ASSESSMENT OF THE PRESENCE OF SOLID FALLOUTS ON THE NEEDLES SURFACE OF *Pinus nigra* AND *Picea pungens* – IN RELATION TO NUTRITION IN THE AREA OF A MAGNESITE PLANT

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Abstract

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We carried out in the area Jelšava – Lubeník, polluted by magnesite fallout, sampling of the foliage of the individuals of Austrian pine (*Pinus nigra* A r n o l d) and blue spruce (*Picea pungens* E n g e l m.) planted out at different distance from the source of pollution. By means of raster microscope JEOL JSM 840 and X-ray analyser LINK 10000 we studied the particles deposited on the surface of needles (year-class 1995, 1996, 1997) it means dustiness in % (relative number of particles or % of a needle area covered by dust), which ranged from 10 to 30%, according to the distance from the source of pollution. We categorized the particles of solid fallout deposited in the stomata according to their shape and chemical composition. The particles typical for the production of magnesite and ferrous metals (Si, Al, Fe, S) with the particles composed of Mg prevailed. The state of stomata was evaluated according to the presence of respective kinds of epicuticular waxes (ratio of original tubular crystal wax and amorphous shapes forming the crust) and it was given in %. In older year-classes we found 30–50% of relatively functional stomata and 5–10% of stomata were non-functional and remaining 35–60% were functional only partially. In the needles of both evaluated tree species we recorded increased concentration of Fe, S, Mg, Ca, Zn and Mn, which corresponds with resultant values of the analyses of particles deposited on the surface of the foliage in particular sampling years.

Key words: air pollutants, foliage, dustiness, functionality of stomata, nutrients

Introduction

At present the most serious problem in forestry and nature conservation is unfavourable effect of polluted air on forest ecosystems. Air pollutants affect not only forests but they cause damage to the whole nature. This fact is confirmed by the data obtained every year within the International Cooperative Programme of the Assessment and Monitoring of Air Pollution on Forests. Most of the European states had in 1990 more than 40% of forests damaged by air pollutants.

Air pollutants affect physiological processes of forest tree species substantially earlier than this effect is reflected on microscopic level, it means by discolouration or reduced volume of foliage (Materna, 1986). Based on performed works concerning magnesite production it follows that main typical and decisive pollutant is magnesite, sulphur and nitrogen from combustion processes (they are emitted also from other sources) and solid pollutants (Maňkovská, 1981, 1995; Tučeková, 2001).

An elaboration of common methodology for the assessment of the changes in foliage chemistry (Stefan et al., 1997) was the result of international efforts. These facts concern older stands, while in our country less attention is paid to the effect of air pollutants on tree species used in reforestation already in juvenile stage.

There is a cuticular wax layer on the surface of needles, which is damaged by air pollutants as first. By Huttunen (1985) for example an erosion of epicuticular wax layer in the vicinity of stomata is the first characteristic symptom of the effect of air pollutants on needles. Polluted air causes damage to the surface of needles, which starts already several weeks after budding (Huttunen, 1985; Turrunen, Huttunen, 1990). In damaging the assimilatory organs by air pollutants, functional disturbances occur as first followed by some disturbances in the morphology of needles (Huttunen, Ruonala, 1986; Maňkovská et al., 2005; Trimbacher, Weiss, 1999). Bednářová found out (1994) that in damaged spruce trees with no so dense foliage there occurs reduction of the size and weight of needles by 10–25%.

The goal of the work was to assess and categorize solid fallout particles deposited in the stomata and on the surface of the needles of young plantations of *Pinus nigra* and *Picea pungens* in B pollution zone and then to find out subsequent effect on the state of nutrition due to magnesite pollutants fallout.

