Long Term Effects of Pollutants on Forest Vegetation in Central Spis Region

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Abstract

Pollution problems in forest ecosystems resulting from 100 year long operation of three smelter complexes in Central Spiš are reviewed. Original data are presented with respect to temporal and spatial trends of nitrogen, sulphur, and heavy metal pollution, and elemental composition of individual aerosols on leaf surface. Spruce stands in Central Spiš are loaded by pollutants. 1.7-fold exceeding of critical values and the highest concentrations of As, Fe, Hg, and N were found in this region. Low Tatras National Park (NAPANT) was the cleanest region where no element maxima were found.

Instrumental neutron activation analysis was used for determination of element concentration (Al, As, Au, Ba, Br, Ca, Cd, Cl, Co, Fe, K, Mn, Na, Ni, Rb, Sb, Sm, Sr, W and Zn. The same elements were determined in atmospheric deposition with moss bio-monitoring technique. In the area of Stredný Spiš we found in comparison with Norwegian limit values (Central Norway- as relatively the cleanest region) exceeded levels for Al, As, Ca, Cd, Cl, Co, Fe, K, Mn, Sb, Sm, Sr, W and Zn. In comparison with Magnitogorsk in Ural Mountains (the most polluted area in Europe) we found in Spiš higher values for Ca, Cl, Co, K and Mn.

Key words: air pollution, spruce needles, mosses

Introduction

Central Spiš is historically linked with exploitation and processing of non-ferrous metals. Since bronze period it had been the place of the exploitation of copper and later also ferrous ores. The history of exploitation has been documented since 1290. In the year 1903 there was constructed, in addition to ferrous metals exploitation, also parching mill for ores in Bindt and own ironworks in Markušovce. During the 19th century a small manufacture production had grown into a large industrial production. Pollution problems in Central Spiš forest ecosystems (area 5 km^2) resulting from 100 year long operation of three smelter complexes (Krompachy, Rudňany a Spišská Nová Ves) and on northern aspects there is evident the effect of transboundary air pollutants from Poland (Katowice)(Maňkovská, 1984; 1988; 2000; Maňkovská et al. 1989; 2000; Markert at al., 1996). The main sources of emission in Central Spiš are Metallurgical factory Krompachy [emission in the years 1997(1998) in $t.year^{-1}$ was as follows: 296(151) - of solid pollutants; 7237(2543) SO_2; 99.4(97.9) NO_x a 690(530) CO]; Finiš Spišská Nová Ves [141 (114) of solid pollutants; 230(172) SO_2; 29(21) NO_x a 67(42) CO] and Želba Rudňany [11(8.2) of solid pollutants; 43.3(10.9) SO_2; 6.1(6.1) NO_x a 11.5(2.1) CO]. Reduction of emission is connected with a decline in industrial production. Parent rock is middle - upper Triassic mainly dolomites, locally limestones and shales. Specific rated emission is as follows: 11.32 $t.km^2$ SO_2, O.31 NO_x t. km^2, 2.38 $t.km^2$ of solid fallout. Pollution deposition types were characterized as acid with smelter dust (Maňkovská, 1996). Regarding the altitude the territory extends from 350 m to 1120 m. Forest communities are situated from the 3rd up to the 6th altitudinal vegetation zone. The highest distribution has particularly the 4th altitudinal vegetation zone with tree species composition as follows: beech 44%, fir 25%, spruce 23%, birch 2% and other tree species 6%.

The aim of this paper is to present actual concentrations of 26 elements in the needles of *Picea abies* [L.] Karst. on the surrounding of three industrial plants in Central Spiš (area 5 km^2) and Low Tatras National Park (NAPANT). We were also interested in metal concentrations in the samples of mosses.

Material and methods

The samples of 2 year old needles of *P. abies* were taken from permanent monitoring plots (PMP), situated on the intersections of 16x16 km Pan-European grid and detailed 1x1 km grid from 282 plots in industrial locality Central Spiš and 70 plots in NAPANT in accordance with international methodology (ICP, 1994) (Tab.1).

T a b l e 1. List of localities, parent rock, specific rated emissions, main sources of emission and pollution deposition types

Locality	Parent rock	Specific rated emissions in t.km^2			Main sources of emissions	Pollution deposition types(PDT)*
		SO_2	NO_x	fallouts		
Central Spiš (282 PMP)	Middle-Upper Triasic mainly dolomites, locally limestones and shales	11.3	0.31	2.38	Non-ferrous metallurgy plants + Mercury +Barium plant	A_{III}
NAPANT (70 PMP)	Gneisses, metamorphoses volcanits, schist, granites	3.81	1.56	1.42	Regional pollution Non point source	A_1

Note: A_I- acid PDT with fly-ash A_{III}- acid PDT with smelter dust ;*Maňkovská, 1996

Sampling of 3 years old segments of mosses *(P. schreberi, H. splendens* and *Dicranum* sp.*)* was made on the PMP (P_5 and R_5) in Central Spiš and in NAPANT (L_5) according to the methodology by Maňkovská,1996. The obtained results were calculated into atmospheric deposition (Rühling et al. 1996) and compared with the data Norway (Central Norway belongs to the least polluted regions in Europe), Ukraine (Magnitogorsk belongs to the most polluted regions in Europe) and Slovakia (78 PMP). The samples of spruce needles were taken by monitoring specialists in August 1995 and the samples of mosses in August 2000.

