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MEASUREMENTS OF THE DEPOSITION OF SELECTED COMPOUNDS IN THE FOREST IN WOLIN NATIONAL PARK; A REVIEW

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Abstract

The article presents results of a study conducted between 1985- 1996 concerning the deposition of sulphur dioxide, nitrogen oxides, fluorine compounds and dust in the forest in the Woliński National Park (WNP) area. Applying standards established by the Forestry Research Institute, Warsaw, potential hazards from particular pollutants were evaluated as medium, high and in some instances - extremely high. Statistical analysis of relationships of monthly depositions of SO_2, NO_x, H_2F_2 and dust fall-out and certain climatological parameters (air temperature, wind speed and direction, amount of precipitation, air humidity), carried out also by statistical methods, indicated that NO_x and dust deposition represented ecological hazards to the tree stand of WNP. Extremely high deposition values of both parameters were observed with air masses from the south. This observation coincides with the extended technical modernisation of the chemical plant „Police" (situated close to Szczecin), including the change of raw material in the WNP production of phosphoric acid. The study confirmed the fact that the greatest threat to WNP forest comes from the nearby pollution sources, mainly NO_x and dust emitters, especially the heating and power plant of the Szczecin agglomeration and the power plant „Dolna Odra", near Gryfino.

INTRODUCTION

Pollution of the atmosphere, spreading globally, creates a great threat to forest stands (Amaya *et al*. 1983, Cosby *et al*. 1985). Sulphur dioxide, fluorine derivatives (most frequently H_2F_2), oxidants (in this category: nitrogen oxides and ozone) and dust play a particularly harmful role in this respect. A highly destructive effect of these pollutants is observed either in solutions (after dissolving in rain), in the form of acid rain (Dotreppe-Grissard 1972, Dunikowski *et al*. 1987, Falkengren-Grerup 1987, Garścia 1983, Grenfelt *et al*. 1994), or in the form of dry gaseous deposits destroying living tissues of plants (Grudziński *et al*. 1991 a & b).

The forest area of the Woliński National Park was included, since 1985, in the national network of forest monitoring. This comprised the determination of SO_2, NO_x, F_2 and dust fall-out and was carried out by the Forestry Research Institute (Lewicki *et al*. 1992, Liwińska & Wawrzoniak 1991, 1992, 1993, Meiwes *et al.* 1986, and many others). Between 1992-1995 WNP was conducting these studies within its own framework (Wawrzoniak *et al*. 1988, Wawrzoniak *et al*. 1991) and the results of studies in 1985-1991 were published in (Wawrzoniak *et al*. 1988a & b).

STUDY AREA AND EXPERIMENTAL METHODS

The dry deposition of sulphur dioxide, nitrogen oxides and hydrogen fluoride were determined by the sedimentation method (Wawrzoniak *et al*. 1988a) using so-called contact candles. The candles were posted in 6 measurement points in the forest area of WNP (Fig.1). Dust fall-out was also measured by the sedimentation method. The applied methods although producing strongly approximated results (Wawrzoniak *et al*. 1988b, Wawrzoniak & Małachowska 1989) and with considerable possibility of analytical error due to the deflection of aerosol and dust particles, were thought adequate to monitor sulphur dioxide, nitrogen oxides and hydrogen fluoride deposition from the air into the forests (Namieśnik *et al*. 1995, Nellemann & Frogner 1994, Poleszczuk & Jakuczun 1996, Sadowska-Janusz 1983, Steinnes *et al*. 1993, Tamm & Hallbäcken 1988, Viollet 1975).

A contact candle and sedimentation tank were placed for 1 month (Fig. 2). The absorbed amounts of SO_2, NO_x, H_2F_2 were determined in a chemical laboratory of the Forest Management and Geodesy Office in Szczecinek, and since 1992 in the WNP laboratory. Dust was determined by weight. In winter, the measurements were carried out from 15 October to 15 April (6 monthly expositions). The remaining part of the year was taken as summer. Monthly results were averaged from 6 measurement points. These generalised data were presented in publications of the Forest Research Institute (IBL) (Lewicki *et al*. 1992, Liwińska & Wawrzoniak 1991, 1992, 1993, Namieśnik *et al*. 1995, Poleszczuk & Jakuczun 1996, Sadowska-Janusz 1983). Subsequent studies, in the years 1992-1995, were carried out according to procedures used by the IBL.