Material and methods

Sampling of the foliage of 5 and 9 years old trees of Austrian pine (*Pinus nigra* A r n o l d) and blue spruce (*Picea pungens* E n g e l m.) was made according to the international methodology (ICP, 1994). Samples were taken two trees from every plot, from 3 branches and needles in three different year-classes (1995, 1996, 1997). We carried out sampling on two research plots (Jelšava 1, Lubeník 1M) and one semi-operational plantation (Lubeník) in different distance from the source of pollution in alkaline pollution region (magnesite) Jelšava-Lubeník. The plantations, where the samples were taken, were established artificially in the management set of forest types 209 – Dry beech oak woods and 305 – Acidic oak beech woods, on clearings formed after salvage felling in the B pollution zone. The samples of the foliage were analysed unwashed. They were dried at the temperature not exceeding 80 °C for 24 hours. Dry samples of the foliage were homogenized consistently. Pressure mineralisation was done by means of microwave furnace MDS 2000 (CEM firm). We determined the total concentration of Ca, Cu, B, K, Mg, Mn, P and Zn in the foliage by ICP –AAS of atomic absorption spectroscopy on the analyser ICP 3000 (LECO).

We carried out sampling on all experimental plots in the depth 0–5 cm, 10–20 cm and 25–40 cm according to the international methodology (ICP, 1994). The methods are presented in Table 1.

T a b l e 1. Methods of soil analyses.

Determined sign	Symbol	Measuring unit	Methods
Active reaction	$pH\text{-}H_2O$	pH	Electrometric (1: 2.5)
Exchangeable reaction	pH-KCl	pH	Electrometric 1M Kcl (1: 2.5).
Total oxide org. carbon	C_{ox}	Weight % of dry matter	Oxidometric with colorimetric determination of Cr^{3+}
Total nitrogen	N_t	Weight % of dry matter	Analyser LECO FP 228
Equivalent of carbonates	Equiv. $CaCO_3$	Weight % of dry matter	Volumetric with calcimeter with HCl 1: 1
Available phosphorus	P	mg.kg–1of dry matter	Method by Mehlich II. AES – ICP; Extraction by 1M solution of ammonium acetate
Available potassium	K	$mg.kg^{-1}$of dry matter	Method by Mehlich II. AES – ICP; Extraction by 1M solution of ammonium acetate
Available calcium	Ca	mg.kg–1 of dry matter	Method by Mehlich II. AES – ICP; Extraction by 1M solution of ammonium acetate
Available magnesium	Mg	$mg.kg^{-1}$ of dry matter	Method by Mehlich II. AES – ICP; Extraction by 1M solution of ammonium acetate
Water soluble magnesium	Mg_{H2O}	$mg.kg^{-1}$ of dry matter	In water leach 1: 5 AES - ICP

Elementary analyser LECO SC 132 was used for the determination of the total concentration of sulphur in the foliage and soil. Total concentration of nitrogen in the foliage and soil was determined on elementary analyser LECO SP 228. The results were calculated to dry matter, which was determined separately. The accuracy of the used methods for the determination of mentioned elements was verified by 109 independent laboratories and tested within IUFRO (Hunter, 1994).

By means of scanning electron microscope JEOL JSM 840 and X-ray analyser LINK 10000 we studied particles deposited on the surface of needles, it means % of foliage surface covered by particles. We categorized solid fallout particles, deposited in stomata, according to their shape and chemical composition (Maňkovská, 1992) (Table 2). We evaluated the state of stomata by the presence of respective kinds of epistomatal waxes (ration between original tubular crystalline wax and amorphous forms forming crust) given in %.

For the assessment of total loading in the vicinity of magnesite by Cu, Fe, Mg, N, Zn, and S pollutants we used Kz coefficient of loading by air pollutants, which gives exceedance of limit values of studied elements in the foliage of forest tree species (Maňkovská, 1996). Coefficient of loading by air pollutants Kz is defined as an arithmetical mean of n elements, which are cumulated in the foliage of forest tree species. Standard values (Yi n of elements) are given by the relation:

$$Y_i = \frac{M_i}{m_i} \quad \text{valid for i element}$$

Where:

M – concentration of Cu, Fe, Mg, N, Zn and S (in $mg.kg^{-1}$) in the foliage of studied forest trees in 2000

m – concentration of Cu, Fe, Mg, N, Zn and S (in $mg.kg^{-1}$) in the foliage of studied forest trees from control areas – sampling in the years 1974–1975 (Maňkovská, 1996): Cu (2), Fe), Mg (1000), N (13500), Zn (45) and S (1000)

n – number of studied elements

Coefficient of loading by air pollutants K_z is defined

$$K_z = \frac{1}{n} \sum_{i=1}^{n} Y_i$$

T a b l e 2. Classification of particles deposited in the stomata of forest tree species foliage.

