Ozone in the Upper Silesia Region — Concentration and Effects on Plants[1]

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Abstract

*In the Beskidy Mountains at Brenna, Poland, and several other locations in the Katowice administrative district, plants were used as bioindicators to determine ozone concentration measurements in 1994 and 1995. Results showed that ozone is the only gaseous air pollutant significantly exceeding the permissible concentrations and causing foliar injury to both test and some native plant species. For all of the tests using plants, the most severe ozone injuries, were found for the Brenna location. The first signs of leaf injury were found on beans (*Phaseolus vulgaris *L.). Tobacco (*Nicotiana tabacum *L.) Bel W3 also showed leaf injury at this time. Less sensitive plants included the tomato (*Lycopersicum esculentum*) and soy bean* (Glycina max). *More severe injuries to the same plant species* (cultivars) *were not found with increased elevation. In the Brenna region only, foliar injury was also found on field-grown plant species:* Achillea *sp.,* Asceplias syriaca *L.,* Impatiens parviflora *DC.,* Sambucus nigra *L., S.* racemosa *L.,* Fagus silvatica *L.,* Prunus avium *L., and* Rubus *sp. The mean ozone concentrations at Brenna were 85.2 and 77.4 $\mu g/m^3$ in the summers of 1994 and 1995, respectively. For the locations in the Katowice area, mean concentrations were 50.3 and 44.5 $\mu g/m^3$. AOT40 calculated on a 24- hour or day-hours (9.00 - 17.00) basis exceeded the critical values of 5,300 ppb.h and 1 ppm.h recommended by the United Nations ECE for crops and forest tree species. Thus, on the basis of these results ozone is a contributing factor to poor forest health conditions in the Upper Silesia Region of Poland.*

Introduction

Leaf injury to native or introduced plant species, such as horse-chestnut *(Aesculus hippocastanum* L.), rose (*Rosa* sp.), and some others, was caused by air pollutants of photochemical origin in the vicinity of coke ovens in the mid-1960's (Godzik and Piskornik 1966). However, injury of tobacco (*Nicotine tabacum* L.) Bel W3 was not the same as that caused by ozone. Nonetheless, air pollutants of photochemical origin can cause leaf injury in locations where sulfur dioxide, nitrogen oxides, and particulate matter were seen as the only "real" problem to the environment.

Exposure started later for the Bel W3 and Bel B tobacco, and for radish (*Raphanus sativa* cv Cherry Bella) with and without ethylene diurea (EDU) treatments in the mountain region (Godzik and others 1991). Injuries to Bel W3 and differences in the response of radish with no EDU treatments have shown that ozone has caused adverse effects, including injury to test plants. Injury to some native or introduced field grown plant species has been observed simultaneously.

A 6-month series of measurements using passive samplers was performed in 1990 for the Rozdroze Izerskie (Sudety Mountains) and Brenna area (Beskidy Mountains). These measurements were completed by 1-week continuous measurements of ozone in these two locations.[3] Data have shown that concentrations are similar to those found in other European countries.

First, short-term ozone concentration measurements using ozone analyzers were done in Brenna in 1990.[3] The highest 1-hour mean concentration was 110 $\mu g/m^3$. Next, more regular measurements of ozone concentration and experiments with several test plants were done. In 1994 an extensive air pollution monitoring program started in the Katowice area by using test plants as bioindicators, including tobacco (*Nicotiana tabacum* L.), Bel W3 and Bel B, bean (*Phaseolus vulgaris* L. cv Lit), clover (*Trifolium subtereanum* cv crimsoni), tomato (*Lycopersicum esculentum* L. cv Tiny Tim), and soy bean (*Glycina max*). These were grown in containers with standardized soil and in the local soil (Godzik and others 1995, 1996 a, b).

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[3] Unpublished data supplied by the author.

The objective of this study was to assess the effect of ambient ozone concentration in the Upper Silesia Region of Poland by using plants as bioindicators exposed at locations that differed in climate and air pollution.

Materials and Methods

In the growing seasons of 1994 and 1995 ozone concentrations were measured by using analyzers, including Environics series 300, MLU and Thermo Environmental.[4] Before each measuring season analyzers were calibrated. Seeds of all but one test plant (tobacco) were provided by the International Cooperative Program (ICP) Crops Coordination Center of Nottingham University, England. Seeds of Bel W3 and Bel B tobacco were provided by the University of Massachusetts.