The potential threat to the tree stand was evaluated using a scale applied by IBL (Tab. I), ((Lewicki *et al*. 1992, Liwińska & Wawrzoniak 1991, 1992, 1993).

Meteorological data presented in this paper were registered at WNP meteorological station in Warnów near Międzyzdroje.

Table I

The scale of pollution hazard to forests

Pollutant	Potential hazard			
	low	medium	high	extremely high
SO_2 (mg SO_2/m^2·day)	0-10	10-30	30-50	>50
NO_x (mg NO_2/m^2·day)	0-0.2	0.2-0.5	0.5-1.0	>1.0
F (mg F/m^2·day)	0-0.3	0.03-0.06	0.06-0.10	>-0.10
Dust fall-out (mg/m^2·month)	0-1	1-3	3-8	>8

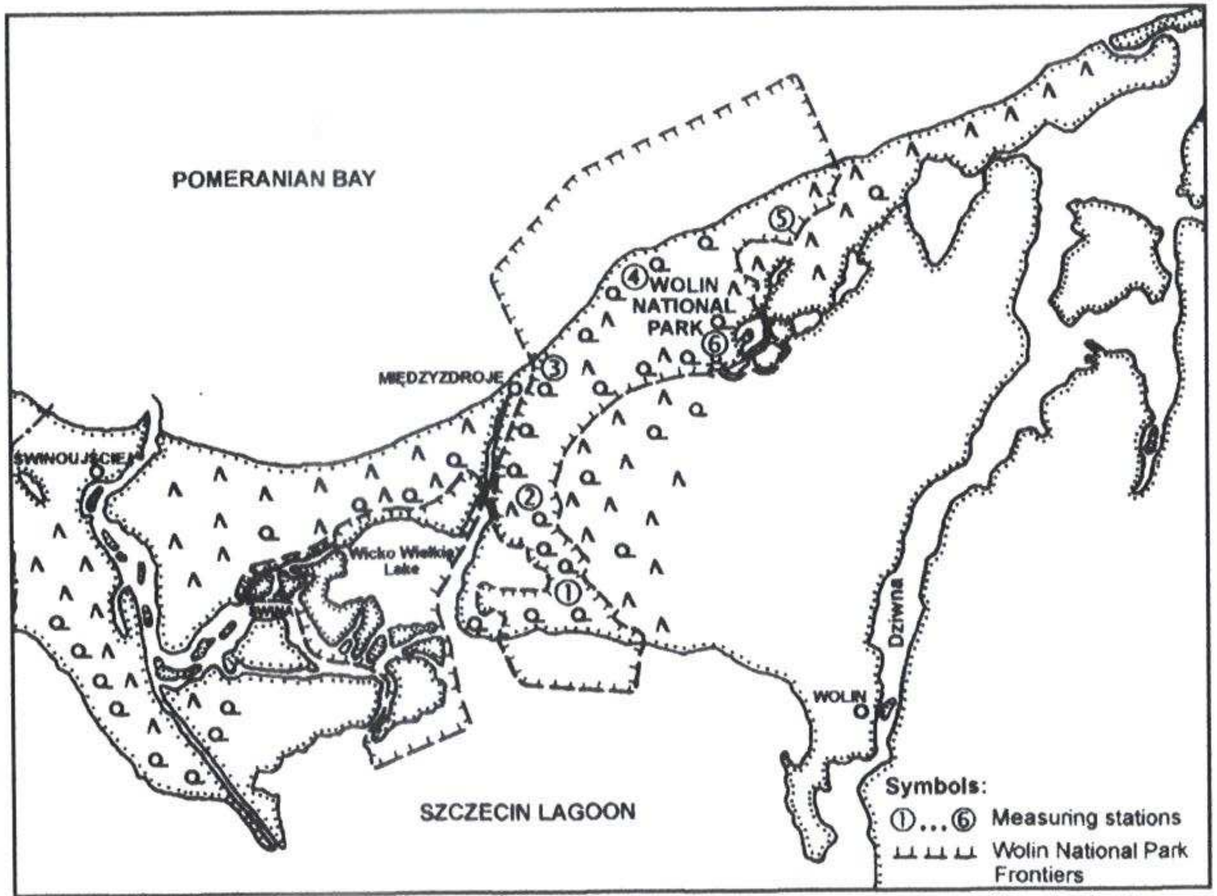

Fig. 1. Location of sampling stations for dry deposition of SO_2, NO_x, H_2F_2 and dust fall-out in the forest in Woliński National Park