Category	Morphology	Major EDX spectrum
A Biological	Characteristic for spores or pollen grains (a)	Low peak for backgroundRatios of the elements: Si, S, Ca, K, P
B Mineral	Non-spherical, irregular forms of large particles, from the soil, limestone ($CaCO_3$), dolomite (Ca, Mg $(CO_3)_2$), SiO_2, $CaSO_4$ and complex mixtures of alkaline origin	High peak for background ratios of the elements Si or Ca and others as Al, K, Ti, Fe, Na
C Fly ash from black oil	Small oval particles rich in Al, Si, S; cenospheric with Al-Si, V and Ni; sulphates rich in Cr, Fe, Ni with metal-black shine	Al, Si, S, V, Ni and Cr
D Fly ash from coal	Small oval particles similar to the ones from B group with Al-Si;	Similar to mineral particles with Al-Si
E Fly ash from black oil and coal	Small oval particles similar to the ones from C group with Al-Si; small porous particles containing carbon together with D category	Al-Si, V, Ni and Cr
F Industrial	Various particles which correspond to production technology: Aluminium production Cement production Magnesite production Iron production Non-ferrous metals production Other production	 I Al II Ca III Mg IV Fe V Mn, Ni, Zn, Br, Rb, Sr VI Other elements

Two-way analysis of variance was used for the evaluation of the difference in elements' concentration for needle year-classes (1995, 1996, 1997) of *Pinus nigra* and between tree species (*P. nigra* and *Picea pungens*) and needle year-classes (1995, 1996, 1997) in the locality Lubeník.

Results and discussion

The magnesite plants Jelšava and Lubeník emitted in 1980 30 000 t of magnesite dust and heavy metals (Pb, Cd, Zn) and 4000 tons of SO_2 what caused extreme damages to the dominant tree species (*Fagus sylvatica* L. and *Quercus* sp.) in the area of 500 km^2 (Tučeková, 2001). In all localities the studied elements accumulated conclusively (Table 3). Coefficient of loading Kz shows exceeding control values (Table 4).The region of Lubeník and Jelšava was classified as alkaline depositions air pollution type (magnesite type) with significant effect of emitted magnesium (Maňkovská, 1981, 1996).

T a b l e 3. Concentration of elements (in $mg.kg^{-1}$) in leaves of *Fagus sylvatica* (FS) and *Quercus* sp. (Q) in area of magnesite plants and control locality of Čierny Balog.

Element	Tree species	Magnesite plants (n = 20)				Control locality (n =10)		Kz for elements	Kz together
		X	SD	Min	Max	X	SD		
Mg	FS	14720	16971	2720	26720	1160	214	12.7	10.9 5.3
S	Q	15100	16603	3360	26840	1220	195	12.4	
	FS	4108	4039	1252	6964	750	92	5.5	
Zn	Q	5183	5772	1102	9265	800	58	1.4	
	FS	74.5	19	61	88	41	5.4	1.8	
Pb	Q	93	47	60	126	45	4.9	2.1	
	FS	31.6	43	1.2	62	2.9	0.5	10.9	
Cd	Q	19	13	10	28	3.6	0.8	5.3	
	FS	21.6	29	1.2	42	0.92	0.12	23.5	
	Q	5	6	1	9	0.93	0.15	5.3	

Note: x – arithmetical means, SD – standard deviation, Min – minimal value, Max – maximal value
Kz – coefficient of loading

