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Original Research

Assessment of Bark Reaction of Select Tree Species as an Indicator of Acid Gaseous Pollution

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Abstract

pH values of the bark of the common tree species black locust (*Robinia pseudoacacia* L.), sycamore maple (*Acer pseudoplatanus* L.), European yew (*Taxus baccata* L.), and European ash (*Fraxinus excelsior* L.) were evaluated to determine the acid gaseous pollution impact on their bark in eight heavily industrialized cities of southern Poland and relatively unpolluted areas of the Beskidy Mountains, Częstochowa Upland, and Nida Basin. It has been stated that the correlation between SO_2 levels in the atmosphere and the reaction of tree bark exists in all investigated tree species. Hence, the reaction of the bark of these species could be used as a simple indicator of air pollution. The results suggest that the European ash bark could be the best bioindicator.

Keywords: bark pH, SO_2 pollution, biomonitoring

Introduction

Gaseous pollution of the atmosphere, harmful for forest ecosystems, requires monitoring systems. There is a need to find methods that allow determining the condition of the environment in a given area in an easy and inexpensive way. The bioindicative methods that use whole plants or plant tissues are of great interest for long-range observations. Special attention is paid to mosses and lichens because of their great accumulation capacity for many pollutants [1-4]. Among higher plants, the tree bark appeared to be a perfect material to determine acid gaseous pollution rates of the environment [5-7]. It has been stated that a correlation between SO_2 levels in the atmosphere and reaction of tree bark exists – a higher concentration of sulphur dioxide results in decreasing pH values [8]. Tree bark, because of its large surface and permanent contact with the air, is a good indicator of the atmospheric condition where the tree is growing. Last but not least, it is ubiquitous and could easily be collected even by untrained persons [6, 9, 10].

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The aim of this research was to determine whether the bark of four tree species is suitable for biomonitoring of acid gaseous air pollution. The pH of the bark of black locust (*Robinia pseudoacacia* L.), sycamore maple (*Acer pseudoplatanus* L.), European yew (*Taxus baccata* L.), and European ash (*Fraxinus excelsior* L.) collected in cities of industrialized southern part of Poland were measured. Obtained data was compared with "control" sites situated in relatively unpolluted areas.

Material and Methods

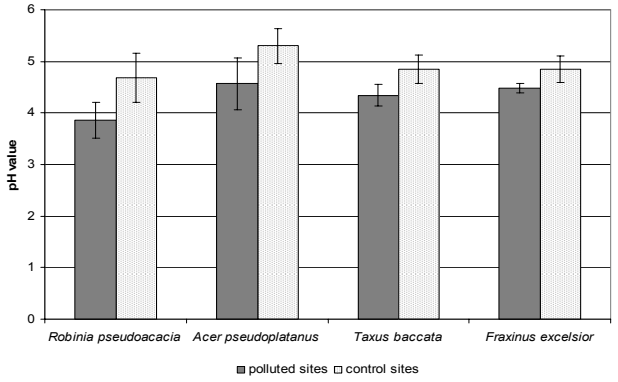
Eight heavily industrialized cities of southern Poland were chosen: Będzin, Katowice, Sosnowiec, Bytom, Dąbrowa Górnicza, Chorzów, Siemianowice Śląskie, and Gliwice. The control samples were taken in relatively unpolluted areas of the Beskidy Mountains, Częstochowa Upland, and Nida Basin (Cieszyn, Ustroń, Cisownica, Skoczów, Brenna, Ogrodzieniec, Pilica, Jędrzejów, and Busko Zdrój).

Before sampling, the bark was cleaned with a synthetic hard brush. Bark chips were collected with a sharp knife, with no relation to cardinal points, at a height of 1.3 m above the ground, and in accessible places in the case of a yew tree. Samples from each location consisted of five subsamples collected in different points in city centers. Based on these five subsamples, a mean pH value was calculated for every location.