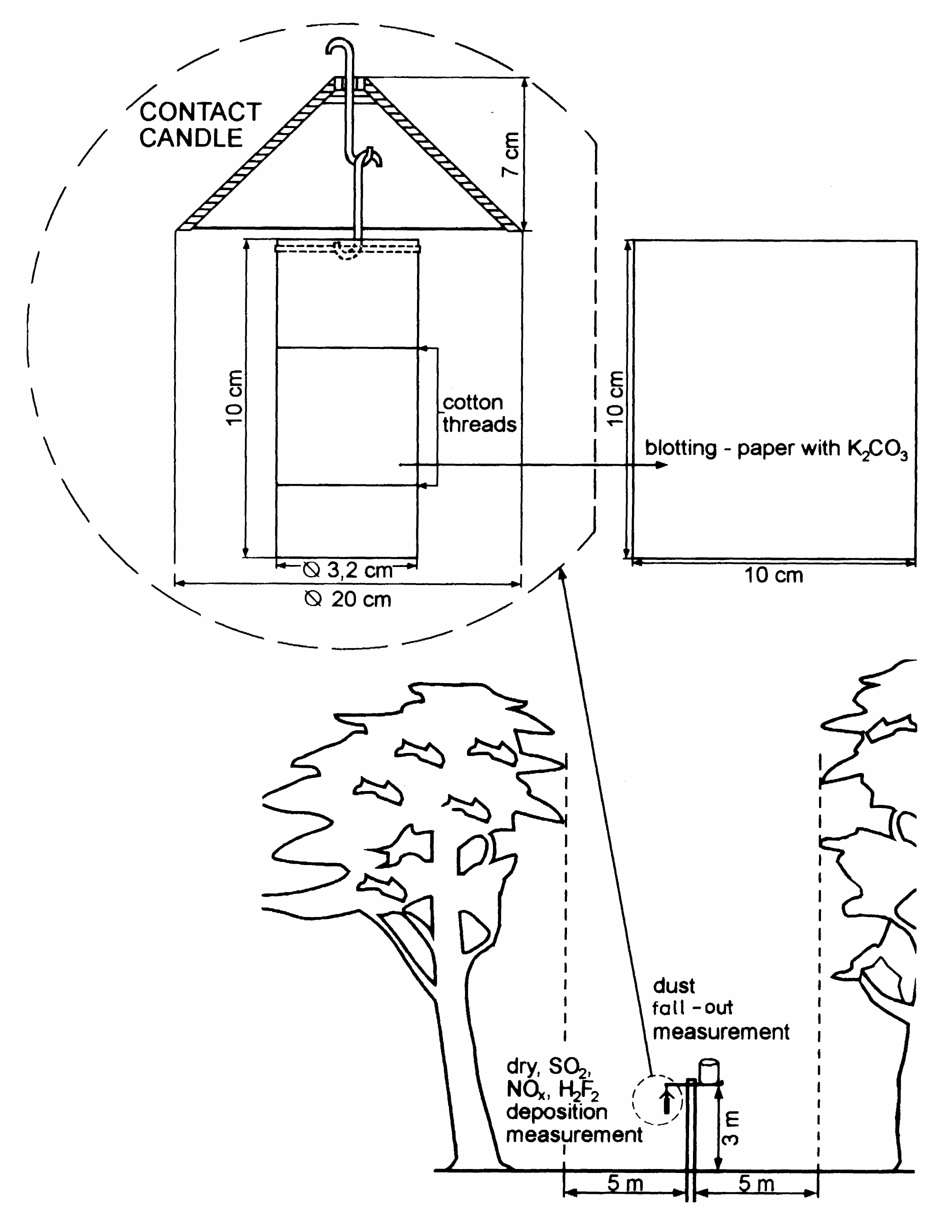

Fig. 2. Schematic illustration of measurement station and contact candle construction

RESULTS

The results of the study on the potential threat to the tree stand of Woliński National Park forest from the dry deposition of sulphur dioxide, nitrogen oxides, hydrogen fluoride and dust fall-out conducted between 1985-1996 are shown in figures 3-6.