Clover and bean in standardized soil and containers were exposed in Brenna, Katowice, Kuznia Nieborowicka, and Slawkow. Before 1994 the number of test plants was limited to clover and tobacco only. Radish, treated and non-treated with EDU, was used during two growing seasons.

Bean, clover, and Bel W3 and Bel B tobacco were grown in standardized soil, in self-watering containers. Procedures were based on guidelines elaborated by the ICP Crops, under the UN ECE Convention on Long Range Transboundry Air Pollution. At Brenna and Katowice, beans, tomato (*Lycopersicum esculentum* L.), and soy bean (*Glycina max*) were also grown in local soils. Foliar injury of both test and native plant species were compared with those given in the literature and photographs[5] (Manning and Feder 1980, Sanders and Benton 1995).

Results and Discussion

Mean concentration of ozone for Brenna in 1994 was 85.2 $\mu g/m^3$, and for 1995 was 77.4 $\mu g/m^3$ *(table 1)*. Mean concentrations for the same period for Katowice region were 50.3 $\mu g/m^3$ and 44.5 $\mu g/m^3$, respectively. The highest ozone concentration was measured in Katowice, June 1994 — 232 $\mu g/m^3$. Other locations did not show high concentrations (Godzik and others 1995, 1996) compared to the data for the years 1994 and 1995. According to the national standards, this finding suggests

Table 1 *– Concentration of sulfur dioxide, nitrogen dioxide, and ozone at some monitoring stations in the Upper Silesia Region, Poland.*[1]

Pollutant and year	Katowics	Kuznia Nieb.	Slawkow	Brenna	Standard value D_{30} D_{24} D_a
Nitrogen dioxide					
					500
1994	50.1	22.7	12.1	3.1	150
1995	23.5	17.0	16.8	5.3	50
Sulfur dioxide					
					600
1994	36.7	14.1	27.8	6.5	200
1995	27.6	10.4	21.5	24.0	32
Ozone					
					100
1994	45.9	50.3	45.8	85.2	30
1995	47.3	44.5	-	77.4	-

[1] Mean values for the period: May 5 – Oct. 31, 1994 and May 5 – Aug. 31, 1995 in comparision to national standards ($\mu g/m^3$). Calculations are based on 24-h mean values (Godzik and others 1996b).

[4] Mention of trade names or products is for information only and does not imply endorsement by the U.S. Department of Agriculture.

[5] Unpublished data supplied by the author.

that ozone concentrations found in the Brenna region and the Katowice area are high enough to cause foliar injury to plants (Council Directive 1992).

In the Brenna and Katowice locations, ozone concentrations set by the UN ECE convention as critical levels were exceeded (Ashmore 1994, Benton and others 1995, Fuhrer and Achermann 1994). These levels were defined as accumulated dose over the threshold of 40 ppb (AOT40), which is the sum of hours during the day of ozone concentration above 40 ppb (Benton and others 1995, Fuhrer and Achermann 1994, and Legge and others 1995).

The patterns of daily ozone concentration differ at locations in the Katowice area and Brenna. Peak day values are higher for the Katowice area, but mean concentrations are higher at the Brenna site. This difference is caused by higher ozone concentrations at night at the Brenna site compared to the Katowice area measurements. On most occasions the concentration at Brenna during the night are in the range of 15 $\mu g/m^3$ *(figs. 1-2, table 1)*. Both for 1994 and 1995 the highest AOT values are for Brenna, not for Katowice, where the highest 1-hour mean values were measured *(figs. 3,4)*.

Foliar injury of the test plants—clover, tobacco, bean, soy bean, tomato, and native plant species—corresponded to that described in the literature (Arndt and others 1987, Manning and Feder 1980, Sanders and Benton, 1995). The first signs of injury were found at the Brenna location and were noted for Bel W3 and bean in both local soil and standardized soil. They appeared after about 2 weeks of