Data from the analyses of deposited particles on the surface of *Pinus nigra* needles detected by means of scanning microscope JEOL JSM 840 and X-ray analyser LINK 100 000 are presented in Table 5. Dustiness of the foliage surface impedes basic physiological processes. Regarding the resultant assessment in Table 1 we can state that dustiness of the surface of *P. nigra* needles on PP Jelšava 1 represented about 10% for the year-class 1997, 10% for the year-class 1996 and 15% for the year-class 1995. On the surface of the needles of year-class 1995 and 1996 there were not found any spores or fungi mycelia. Fungi covered the surface of needles of the youngest year-class 1997 in 10%.

There were also identified on the surface of needles particles of mineral origin and particles typical for the production of ferrous metals, which corresponded by their chemical composition (Si, Al, Fe) to the particles typical for the combustion of fossil fuels. Particles composed of magnesium, which are typical for magnesite production, were noticeable.

For the *P. nigra* needles, year-class 1995 there are 50% of relatively functional stomata, 35% of stomata had about one half and 10% of stomata had one quarter of the surface of stomatal area damaged. 5% of stomata were not functional. For the year-class 1996 50% of stomata were relatively functional, 40% had one half of their surface damaged and 5% of stomata had one quarter of the surface damaged. Similarly to previous case 5% of stomata were not functional. We can observe this trend of reducing the values for the year-class 1997 with 55% of stomata relatively functional, 35% of stomata with one half of their surface damaged and 5% of stomata with one quarter of their surface damaged. 5% of stomata were not functional for this year-class as well.

T a b l e 4. Analysis of deposited particles on the surface of needles on the plot Jelšava 1 (*Pinus nigra*), Lubeník 1M (*P. nigra*) and Lubeník (*Picea pungens*).

Locality	Jelšava 1 (*P. nigra*)				Lubeník 1M (*P. nigra*)				Lubeník (*P. pungens*)			
Needles year -class	Category of particles	Element composition		Dustiness of the surface in %	Category of particles	Element composition		Dustiness of the surface in %	Category of particles	Element composition		Dustiness of the surface in %
		‹ 50 %	› 50 %			‹ 50 %	› 50 %			‹ 50 %	› 50 %	
1995	B, E, F_{II}, F_{IV}, F_{VI}	Si Si,Al Fe Mg,Fe Ca	Mg,K,Ca,Fe Mg,Al,Si,K Si,Cl,K,Ca Mg,Al,Si,K,Fe	15	A, B, E, F_{II}, F_{IV}, F_{VI}	Ti Ca,Fe Ca,Fe Fe,Ti Al,Si Mg	Al,Si,K,Ca,Cl,Fe Mg,Al,Mn Mg,Al,Si,K,Ti,Mn Mg,Al,Si,Ca,Mn K,Ti,Fe Si,Ca,Fe	30	B, E, F_{II}, F_{IV}, F_{VI}	Ca Mg Mg,Si,Fe,Ti Fe Cr	Mg,Cr,Si,Fe Al,Si,K,Ca,Mn,Fe Al,Cr,K,Ca,Mn Mg,Al,Si,K,Ca,Mn Mg,Al,Si,Fe	30
1996	B, E, F_{II}, F_{IV}, F_{VI}	Al,Si Ca,Mg Ti Ca,Ti,Fe	K,Ca,Fe Si,K,Ca Si,K,Ca Ca,Ti,Fe	10	A, B, E, F_{II}, F_{IV}, F_{VI}	Mg Cr,Fe Si Fe	Si,K,Ca,Fe Mg,Al,Cl,K,Ca Mg,Al,K,Fe Mg,Al,Si,K,Ca,Mn	15	B, E, F_{II}, F_{IV}, F_{VI}	Si Mg Fe Al,Si	Ca Si,Ca,Fe Mg,Al,Si,K,Ca Mg,K,Ca,Fe	30
1997	A, B, E, F_{II}, F_{IV}, F_{VI}	Fe Mg,Fe Fe,Ca,S Si,Al Mg,Fe,S	Si,K,Ca,Ti Si,K,Ca Mg,Al,Si,Cr,K Na,Mg,K,Ca,Fe Cl,K,Ca,Mn	10	A, B, E, F_{II}, F_{IV}, F_{VI}	Fe Si Fe,Ca Ti Si,Ti Si,Al	Mg,Al,Si,K,Ca Mg,K Al,Si,Ca,Fe Mg,Al,K,Ca,Fe K,Ca,Fe	10	B, E, F_{II}, F_{IV}, F_{VI}	Si Mg Al,Mg Ca,Fe Ca,Fe	Al,K Si,K,Ca,Fe Al,Si,K,Mn Al,Si,K,Mn	10