Taking into account dry deposition of SO_2 and NO_x, the threat to the WNP forest is considered at a low level in summer and medium level in winter. It has to be mentioned that in winter extremely high monthly mean dry deposition values of SO_2 and NO_x were recorded, exceeding deposition values calculated from the emission balance for Poland (C = 21.918 mg SO_2/m^2/day) and in Poland and neighbouring countries (C = 24.794 mg SO_2/m^2/day), the data from 1982 (Amaya *et al.* 1983).

The results give evidence of particularly hazardous situations and threat to the WNP forest from high emission from sources located in the vicinity of WNP, e.g. a chemical plant in Police and „Dolna Odra" power plant in Gryfino, but also from emission from very distant sources - in the case of SO_2 from the middle of Europe (Wawrzoniak *et al*. 1989). Particularly hazardous situations appeared under unfavourable meteorological conditions - wind from a southern direction, lack of precipitation and specific air humidity.

To find support for the above conclusions, linear correlation coefficients were calculated between monthly deposition values of SO_2, NO_x and dust fall-out and selected meteorological parameters such as: monthly mean air temperature - which adequately characterises seasonality of the heating period in the Polish municipal heating system ($t_{air}<10^oC$); amount of wet precipitation (h_{H_2O}) - this, formally, is a factor decreasing the amount of SO_2, NO_x and dust deposited from the atmosphere, similarly to air humidity, though high humidity facilitates the formation of fogs which might migrate with wind and adsorb on contact candles; and finally - wind direction, expressed by the „mean wind modulus" = $|\alpha - 180|$. The mean wind modulus can be applied as an approximate measure of wind frequency; it classifies wind directions into the following categories: winds from WSS, S and SSO are characterised by $0^o \leq$ wind direction modulus $\leq 45^o$, winds from WN, WNN, N and NNO – $0^o \leq$ wind direction modulus $\leq 180^o$. The correlation coefficient was also calculated for the wind speed, the factor responsible for the intensity of gaseous phase penetration into blotting paper soaked in K_2CO_3 inside the contact candle. An additional parameter was introduced, the so-called directional modulus of ventilation intensity, calculated as a product of wind speed modulus and wind speed (Table 2).

The calculated values of correlation coefficients are presented in Table 3. A negative correlation was obtained between SO_2 deposition and NO_x deposition, and a positive one between NO_x and dust fall-out. Similarly, a negative correlation was found between SO_2 deposition and wind speed, and a positive one between this deposition and wet precipitation, which indicates the decisive effect of acidic fogs and rains on SO_2 deposition. Dust fall-out is negatively correlated with wind speed,