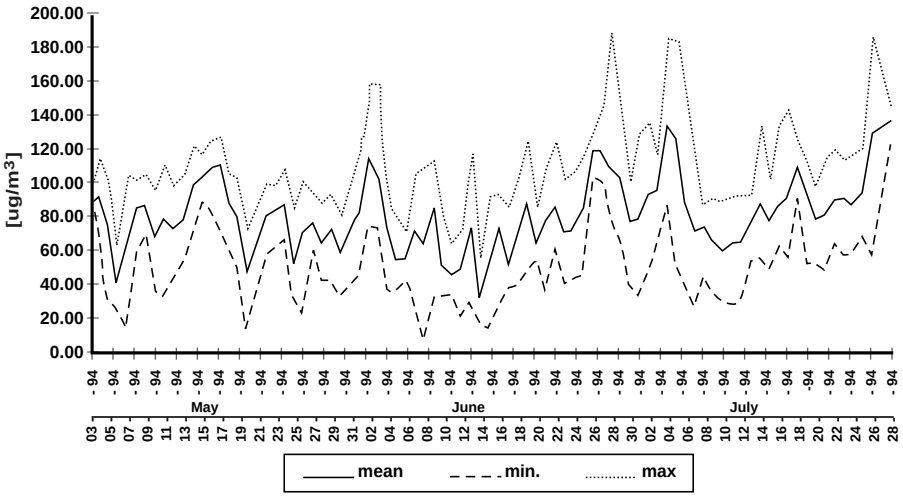

Figure 1 — Daily pattern of ozone concentrations at the Brenna, Poland monitoring station, summer 1994. (1µg/m^3 O_3= 0.51 ppb O_3 at 25ºC, 760 mm of Hg.)

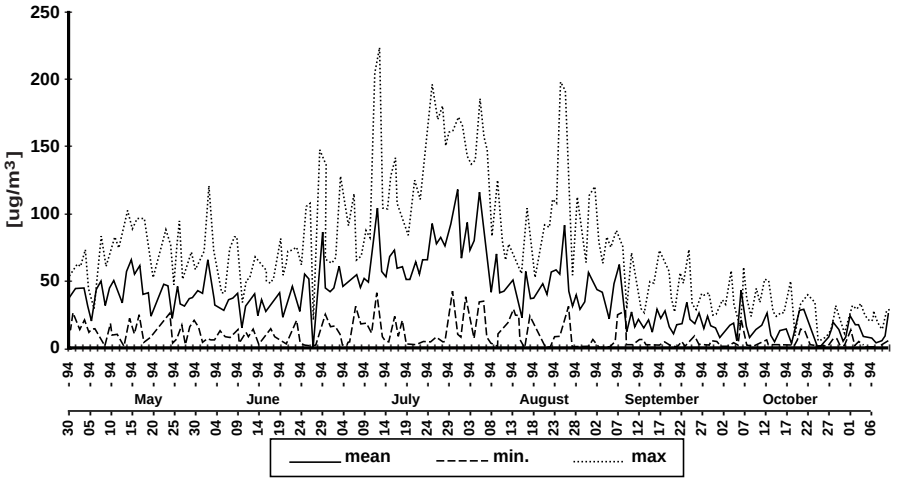

Figure 2 — Daily pattern of ozone concentrations at the monitoring station of the Institute for Ecology of Industrial Areas, Katowice, 1994.

exposure. Intensity of injuries increased during the growing season. In the Brenna location all test plants—species or cultivars—showed foliar injury. Statistically significant differences were not found in dry mass production of test plants treated and non-treated with EDU and grown in standardized soil at different locations. The number and weight of pods of bean cultivar Lit grown in local soil in both Brenna and Katowice was lower than cultivars of Stella and Grophy. Crops of pods of beans cultivars Stella and Grophy were very similar (Godzik and others 1996b).

Differences were found in plant responses in 1994 and 1995 between elevations in the Brenna region and the Katowice area. At Salmopol less severe injuries were observed in 1995. The opposite was found for the Katowice area. The reason for these differences was undetermined. These 2 years differed in climatic conditions, with air temperatures higher for 1994; but they also differed in concentrations of other air pollutants (Godzik and others 1996a, 1996b; table 1). Air temperatures close to and above 30 °C at the Brenna location were measured in June and July in 1994 for several days. A similar phenomenon was not found in the same period of 1995. Temperatures in the Katowice area for the same days were higher by a few degrees Celsius (Godzik and others 1996a, 1996b).