T a b l e 5. Concentration of B, Ca, Cu, Fe, K, Mg, Mn, N, P, S and Zn (median) in the needles of Pinus nigra needles on PP Jelšava 1 and Lubeník 1M and Picea pungens on PP Lubeník in sampling year 1995–1997 (mg.kg^{-1} of dry matter).

Localities	Tree sp.	Year	n	B	Ca	Cu	Fe	K	Mg	Mn	N	P	S	Zn
Jelšava 1	PN	1995	6	12.2	3700	**5.19**	**396**	*2100*	**3700**	*86.5*	10500	1000	**2480**	58.2
		1996	6	*9.67*	3800	**5.52**	**350**	3600	**3200**	*49.4*	12800	**1600**	**2710**	52.9
		1997	6	15.8	3200	**7.05**	141	3300	**3900**	*70.4*	14700	1500	**2550**	65.4
Lubeník 1M	PN	1995	6	17.4	4400	**5.89**	**268**	*2300*	**4400**	*68.8*	11000	1200	**2110**	70.8
		1996	6	17.3	3600	**6.45**	**252**	*3100*	**3300**	*86.2*	13900	**1600**	**2470**	43.9
		1997	6	21.2	3900	**7.18**	106	3500	**4000**	*104.2*	16900	1500	**2810**	53.9
Lubeník	PN	1995	6	14.8	3800	**6.32**	**330**	4400	**4200**	*62.3*	**17800**	1500	**2720**	56.8
		1996	6	*9.29*	4900	**6.26**	**323**	3400	**4200**	*46.4*	**17900**	1300	**2660**	64.7
		1997	6	11.5	3600	**5.99**	179	4700	**3600**	*57.4*	**21100**	1600	**2400**	67.9
Lubeník	PP	1995	6	14.3	4500	**4.61**	**314**	4700	**3800**	*45.9*	16200	**3100**	**2010**	69.1
		1996	6	13.2	4300	**5.51**	**284**	5400	**3800**	*97.9*	16500	**3500**	**2110**	66.8
		1997	6	12.4	3600	**5.89**	143	5600	**2700**	*95.3*	17000	**3100**	**2130**	61.8
Limit value*		from		11	1500	2	50	3500	600	200	12000	1000	1000	30
		to		100	6000	5	200	9000	1500	1000	17000	1500	1500	45

Note: PN – P. *nigra*; PP – P. *pungens*: *Innes (1995); Maňkovská (1996); **values in bold are exceeded limit values**; *values represent insufficient nutrition*

T a b l e 6. Coefficient of loading Kz for Cu, Fe, Mg, N, S and Zn.