The samples were pulverized and dried at 105ºC for 24 h. 8 ml distilled water (pH 7±0.05) was added into 2 grams of dried samples. Each sample was prepared in two replicates. The pH measurements were done after 48 hours [11].

All measurements were carried out in one month's time from the date of sampling.

The statistical significance of differences between bark pH values in polluted and control sites was verified using T-test (Statistica 9).



	Robinia pseudoacacia	*Acer pseudoplatanus*	*Taxus baccata*	*Fraxinus excelsior*
Polluted sites	3.86±0.35	4.57±0.50	4.34±0.22	4.48±0.10
Control sites	4.69±0.48	5.31±0.34	4.85±0.27	4.84±0.26

Fig. 1. Mean bark pH values ±SD at polluted and control sites [23].

Obtained pH values were referenced to mean SO_2 concentrations (measured, modelled, or interpolated) in atmosphere at examined locations. Sources of those data were: IETU [12], WIOŚ Bielsko-Biała (for Ustroń and Cieszyn) [13], Gospodarka Surowcami Mineralnymi [14] (for Busko Zdrój), and WIOŚ Kielce (for Chęciny – data used for Jędrzejów) [15]. And for Dąbrowa Górnicza, Katowice, and Chorzów – concentrations measured; for Będzin, Sosnowiec, Siemianowice Śląskie, and Gliwice – concentrations modelled; and for Bytom – concentration interpolated.

The prevailing acid gaseous pollution in the investigated area according to Central Statistical Office [16] is sulphur dioxide.

Results and Discussion

The bark pH values of examined tree species differed significantly between polluted and relatively unpolluted locations (yew tree $t=-4.57$, $p\leq0.05$, $df=18$, ash $t=-4.32$, $p\leq0.05$, $df=18$, blac locust $t=-3.05$, $p<0.05$, $df=7$, sycamore maple $t=-2.47$, $p<0.05$, $df=7$) (Fig. 1). The lowest differences relate to European ash (0.36 pH unit) and the greatest to black locust and sycamore maple (respectively 0.8 and 0.7 pH unit). However, it should be stated that the relatively unpolluted sites, from which the samples of black locust and sycamore maple were collected, were less polluted by SO_2 than the locations from where the ash tree samples were collected (Fig. 2). Among heavily polluted locations, where the SO_2 concentrations were on a similar level, the lowest pH characterized the black locust bark and the highest the European ash bark. The pH values at unpolluted sites for sycamore maple and European ash bark were 4.9-7.5 according to Wirth [17]. Similarly, at our control sites the mean pH for sycamore maple and European ash were 5.30±0.34 and 4.84±0.26, respectively. The European ash is also characterized by the highest bark pH values in Grodzińska [5] research.

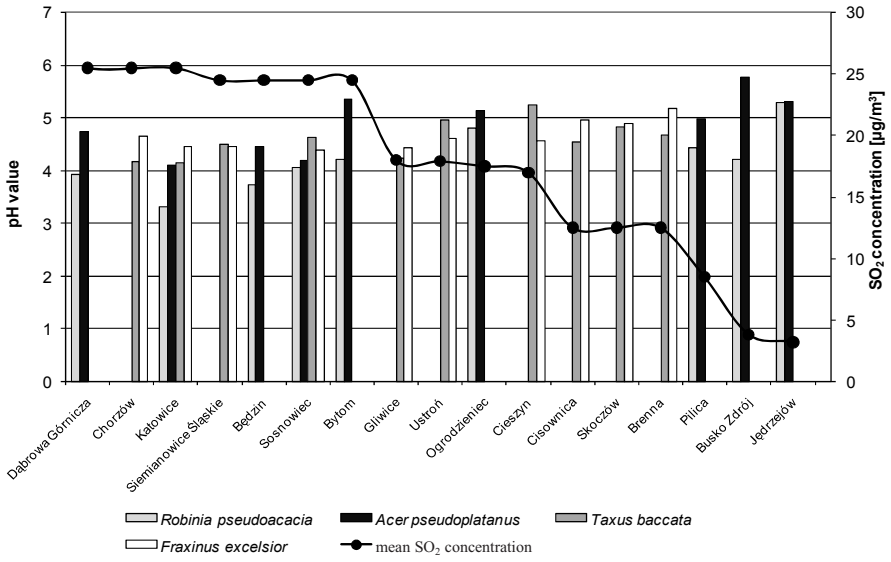


Fig. 2. Mean bark pH and SO_2 concentrations [µg/m^3] at investigated locations.