Results of other investigations performed in the Brenna region in forests suggest that climatic parameters are important factors to include when determining severity

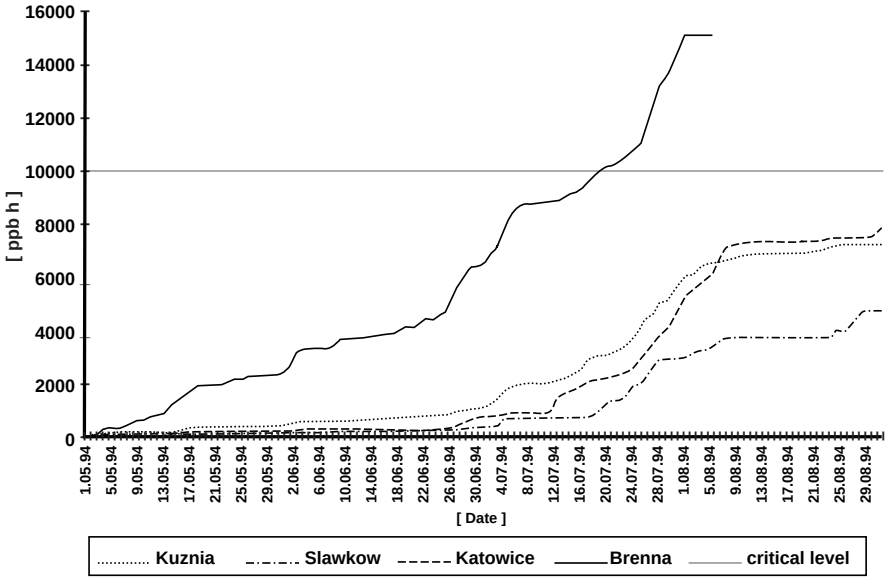

Figure 3 — Accumulated dose over the threshold of 40 ppb (AOT40) for locations in Brenna and Katowice district. Values for the daily hours (9:00 – 17:00) were used for calculations.

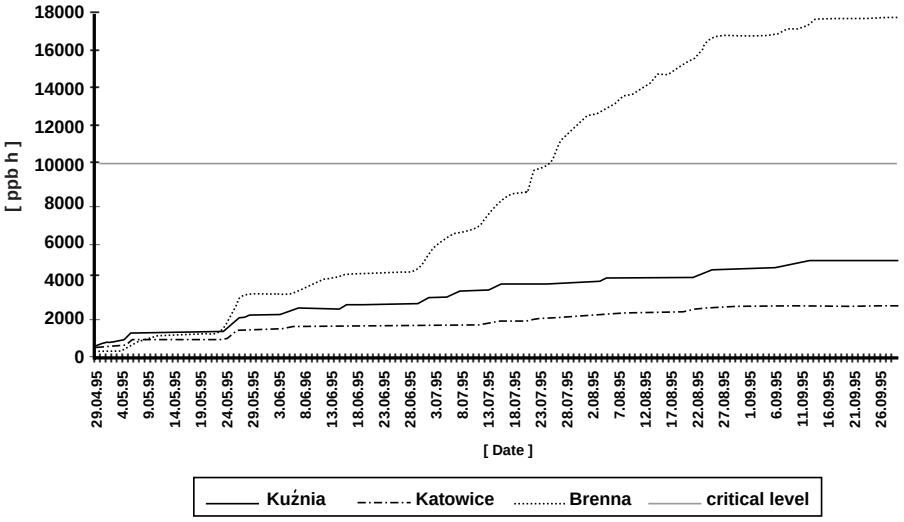

Figure 4 — Accumulated dose over the threshold of 40 ppb (AOT40) for Brenna and Katowice growing season, 1995. Twenty-four hour values were used for calculations.

of injury (Godzik and others, this volume). Ozone-like foliar injuries have been frequently found on field-grown plant species: *Achillea* sp., *Asceplias syriaca* L., *Impatiens parviflora* DC., *Sambucus nigra* L., S. *racemosa* L., *Fagus silvatic*a L., *Prunus avium* L., and *Rubus* sp. Except *Asceplais syriaca* grown in the Katowice area, all other species mentioned have shown signs of injury in the Brenna region only. These findings have not been confirmed by controlled O_3 fumigations.

Foliar injury on all test plants appeared in late June and increased during the growing season. Foliar injury on *Impatiens parviflora, Achillea* sp., *Asclepias syriaca* and *Rubus* sp. were noted from mid-July. On other tree or shrub foliage, signs of injury were found in August.

Conclusion

Severe ozone injury has been observed for tobacco Bel W3 and beans grown in the Brenna and Salmopol locations. Injuries of other plant species such as soy bean and tomato were less severe. Ozone injury to the same plant species grown in the Upper Silesia Industrial Region (USIR) were observed less frequently and differed between 1994 and 1995.