Locality	Tree sp.	Year	Kz-Cu	Kz- Fe	Kz -Mg	Kz-N	Kz-S	Kz-Zn	Kz -Mg	Kz for elements	Kz together
Jelšava 1	PN	1995	2.60	7.92	3.70	0.78	2.48	1.29	3.70	18.77	3.13
		1996	2.76	7.00	3.20	0.95	2.71	1.18	3.20	17.79	2.97
		1997	3.53	2.82	3.90	1.09	2.55	1.45	3.90	15.34	2.56
Lubeník 1M	PN	1995	2.95	5.36	4.40	0.81	2.11	1.57	4.40	17.20	2.87
		1996	3.23	5.04	3.30	1.03	2.47	0.98	3.30	16.04	2.67
		1997	3.59	2.12	4.00	1.25	2.81	1.20	4.00	14.97	2.49
Lubeník	PN	1995	3.16	6.60	4.20	1.32	2.72	1.26	4.20	19.26	3.21
		1996	3.13	6.46	4.20	1.33	2.66	1.44	4.20	19.21	3.20
		1997	3.00	3.58	3.60	1.56	2.40	1.51	3.60	15.65	2.61
Lubeník	PP	1995	2.31	6.28	3.80	1.20	2.01	1.54	3.80	17.13	2.86
		1996	2.76	5.68	3.80	1.22	2.11	1.48	3.80	17.05	2.84
		1997	2.95	2.86	2.70	1.26	2.13	1.37	2.70	13.27	2.21
Kz -Limit value*			1	1	1	1	1	1	1	6	1

Note: PN – *Pinus nigra*; PP – *Picea. pungens*: *Innes (1995); Maňkovská (1996)

Similar situation was recorded also for *P. nigra* needles on PP Lubeník 1M (Table 6). In comparison with the samples from Jelšava 1 plot we observed for all three year-classes increased percentage of needles' dustiness, particularly 30% for 1995 year-class, 15% for 1996 year-class and 15% for the year-class 1997. One of the reasons of almost double dustiness can be also the distance of the research plot from the plant in Lubeník, which is about 500 m, whereas the plot in Jelšava is distant from the source about 1500 m. Another reason can be unequal amount of respective fallout of dust in the vicinity of both plants.

On the basis of other results of the analyses we can state the stomata of *P. nigra* needles are disturbed due to air pollutants effect. 10–30% of the surface is covered by fly ashes, which are produced in combustion of fuels, and by particles from industrial emission with some proportion of iron. Particles containing magnesium were present as well. We found that 50–55% of the stomata of *P. nigra* needles were relatively functional and 5% for all observed year-classes were completely non-functional.

On the samples needles we did not observe the symptoms of necrosis or chlorosis but the surface of *P. nigra* needles of the youngest year-class (1977) were covered by fungi in 10%.

On the surface of *Picea pungens* needles there were not spores and fungi mycelia. But we identified on the surface of the needles particles of mineral origin typical for the production of ferrous metals and spherical, smooth, glassy, small particles of fly ashes, which were present in the stomata as well. Similarly to previous tree species we observed the particles composed of magnesium. The dustiness of needles on the surface was the same for two older year-classes (1995 and 1996), namely 30% and 10%.

In the stomata of the oldest year-classes chromium was present as well, what we have not observed for Austrian pine. Spruce needles' stomata are disturbed due to air pollutants effect more than pine ones. We observed that 30% up to 45% of spruce needles' stomata are relatively functional and almost 10% are not functional at all for all observed year-classes. We observed also the trend of reducing the values of stomata functionality starting from the oldest year-class down to the youngest one. On the spruce needles we observed the changes of colouration (yellowing) and the changes in needles morphology (shortening of needles, so called starvation needles).

The samples of needles, which we observed by microscope, were analysed in the laboratories of the institute with the aim to find out the state of nutrition in respective year-classes of sampling (1995, 1996, 1997). The results of the analyses of the needles of Austrian pine and blue spruce are presented in Table 6.

