Detection of Tropospheric Ozone in North Central Pennsylvania Utilizing Passive Samplers and Bioindicator Plants

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Introduction

Tropospheric ozone is a phytotoxic air pollutant formed by photochemical processes and precursors that include oxides of nitrogen and hydrocarbons. Concentrations of ozone increase with elevation and can be transported long distances from sources due to atmospheric circulation patterns. Several species of plants known to be sensitive to ambient ozone concentrations serve as good bio-indicators. In Pennsylvania, two plants sensitive to ozone are black cherry (*Prunus serotina, Ehrh.*) and common milkweed (*Asclepias syriaca, L.*) (Skelly 2000). Symptoms exhibited by native plants to elevated ozone concentrations include interveinal chlorosis, adaxial stipple, and premature leaf drop. Native plant bioindicators directly assist in determining the presence of ozone but research thus far has not determined the ambient exposures leading to symptom development. A relatively inexpensive means to detect concentrations of ozone in the atmosphere involves the use of passive sampling techniques. Passive samplers may be deployed in remote areas where no electricity is available (Krupa and Legge, 2000). Current research has shown a high correlation between the accuracy of passive ozone monitors when compared to real-time, continuous ozone monitors (Manning et al.,1996). The Ogawa passive sampling device utilizes two nitrate-coated filters. In the presence of ozone, nitrite ions are oxidized to nitrate ions. Filters may then be analyzed in a laboratory using ion chromatography and average ozone concentration may be determined over the duration of the time of exposure. The objective of this study was to measure ambient ozone in remote forested areas of north central Pennsylvania and to determine relationships between exposure, concentration time, and foliar injury on two bioindicator species.

Materials and methods

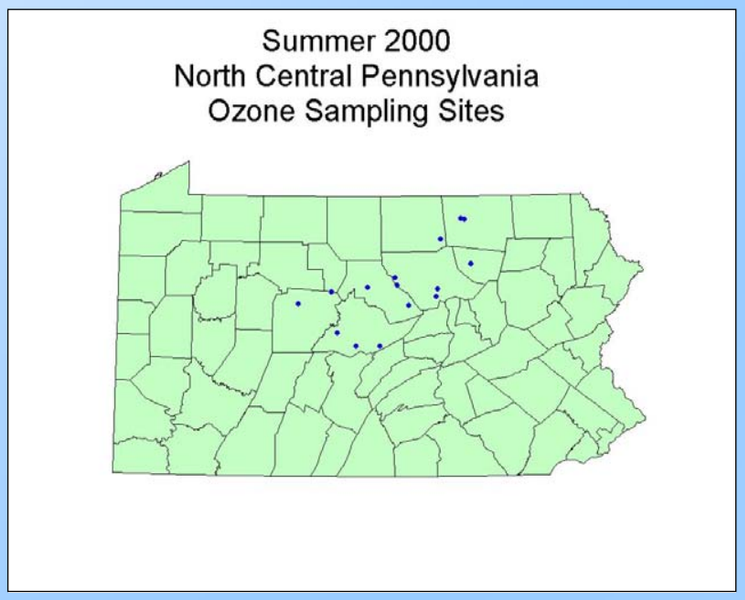
Fifteen sites were chosen in north central Pennsylvania in early spring 2000 as locations to record ozone concentrations and plant injury. All sites, with the exception of Williamsport, PA, were located in forested areas away from urban and industrial sources of the precursor primary pollutants. The period of study lasted from May 29 to September 5, 2000, which coincides with the usual peak ozone season of eastern United States. Correlation analysis was used to compare the weekly ozone concentrations determined by the Ogawa passive ozone samplers versus continuous TECO Model 49 ozone analyzers; ozone concentrations were also compared to site elevation and foliar symptom occurrence at each of the respective sites.

Passive Samplers

Ogawa passive ozone sampling devices were located in open areas, approximately 2 meters above the ground, at each site. The samplers were shielded from wind and rain with a 7.6cm PVC end cap. Six of the sites were co-located with TECO Model 49 continuous ozone analyzers. Beginning May 28, 2000, devices were prepared in the laboratory and kept refrigerated until placed in the field. Field deployment of the devices occurred Monday May 29 and Tuesday May 30, 2000. Each following week, through Tuesday, September 5, 2000, the passive sampling devices were collected and replaced at each site within 1 hour of the previous week's replacement time. Collected devices were stored in a cooler in the field then refrigerated in the laboratory. On Wednesday of every week, filters of the sampling devices were carefully removed, placed in plastic vials, and sent to the US Environmental Protection Agency, Research Triangle Park, NC for ion chromatography analysis.

Bioindicators

Fifteen black cherry and fifteen common milkweed plants were identified prior to the observation period and numbered with either a flag or ground stakes for ozone-induced symptoms at each study site. All plants were located within a 2km radius and 50m of elevation from the passive ozone sampling device. Each week starting June 5, 2000, both species of plants were observed for ozone injury at each site. Injury observations consisted of the percent of leaves injured per plant and area per leaf injured. A modified Horsfall-Barratt rating scale was used to record injury and an injury class was developed for statistical analyses. The injury was classified to represent a "0" for no injury, "1" for 1-6% injury, "2" for 6-25% injury, "3" for 25-50% injury, "4" for 50-75% injury, and "5" for >75% injury.