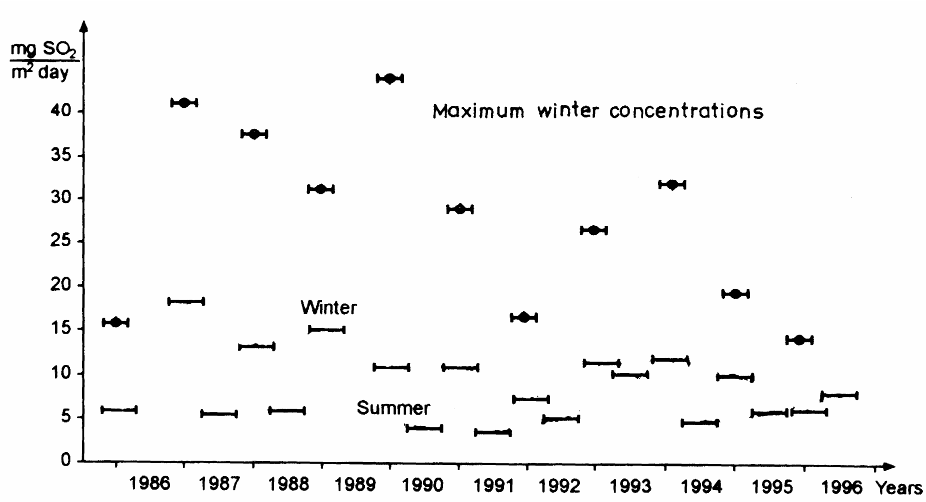

Fig. 3. Seasonal mean (winter-summer) and maximal monthly values of dry SO_2 deposition measured in Woliński National Park (mean values from 6 measurement stations)

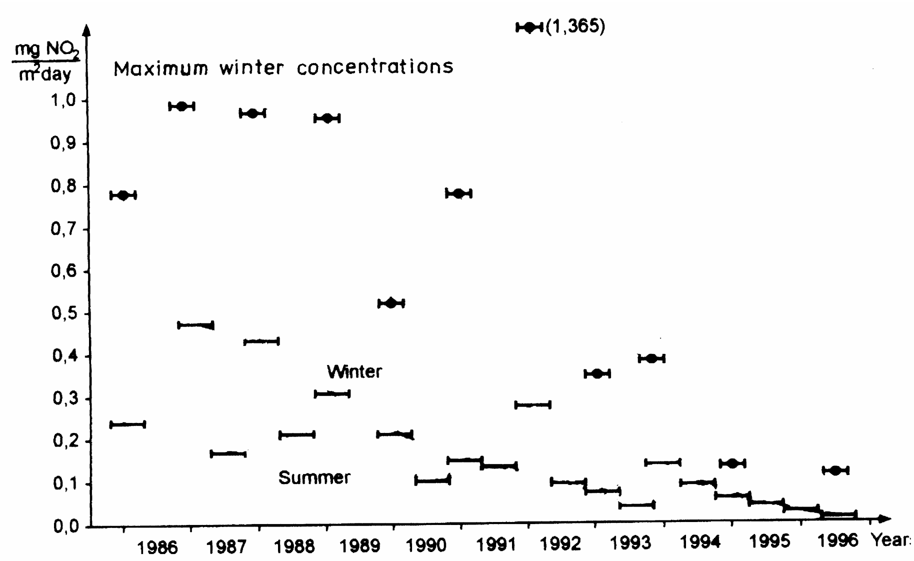

Fig. 4. Seasonal mean (winter-summer) and maximal monthly values of dry NO_x deposition measured in Woliński National Park (mean values from 6 measurement stations)

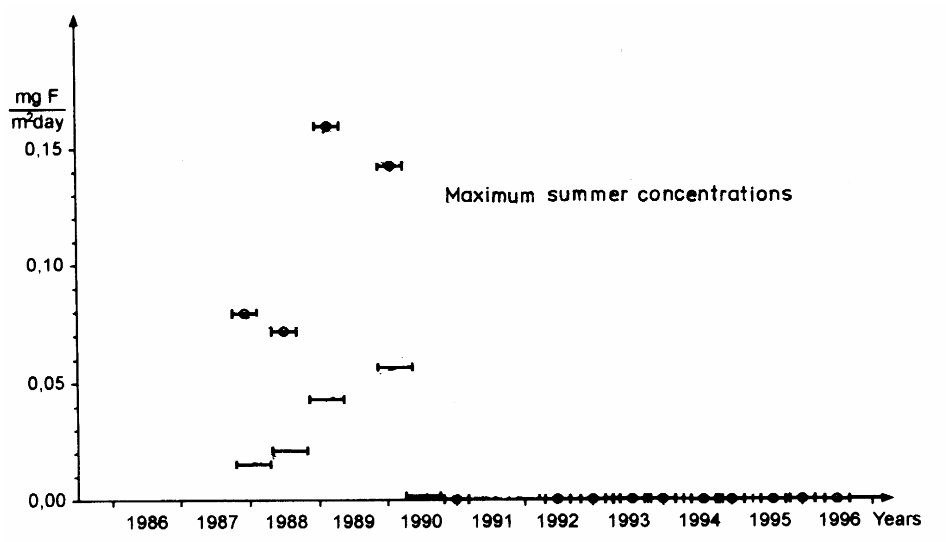

Fig. 5. Seasonal mean (winter-summer) and maximal monthly values of dry deposition of acidic fluorine derivatives measured in Woliński National Park (mean values from 6 measurement stations)