The results of chemical analyses of Austrian pine needles correspond with resultant values from the analyses of the particles deposited on the surface of foliage in respective sampling year-classes. Increased concentration of Fe, S, Mg, Ca, Zn and Mn was recorded in the needles as well. We can state, that increased concentration of dust particles of mineral origin appears more markedly already in the youngest year-classes, namely in increased values of some elements in the needles of pine trees, though the values vary between year-classes. We can frequently observe the highest values (Mg, S, Mn) for the youngest year-class. Except for nitrogen (year-class 1995) and potassium (1995–1997), which reached critical level, other elements had optimal concentration for all year-classes. In foliage diagnoses (Bonneau, 1988) sometimes comparison of the results with the values of optimal concentrations is made more accurate by giving the ratios of the elements. As for example N/P should range from 15 to 20, the ratio N/Mg should be lower than 17.5 (if this is not the case the concentration of magnesium is low), the ratio K/Ca should be lower than 1.3 and the ratio S/N should be close to 0.069 (higher value means insufficient nitrogen). Thus lack of N in all taken year-classes of needles was confirmed as well as several times increased concentration of Mg (critical level), toxic level of S and critical (subnormal) level of K, increased up to insufficient level of Fe.

Results of statistical analysis carried out between localities and needle year-classes (1995, 1996, 1997) of *Pinus nigra* and between tree species *(P. nigra* and *Picea pungens)* and needle year-classes (1995, 1996, 1997) in the locality Lubeník are in Table 7.

Evers (1986) notes, that the concentrations of elements in the foliage are not unanimous. He observed great differences in the concentration of mineral substances in the foliage of the same tree in light and shadow. Also the concentrations of elements in the needles of different whorls are different; in younger needles are different than in older needles. The composition of the foliage depends also on site factors (soil, aspect, relief, altitude, climate, etc.). It was proved that high concentrations of sulphur in the soil cause high concentration of sulphur in the foliage, what is in good correspondence with our results as well (Table 8).

With long-term fallout and accumulation of air pollutants in the soil properties can change to such extent that they can cause disturbance in nutrition and thus brought about external symptoms of the damage to the foliage. They reflect mostly in chlorosis, in worse cases

T a b l e 7. Two-way analysis of variance (one measurement within the group) – testing the differences between localities and needle year-classes for *Pinus nigra* (a) and differences between needle year-classes and tree species *(P. nigra and Picea pungens*) in the locality (Lubeník (b).

Element	Localities[a]		Needle year-class[a]		Forest tree species[b]		Needle year-class[b]	
	F-value	Signif.	F-value	Signif.	F-value	Signif.	F-value	Signif.
B	9.06	*	2.82	ns	1.22	Ns	2.39	ns
Ca	0.88	ns	0.88	ns	0.01	Ns	2.37	ns
Cu	0.70	ns	1.91	ns	3.33	Ns	0.41	ns
Fe	7.50	*	38.06	**	17.66	Ns	198.59	**
K	3.26	ns	1.41	ns	4.59	Ns	0.85	ns
Mg	0.75	ns	1.23	ns	11.56	Ns	11.56	ns
Mn	2.88	ns	0.87	ns	1.38	Ns	0.43	ns
N	44.85	**	20.67	**	7.42	Ns	2.26	ns
P	0.17	ns	1.82	ns	65.33	*	0.07	ns
S	0.22	ns	0.39	ns	15.73	Ns	0.33	ns
Zn	0.39	ns	0.74	ns	0.27	Ns	0.10	ns

Note: ns-not significant, * significant at p-level = 0.05, ** significant at p-level = 0.01

Ta b l e 8. Results of chemical analyses of soil samples on PP Jelšava 1 and Lubeník 1M (in $mg.kg^{-1}$).

Name of locality	Depth of sampling in cm	pH		Available nutrients				Water-solution	S	C_{ox}
		H_2O	KCl	P	K	Mg	Ca	Mg		
Jelšava 1	0–5	8.09	7.56	15.1	133	1424	903	113	950	3970
	15–20	8.05	7.28	9.0	71	757	167	75	330	1670
	30–40	7.99	6.83	7.5	42	462	155	59	100	1840
Lubeník	0–10	7.96	7.45	20.0	93	2302	674	186	860	3200
1M	15–25	7.61	7.11	18.0	68	1367	190	80	290	1600

also marginal or total necrosis (Maňkovská, 1996). Also Evers (1986) notes that analysis of foliage or needles can frequently indicate possible causes of necrosis.

