly outdoor, personal, and indoor ozone exposures for six weeks during the summer of 1994.

Conclusions

This study clearly demonstrates the limitations of using continuous outdoor O_3 monitors to estimate indoor O_3 levels and actual human exposure. From this study we learned that:

- Average indoor O_3 levels were 10 percent of outdoor O_3 levels, whereas personal exposures averaged 16 percent of outdoor levels (Figure 2).
- The amount of time spent outdoors and having pets were associated with increased personal O_3 exposure. Personal exposures were not only affected by

the total outdoor time, but also by the time of day when outdoors (Figure 3).

- Most indoor environments-especially closed, air conditioned homes-provide protection from outdoor O_3. Indoor O_3 concentrations in these homes were close to zero.
- Homes without air conditioning and those homes that frequently ventilate with fans and open windows exhibit higher indoor O_3 levels. Nevertheless, these homes provided some protection from outdoor O_3.

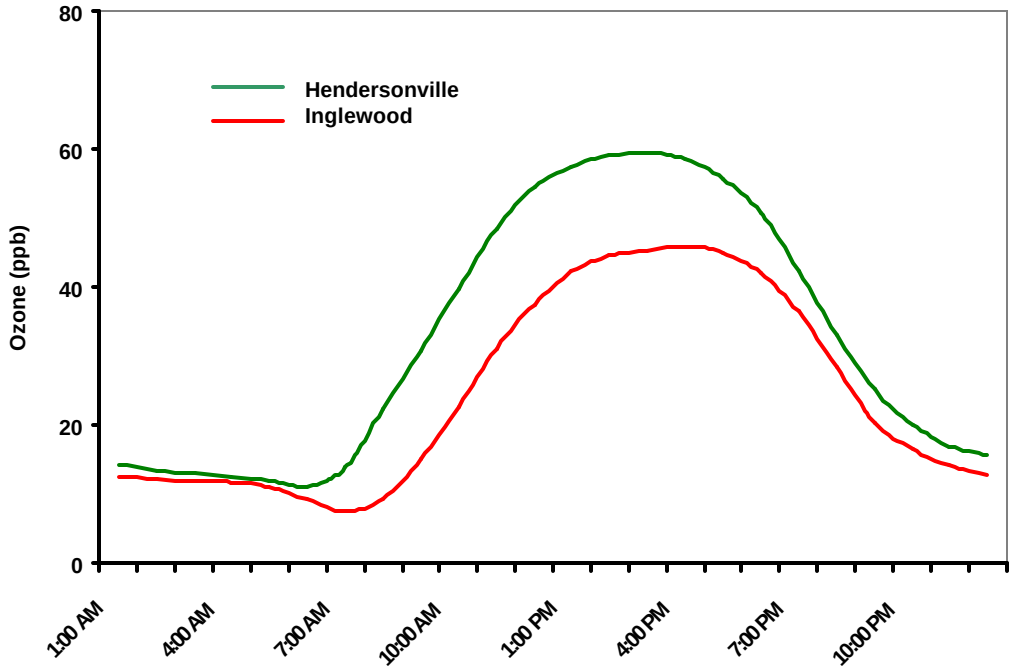

Figure 3. Mean hourly levels of community ozone obtained at continuous monitoring sites during this six-week study during the summer of 1994.

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