The spruce needles and mosses were not washed before analysis. The spruce needles were analysed for the concentrations of following 26 variables in the laboratories of Dionýz Štúr Institute of Geology in Bratislava. Elemental analysis was applied to determine the concentration of S (LECO SC 132) and N (LECO SC 228). The accuracy of data published in paper was verified by 109 separate laboratories and tested by the IUFRO programme (Hunter, 1994).

The mosses samples were analysed for determination of Al, As, Au, Ba, Br, Ca, Cd, Cl, Co, Fe, K, Mn, Na, Ni, Rb, Sb, Sm, Sr, W and Zn with the Pulsed fast reactor IBR-2 in FLNP JINR, Dubna, Russia equipped with the fast pneumatic transfer system REGATA and four irradiation channels for Instrumental neutron activation analysis, provides activation with thermal, epithermal and fast neutrons (Frontasyeva and Pavlov, 2000). Two channels are cadmium screened for activation with epithermal neutrons (Frontasyeva and Steinnes, 1997). The neutron flux density (for thermal or epithermal neutrons) inside the channels is of the order 10^{12} $cm^{-2}.s^{-1}$ (Peresedov, 1997). The induced activity can be measured using ë-spectrometers with Ge (Li) ORTEC electronics. The software developed at FLNP JINR is used for data processing.

The vegetation samples were evaluated by common statistical methods(ANOVA).

Results and discussion

Total concentration of the 26 elements (mg. kg^{-1}) studied in the 2 years needles of *P. abies,* collected from Central Spiš and NAPANT and literature value of studied elements in the foliage are given in Table 2. The principal component analysis for Central Spiš and NAPANT is in Tab.3. The assessment of overall total load on the study localities by pollutants was expressed by means of the pollution impact coefficient (K_z), which shows exceeding the limit values for As, Cd, Cr, Cu, F, Fe, Hg, Ni, Pb, S, V and Zn. The overall loading to the K_z represented 1.74 increase in Central Spiš and 1.3 in NAPANT (Tab.2).

T a b l e 2. Concentration of elements in 2 year old needles of *P. abies* from industrial locality Central Spiš (n=282) and NAPANT (n=70) [in mg.kg^{-1}]

Element	Central Spiš	NAPANT	Limit .	**Element**	Central Spiš	NAPANT	Limit
	x (SD)	x(SD)	min-max		x(SD)	x(SD)	min-max
Al	117(50.6)	105 (108)	50-150	**As**	**0.68(2.14)**	0.19(0.15)	<0.2
Ba	39.9(31.3)	46.8(32.6)	<100	**Be**	0.005(0.01)	0.009(0.02)	<0.04
Ca	5711(5344)	**9567 (4427)**	4000-8000	**Cd**	0.18(0.14)	0.12(0.09)	<0.5
Co	0.21(0.17)	0.062(0.09)	<1.0	**Cr**	0.55(0.65)	**1.02(2.50)**	<1.0
Cu	**5.85(5.18)**	**3.41(1.19)**	2-3	**F**	**6.90(2.40)**	**5.35(1.74)**	<2
Fe	**147(406)**	94 (64.8)	50-100	**Hg**	**0.13(0.09)**	**0.09(0.11)**	<0.06
K	6396(1861)	5136(1331)	5000-10000	**Li**	0.17(0.12)	0.23(0.33)	<0.5
Mg	998(602)	1110(551)	1000-5000	**Mn**	**1166(742)**	**738(809)**	500
N	17920(5610)	14930(2404)	18000-25000	**Na**	34.9(55.3)	40.9(81.5)	<100
Ni	**2.64(1.70)**	1.49(1.16)	<2	**Pb**	1.99(3.31)	2.6(7.1)	<6
Rb	**12.1(10.0)**	8.3(5.9)	<10	**S**	**2093(785)**	**1846(837)**	<1000
Se	**0.053(0.038)**	**0.038(0.026)**	<0.03	**Sr**	**12.1(9.9)**	**21.4(20.7)**	<10
V	**1.12(3.50)**	0.47(0.91)	<1	**Zn**	39.1(23.2)	43.2(16.9)	35-45
K_z	**1.74(1.31)**	**1.29(0.59)**	1				

Note: x - arithmetical mean; SD - standard deviation in parentheses; n- number of samples from permanent monitoring plots NAPANT (in 4x4km) and Central Spiš (in 1x1 km);
K_z- Pollution impact coefficient; Limit values (Maňkovská ,1996; Stefan et al. 1997).