Table 1. The correlation coefficient value between bark pH and SO_2 concentration in the atmosphere.

Tree species	Correlation coefficient
Robinia pseudoacacia	-0.52**
Acer pseudoplatanus	-0.70*
Taxus baccata	-0.50***
Fraxinus excelsior	-0.78*

r-correlation significance *p=0.001, **p=0.02, ***p=0.05, n=8 (for *Robinia pseudoacacia* and *Acer pseudoplatanus*), n=10 (for *Taxus baccata* and *Fraxinus excelsior*).

The correlation coefficient shows a statistically significant negative relationship between bark pH and SO_2 concentration in the atmosphere in all investigated species (Table 1). The strongest correlation applies to European ash bark and the lowest, although statistically significant (p=0.05, r = -0.50), to the European yew bark. The increasing pH value in relation to decreasing atmospheric SO_2 concentrations confirms the influence of atmospheric pollution on the external bark layer. The same relation was stated in research carried out in Frankfurt a. M. [18], London [19], and Copenhagen [20].

First of all, the bark is permanently leached by stemflow during rainfall, which often is acid in polluted areas [10]. Bark of the species with high pH value may be acidified with time, because of buffer capacity loss caused by gradual cation leaching by acid rain [21].

It is considered that due to the process of bark formation it is better to use the deciduous trees for acid gaseous pollution monitoring purposes. They are more sensitive to acidity changes [6]. The influence of living tissues could be avoided in the case of trees with thick rough bark. Because of that the bark composition is determined mostly by environmental conditions [6]. For example, beech bark is quite thin because of constant cambium activity and its pH is relatively high (5.3 pH unit) [6]. Among species that have thick and rough bark it often comes into permanent acidification because there is no contact with the living tissue and the cation amount is not complemented [22].

These characteristics refer to the bark of black locust, sycamore maple, and European ash, but in comparison to other investigated species the reaction of European ash bark is especially strongly correlated with the atmospheric SO_2 concentration.

Conclusions

It has been stated that the acid pollution of the atmosphere has an impact on tree bark reaction.

The results suggest that all investigated tree species could be useful in environmental acid gaseous pollution monitoring. European ash bark seems to be the best bioindicator because its pH values were most related to the SO_2 concentration in the atmosphere.