Ozone concentration during the day was the highest in the USIR, but the mean concentration was the highest in the Brenna location. The accumulated dose over the threshold of 40 ppb (AOT40) was also much higher at the Brenna. Ozone of photochemical origin is likely the only air pollutant in southern Poland causing foliar injury to both test and some field grown native or introduced plants, including some broad leaf tree species.

The effects of climatic parameters and other air pollutants, such as sulfur dioxide and nitrogen dioxide, to plant injury are not yet known. The role of air pollutants on crop of test plants used in our experiments remains uncertain. Data from experiments performed were not consistent with ozone concentration. For a few locations in the Katowice area, dry mass production was the highest where $N\text{-}NH_4$ in bulk deposition was found to be the highest. However, more data are needed to confirm these results.

Acknowledgments

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References

Arndt, U.; Nobel, W.; Schweizer, B. 1987. **Bioindikatoren. Moeglichkeiten, Grenzen und neue Erkentnisse.** Verlag Eugen Ulmer. Stuttgart.

Ashmore, M.R. 1994. **Critical levels for ozone.** In: Ashmore, M.R.; Wilson, R.B., ed. 1994. Critical levels of air pollutants for Europe. London: Department of Environment; 20-47.

Benton, J.; Fuhrer, J.; Gimeno, B.S.; Skarby, L.; Balls, G.; Palmer-Brown, P.; Roadknight, C.; Sanders, G. 1995. **ICP-crops and critical levels of ozone for injury development.** In: Exceedances of critical loads and levels. Vienna: 1995 November 22-24; Austrian Research Centre Seibersdorf; 1-15.

Council Directive. 1992 92/72/**EEC of 21 September 1992 on air pollution by ozone.** Official Journal of the European Communities, No L 297/1-7, 13.10.92.

Fuhrer, J.; Achermann, B. eds. 1994. **Critical levels for ozone:** a UN-ECE workshop report. Schriftenreihe der FAC 16. Libefeld.

Godzik, S.; Piskornik, Z. 1966. **Transpiration of *Aesculus hippocastanum* L. leaves from air polluted and rural areas.** Bulletin Acad Polon. Sci., Ser.Sci. Biol. 14: 181-184.

Godzik, S.; Staszewski, T.; Kubiesa, P.; Szdzuj, J. 1996a. **Monitoring biologiczny wojewodztwa katowickiego (Biological monitoring of the Katowice administrative district).** Report 546/DN/95. Katowice: Instytut Ekologii Terenow Uprzemyslowionych.

Godzik, S.; Staszewski, T.; Kubiesa, P.; Szdzuj, J. 1996b. **Wykorzystanie roslin do oceny oddzialywania ozonu na srodowisko (Use of plants in assessing ozone effects on environment).** Report 4 S401 014 05. Katowice: Instytut Ekologii Terenow Uprzemyslowionych.

Godzik, S.; Szdzuj, J.; Osrodka, L.; Stawiany, W. 1995. **Time and spatial differentiation of ground level ozone concentration from four monitoring stations in the Upper Silesia Region - summer 1994.** In: Godzik, S.; Starkel, L., eds. Ozone — a global and regional problem. Polish National Commission on Global Change. Katowice: Institute for Ecology of Industrial Areas; 41-50.

Godzik, S.; Szdzuj, J.; Pawlinska, R. 1991. P**roby oceny bezposredniego i posredniego udzialu zanieczyszczen powietrza w uszkadzaniu drzewostanow poza rejonami przemyslowymi (An attempt to assess the direct and indirect effects of air pollutants on trees outside industrial areas).** In: Poznawcze i praktyczne efekty badan prowadzonych w CPBP 03.11 w latach 1986 - 1990. Zabrze: PAN IPIS.

Legge, A.H.; Gruenhage, L.; Nosal, M.; Jaeger, H.J.; Krupa, S.V. 1995. **Ambient ozone and adverse crop response: an evaluation of North American and European data as they relate to exposure indices and critical levels.** In: Exceedances of critical loads and levels. Vienna 1995 November 22-24, Austrian Research Centre Seibersdorf; 1-35.

Manning, W.J.; Feder, W.A. 1980. **Biomonitoring of air pollutants with plants. London: Applied Science Publishers.**

Sanders, G.; Benton, J. 1995. Ozone pollution and plant response in Europe — an illustrated guide. The Nottingham Trent University, Nottingham: UN ECE. The ICP-Crops Coordination Centre.