In the observation of the causes of damage to stands it is obvious, that for the state of stands balanced (not balanced) nutrition is more decisive than the deficit of some elements (Oren et al., 1983). Also Hüttl (1987) notes, that optimum of balanced supplies of nutrients is important to suppress the stress.

Unwashed needles were analysed. The presence of elements on foliage surface is dangerous especially for elements that are important for nutrition. These distort total concentration of elements as frequently they are deposited in stomata and they cannot be removed by washing the surface. Plants cannot use them for own physiological processes. There were present on the surface of the needles of *Pinus nigra* (Jelšava 1 and Lubeník 1M) and *Picea pungens* (Lubeník) elements as Mg, K, Ca, Fe (Table 5). But in analysing the same samples these elements showed in case of magnesium exceedance but in case of potassium insufficient under limit concentration (Table 6). Similarly concentration of manganese was insufficient and this element is considered stress (Maňkovská, 1996). In future it will be necessary to find what is the proportion of element concentration of surface solid particles and proportion of internal element concentration in needles in the total element concentration of the needle samples.

Conclusion

All, even the needles of *Pinus nigra* and *Picea pungens*, living only one year, have deposited on their surface the particles of dust pollution fallout, which subsequently affect the state of stomata and thus the nutrition as well. The needles have increased concentration of Fe, S, Mg, Ca and Zn. We can state the increased concentration of dust particles of mineral origin appear more markedly already in the youngest year-class in the increased values of some elements in the foliage of both studied tree species. On the other side boron was insufficient in the needles (25% of samples) and of manganese in all samples. Statistically significant difference in the concentration of B, Fe, N and P was found when we compared the localities for *Pinus nigra* and *Picea pungens* and the age of needles.

Anthropogenic loading of all tree species in area of magnesite plants being expressed by means of the coefficient of loading Kz reached the values from 2.1 to 3.1. For the reforestation of localities endangered by air pollutants in the surrounding of magnesite plants and Jelšava it will be necessary in addition to the change of the technology of magnesite production also to know the state of plants nutrition.

Translated by the authors

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Tučeková A., Sedmáková D., Maňkovská B., Oszlányi J.: **Hodnotenie prítomnosti pevných emisných spádov na povrchu ihličia** ***Pinus nigra*** **a** ***Picea pungens*** **– vo vzťahu k výžive v oblasti magnezitového závodu.**

V imisnej magnezitovej oblasti Jelšava – Lubeník v rôznej vzdialenosti od imisných zdrojov sa odobrali na analýzy asimilačné orgány umelo vysadených jedincoch borovice čiernej (*Pinus nigra* A r n o l d) a smreka pichľavého (*Picea pungens* E n g e l m.). Na odoberaných ihliciach z posledných troch ročníkov (1995, 1996, 1997) sa pomocou rastrovacieho mikroskopu JEOL JSM 840 a rőntgenového analyzátora zisťovali častice usadené na povrchu ihlíc t. j. zaprášenosť v %, ktorá sa pohybovala od 10 do 30%, podľa vzdialenosti od zdroja imisií. Častice tuhých spadov usadené v prieduchoch sa kategorizovali podľa ich tvaru a chemického zloženia pričom prevahu mali častice typické pre výrobu železných kovov (Si, Al, Fe, S) s nápadnými časticami zloženými z Mg. Stav prieduchov bol hodnotený na základe prítomnosti jednotlivých druhov epistomatálnych voskov (pomer medzi originálnym tubulárnym kryštalickým voskom a amorfnými formami, tvoriacimi krustu) vyjadrený v %. V starších ročníkoch sa zistilo 30 50% relatívne funkčných prieduchov a až 5–10% prieduchov bolo nefunkčných. Približne 35 60% bolo len čiastočne funkčných. V ihliciach obidvoch hodnotených drevín sa zaznamenal zvýšený obsah Fe, S, Mg, Ca, Zn a Mn, ktorý korešponduje s výslednými hodnotami analýz usadených častíc na povrchu asimilačných orgánov v jednotlivých odberových ročníkoch.