References

1. WINDISCH U., VORBECK A. Lichens as bioindicators of air quality in Bavaria. Aschaffenburg, pp. 62, **1996** [In German].
2. LOPPI S., NELLI L., ANCORA S., BARGAGLI R. Passive monitoring of trace elements by means of tree leaves, epiphytic lichens and bark substrate. Environ Monit Assess. **45**, 81, **1997**.
3. POIKOLAINEN J. Mosses, epiphytic lichens and tree bark as biomonitors for air pollutants – specifically for heavy metals in regional surveys. Oulu University Press: Oulu, pp. 64, **2004**.
4. SROGI K. Bioindicators in environmental pollution monitoring – a review. Wiad. Chem. **59**, (11-12), 1001, **2005** [In Polish].
5. GRODZIŃSKA K. Acidity of tree bark as a bioindicator of forest pollution in southern Poland. Water Air Soil Poll. **8**, 3, **1977**.
6. SANTAMARIA J. M., MARTIN A. Tree bark as a bioindicator of air pollution in Navarra, Spain. Water Air Soil Poll. **98**, 381, **1997**.
7. REISNER V., OTS K. Bark pH of Scott pine in industrial areas of Lääne- and Ida-Viru counties. Forestry Studies. **XXXVI**, 62, **2002**.
8. PALOWSKI B., ŁUKASIK I., CIEPAŁ R., KORCZAK A. Bioindication of the urban environment with tree bark. In: "Biological reactions of trees to industrial pollution" Materials for the Fourth National Symposium Poznan-Kórnik, Bogucki Wydawnictwo Naukowe: Poznań, pp. 369-372, **2002** [In Polish].
9. KUIK P., WOLTERBEEK H. TH. Factor analysis of trace-element data from tree-bark samples in the Netherlands. Environ Monit Assess. **32**, 207, **1994**.
10. KUANG Y., ZHOU G., WEN D., LIU S. Acidity and conductivity of *Pinus massoniana* bark as indicators to atmospheric acid deposition in Guangdong, China. J. Environ. Sci. **18**, (5), 916, **2006**.
11. OSTROWSKA A., GAWLIŃSKI S., SZCZUBIAŁKA Z. Methods of analysis and evaluation of properties of soils and plants. Catalogue of the Environmental Protection Institute, Warszawa, **1999** [In Polish].
12. CENOWSKI M., LIŚ CZ., BRONDER J. Updating for assessment of air pollution in the Silesian region for time period 2005-2007, based on mathematical modeling with particular emphasis on the impact of various emission sources and the parameters used for calculations for sulfur dioxide, nitrogen oxides, PM10, benzene, lead and carbon monoxide and arsenic, cadmium, nickel and benzo/a/pyrene in 2007. IETU, Katowice, **2009**.
13. WIOŚ DELEGATURA W BIELSKU-BIAŁEJ. Assessment of air quality in the Silesian Voivodship in the years 2002-2006. part II. The report on the implementation of environmental protection program for the Cieszyn district in 2004-2006 www.powiat.cieszyn.pl/includes/informacje/ws/r1.doc (04.2010).
14. GAŁAŚ S., KRÓL E. Indicators for environmental – spatial order assessment on the example of the Busko and Solec spa communes. Gospodarka Surowcami Mineralnymi. **24**, (2/2), 95, **2008** [In Polish].
15. WIOŚ KIELCE http://www.kielce.pios.gov.pl/monit/wyniki/2006/cheso206.gif (04.2010)
16. CENTRAL STATISTICAL OFFICE (GUS). Environment 2007. Warsaw, pp. 233, **2007**.
17. WIRTH V. The lichens of Baden-Wuerttemberg, Part 1. Stuttgard, Verlag Eugen, Ulmer. pp 572, **1995** [In German].

18. LŐTSCHERT W., KŐHM H.-J. Characteristics of tree bark as an indicator in high-immission areas. Oecologia (Berl.). **27**, 47, **1977**.
19. LARSEN R.S., BELL J.N.B., JAMES P.W., CHIMONIDES P.J., RUMSEY F.J., TREMPER A., PURVIS O.W. Lichen and bryophyte distribution in oak in London in relation to air pollution and bark acidity. Environ. Pollut. **146**, 332, **2007**.
20. JOHNSEN I., SØCHTING U. Influence of air pollution on the epiphytic lichen vegetation and bark properties of deciduous trees in the Copenhagen area. Oikos **24**, (3), 344, **1973**.
21. FARMER A. M., BATES J. W., BELL J.N.B. Seasonal variations in acidic pollutant inputs and their effects on the chemistry of stemflow, bark and epiphyte tissues in three oak woodlands in N. W. Britain. New Phytol. **118**, 441, **1991**.
22. LEGRAND I., ASTA J., GOUDARD Y. Variations in bark acidity and conductivity over the trunk length of silver fir and Norway spruce. Trees. **11**, 54, **1996**.
23. KASPRZYK M. Environment monitoring with use of *Acer pseudoplatanus* L. and *Robinia pseudoacacia* L. as bioindicators. Master of Science Thesis. Katowice, **2008** [In Polish].