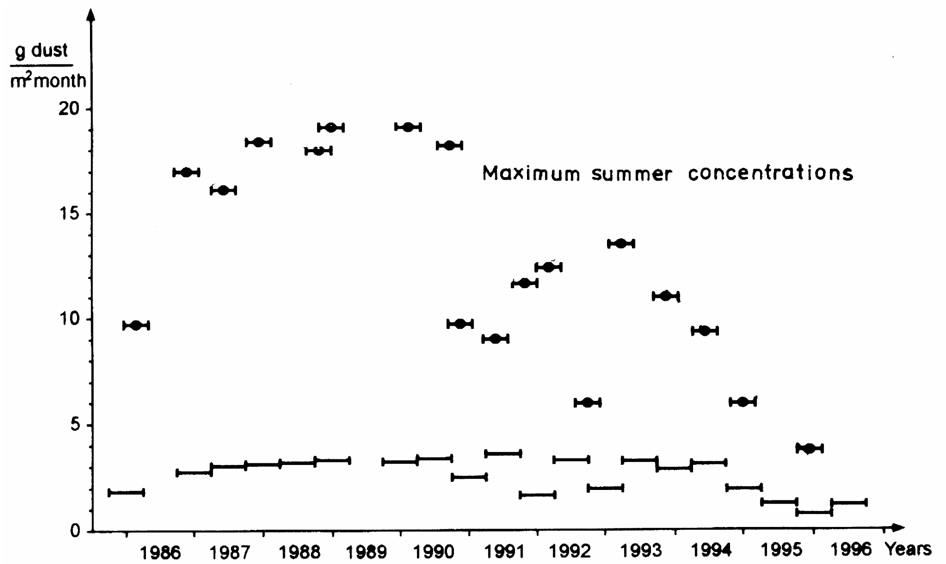

Fig. 6. Seasonal mean (winter-summer) and maximal monthly values of dust fall-out deposition measured in Woliński National Park (mean values from 6 measurement stations)

Table II

Results of airborne pollutant measurements in forests of Woliński National Park (y_{pi1}) and meteorological parameters (x_{p1}) between 15.01.1992 and 15.12.1992 (Wawrzoniak *et al.* 1991)

No	Period	SO_2 deposition ($mgSO_2/m^2$ day)	NO_2 deposition ($mgNO_2/m^2$ day)	F deposition (mgF/m^2 day)	Dust fall-out (mg/m^2 month)	Humidity (monthly mean) (mm H_2O)	Air temperature (°C)	Wind speed (monthly mean) (m/s)	Rain (monthly mean) (mm)	Wind direction modulus[1] (°)	Directional modulud of ventillation intensity $(m°/s)^2$
		y_{p1}	y_{p2}	y_{p3}	y_{p4}	x_{p1}	x_{p2}	x_{p3}	x_{p4}	x_{p5}	x_{p6}
1	I/II	2.957	0.185	0.000	1.429	5.9	0.15	2.77	35.5	55	152.35
2	II/III	5.154	0.106	0.000	1.325	7.0	2.90	3.50	61.3	47	168.73
3	III/IV	6.718	0.167	0.000	1.828	7.5	3.62	2.45	60.5	18	44.10
4	IV/V	9.168	0.248	0.000	12.321	9.4	7.61	2.30	37.5	01	2.30
5	V/VI	1.256	0.146	0.000	0.868	13.6	14.77	3.60	25.2	71	255.60
6	VI/VII	3.768	0.094	0.000	3.478	16.4	16.30	3.47	21.2	20	69.40
7	VII/VIII	6.823	0.055	0.000	1.878	16.8	17.33	2.58	67.4	30	77.20
8	VIII/IX	27.186	0.049	0.000	11.363	14.2	13.87	2.61	62.5	38	9918
9	IX/X	6.324	0.286	0.005	5.788	10.9	7.24	3.43	35.4	23	78.89
10	X/XI	6.540	0.068	0.000	1.976	7.6	4.11	2.97	52.1	24	71.28
11	XI/XII	10.075	0.075	0.000	2.125	7.1	2.96	3.00	50.2	13	39.00