Map of ozone sampling locations for the summer of 2000.

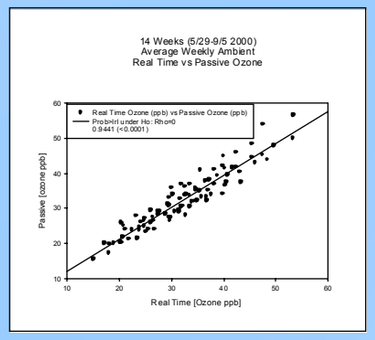


Figure 1. Correlation analysis between 7 passive ozone sampling devices co-located with real-time Teco Model 49 ozone analyzers. 7 sites X 14 weeks = 98 points along the line.

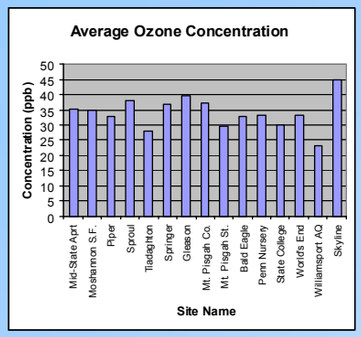


Figure 2. Average ozone concentrations for all sites over monitoring period.

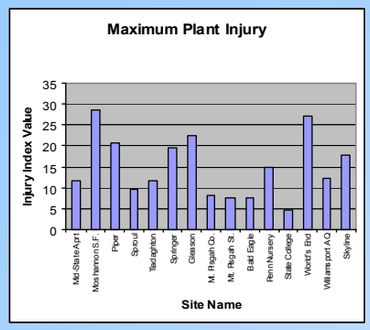
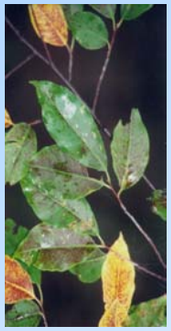


Figure 3. Maximum plant inury as a result of tropospheric ozone over the entire study period.



Ozone induced Injury to common milkweed (left) and black cherry (right).

Results and Discussion

Weekly ozone concentrations were recorded at fifteen sites throughout north central Pennsylvania over a fifteen week time period. Data for the study indicated a high correlation between the Ogawa passive samplers and the TECO Model 49 continuous ozone analyzer with an r-value of 0.9441 ($p<0.0001$) (Figure 1). Skelly et al. (2000) and Manning et al. (1996) observed similar results when correlating ozone passive sampling devices to continuous ozone analyzers in previous research. Data also indicated a high correlation between ozone concentration and elevation ($r=0.86126$, $p<0.0001$) showing that higher elevations received greater ozone concentrations. Highest seasonal ozone concentrations (Figure 2) among all sites were recorded at Skyline mountain (mean sea level elevation of 580 m) while lowest concentrations were recorded less than 3 miles away in the city of Williamsport (mean sea level of 202 m). Black cherry and common milkweed were observed for foliar injury at each of the sites with highest combined foliar injury observed at the Moshannon State Forest site (Figure 3). The lowest combined foliar injury observed was recorded at the State College site. Possible reasons for these results may be linked to plant genetics and/or proximity to the western Pennsylvania and Ohio Valley source region. However, there were no significant relationships between sites and foliar injury on the two ozone-sensitive bioindicator species due to the very low ozone presence during the latter part of the 2000 growing season.

Site Name	Elevation (m)	County	Landuse Category	Site Description
State College	425	Centre	Pasture/Open Field	Large, open area with forested hedgerows, TECO Model 49 co-located
Mid-State Airport	594	Centre	Forested	Large, open area outlined with eastern hardwood species
Moshannon State Forest	653	Clearfield	Forested	Small, open area encompassed by eastern hardwood, TECO Model 49 co-located
Piper	676	Clearfield	Forested	Eastern hardwood forest
Sproul	719	Clinton	Forested	High elevation, low canopy eastern hardwood
Tiadaghton	562	Lycoming	Forested	Eastern hardwood forest, TECO Model 49 co-located
Springer	588	Clinton	Pasture/Open Field	Large, open area outlined with eastern hardwood species
Gleason	758	Tioga	Forested	Small, open area encompassed by eastern hardwood, TECO Model 49 co-located
Mt. Pisgah State Park	429	Bradford	Public Use	Large, open area outlined with eastern hardwood species
Mt. Pisgah County Park	760	Bradford	Public Use	High elevation, small open tract encompassed by eastern hardwood
World's End	662	Sullivan	Forested	Small, logged, open area encompassed by eastern hardwood
Williamsport Air Quality	202	Lycoming	Urban	Metropolitan area, bioindicators located <2km away in county park
Skyline	580	Lycoming	Forested	Small, open ridge-top area outlined with eastern hardwood species
Bald Eagle	510	Clinton	Forested	Large, open area dominated by low canopy eastern hardwood species
Penn Nursery	515	Centre	Agricultural	State research land, TECO Model 49 co-located

Summer 2000 ozone sampling site descriptions.

Literature Cited

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Manning, W.J., Krupa, S.V., Bergweiler, C.J. and K.I. Nelson 1996. Ambient ozone (O_3) in three Class I Wilderness Areas in the Northeastern USA: measurements with Ogawa passive samplers. Environmental Pollution, 91(3): 399-403.

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