[1] Wind direction modulus = $|\alpha - 180°|$

[2] Directional modulus of ventilation intensity = wind direction modulus * wind speed

Table III

Coefficients of linear correlation between pollutant deposition values (y_i^1) and meteorological parameters (x_i^1) (Wawrzoniak *et al.* 1991), data from 1992

No	Pollutant/parameter	Symbol	y^1	y^2	y^4	x^1	x^2	x^3	x^4	x^5	x^6
1	SO_2 deposition (mg SO_2/m^2 day)	y_1	1								
2	NO_2 deposition (mg NO_2/m^2 day)	y_2	-0.335*	1							
3	Dust fall-out (mg/m^2 month)	y_4	0.011	0.634*	1						
4	Humidity (hPa)	z_1	0.180	-0.299	0.029	1					
5	Air temperature (°C)	x_2	0.180	-0.316	-0.013	-0.988*	1				
6	Wind speed (m/s)	x_3	-0.436*	-0.016	-0.329*	0.116	0.104	1			
7	Rain (mm H_2O)	x_4	0.483*	-0.479	-0.303	-0.141	-0.144	-0.454*	1		
8	Wind direction modulus $(°)^2$	x_5	-0.205	-0.130	-0.636*	0.077	0.107	0.467*	-0.135	1	
9	Directional modulus of ventilation intensity $(m\,°/s)^3$	x_6	-0.299	-0.077	-0.563*	0.082	0.125	0.610	-0.232	0.974*	1

* Correlation significant at $\alpha = 0.05$,

[1] for variables: $Y = \frac{Y_{pi}}{Y_{p\max}}$, (yp and xp - measurement results - Table 3)

[2] wind direction modulus = $|\alpha - 0.05|$, (where α - monthly mean wind angle),

[3] directional modulus of ventilation intensity = wind direction modulus * wind speed

this finding was expected. A strong negative correlation appeared between wind direction modulus and dust fall-out. It is worth noticing here that the greatest dust fall-out was measured under clearly southern winds, this pointing out to a point source of dust pollution to WNP forest. Power Plant „Dolna Odra" and heating plants of Szczecin agglomeration are situated directly south of WNP. Because the data set for statistical analysis was rather limited (11 monthly mean values), the conclusions drawn from correlation coefficient values between measurement results and environmental parameters have to be considered as an approximation.

CONCLUSIONS

- The negative effects of dry deposition of SO_2, NO_x and dust fall-out on the forest of Woliński National Park were measured, by the technique of contact candles, in 1985-1994. The potential threat was assessed at low level in summer and medium in winter. Incidentally, high values of potential hazard were recorded, especially in winter.
- Dust fall-out values were evaluated as moderately and highly hazardous to the WNP forest. In winter extreme values of dust fall-out were registered (usually between January and April).
- From 1987 to 1990 a constant increase of hazards from fluorine was observed, increasing up to the high level. Since 1990 this pollution element disappeared, due to the change in production technology of orthophosphoric acid at the chemical plant „Police". The plant switched production from fluorine containing apatites $[Ca_3(PO_4)_2CaF_2]$ to fluorine-free phosphorites.
- The greatest potential threat to WNP forest from NO_x deposition and dust fall-out was registered under southern winds and weak wet precipitation. This strong relationship between NO_x and dust fall-out and southern wind gives strong evidence for the dominating effects from emission sources, i.e. from heating and power plants of the Szczecin agglomeration and the power plant „Dolna Odra" which are situated directly south of Woliński National Park.
- As regards dry deposition of sulphur dioxide, the level of this deposition depends mainly on the continental (European) air pollution with SO_2, and the measurements carried out in the vicinity of marine waters surrounding Wolin Island might be very erroneous due to sulphate defloated with aerosols and fogs.

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