T a b l e 3 Percentage of explained variance for eight factors obtained in the principal component analysis (Varimax analyse) for Central Spiš and NAPANT.

Localities		Factors								
		1	2	3	4	5	6	7	8	Together
Central Spiš	EV	1.82	1.66	1.50	1.24	1.08	0.99	0.92	0.88	
	% var.	15.2	13.8	12.2	10.3	9.0	8.2	7.7	7.3	83.7
NAPANT	EV	2.37	2.01	1.63	1.47	1.12	0.90	0.70	0.56	
	% var.	19.6	16.7	13.6	12.3	9.3	7.5	5.9	4.6	89.5

Note: EV-Eigen values: % of variability

Atmospheric deposition of elements (mg.m^{-2}.year^{-1}) in three mosses species in studied PMP in Spiš and NAPANT, compared with results of 2000 in Slovakia, Ural and Norway is given in Table 4. Concentrations of Cd, Cu, Fe, Hg, Ni, Pb, V and Zn are many- fold higher in industrial region Central Spiš than NAPANT. The level of maximal values found in Slovakia and in Norway reaches the value of Cd and Hg.

T a b l e 4. Atmospheric deposition of elements (mg.m^{-2}.rok^{-1}) from Central Spiš (PMP R_5 and P_5); NAPANT (PMP L_5); Slovakia; Ural Mountains and Norway calculated from concentration of elements in 3 year old segments of *P. schreberi; H. splendens* and *Dicranum* sp.

Element	Central Spiš		NAPANT	Ural Mts.*	Slovakia **	Norway***
	PMP - R_5	PMP -P_5	PMP - L_5			
Al	**583**	**490**	**300**	702	618	88
As	**0.21**	**0.15**	**0.12**	0.26	0.18	0.08
Ba	**22.5**	5.8	**20.5**	13.6	12.9	6.0
Br	0.61	0.59	0.85	0.77	0.88	1.25
Ca	**1175**	**653**	**7590**	883	1231	375
Cd	**0.14**	**0.35**	**0.18**	0.065	0.15	0.02

Cl	**111**	**76**	23	32	62	50
Co	**0.31**	**0.20**	**0.40**	0.09	0.21	0.08
Cr	**1.10**	**0.70**	**0.65**	-	1.62	0.38
Cu	**3.13**	**1.49**	**2.31**	1.65	2.19	1.05
Fe	**340**	**184**	**742**	677	390	100
Hg	**0.18**	**0.05**	**0.03**	-	0.04	0.03
K	**1925**	**1818**	**1199**	1088	1747	750
Hg	**0.18**	**0.05**	**0.03**	-	0.04	0.03
K	**1925**	**1818**	**1199**	1088	1747	750
Mn	**378**	**93**	**101**	43	88	50
Mo	0.32	0.12	0.11	-	0.23	-
Na	**125**	**117**	**180**	111	90	50
Ni	0.38	0.40	**0.93**	0.93	0.80	0.40
Pb	**7.08**	**7.48**	**5.78**	-	7.10	1.25
Rb	**2.56**	**2.93**	1.90	2.13	3.35	2.50
Sb	**1.94**	**0.72**	**0.15**	4.74	0.22	0.02
S	555	455	560	-	300	-
Sr	**10.3**	**8.50**	**37.8**	-	15.5	2.88
U	**0.025**	**0.013**	0.010	-	0.025	0.012
V	**0.90**	**0.60**	**0.80**	-	1.43	0.50
W	**0.073**	**0.048**	**0.065**	0.050	0.063	0.010
Zn	**16.5**	**12.3**	**9.50**	9.80	13.9	9.0

Note: Slovakia ** - average from 78 PMP; *** Norway (Central Norway belongs to the least polluted regions in Europe) (Rühling et al.1996). Concentrations of elements higher than the data from Norway are in bold face; concentrations higher than in Ural* (Magnitogorsk belongs to the most polluted regions in Europe) are in bold face and underlined.

Conclusion

It was determined on the basis of monitoring performed in *P. abies* needles on 282 plots in industrial areas Central Spiš and 80 plots in Low Tatras National Park (NAPANT):

1. The absolutely highest values of Al, As, Cd, Co, Cu, F, Hg, Mn, N, Ni, Rb, S, Se, and V were found in the industrial area of Central Spiš and Ba, Be, Ca, Cr, Li, Mg, Na, Sr and Zn from the National Park Low Tatras. The overall loading to the K_z represented 1.74 increase in Central Spiš and 1.3 in NAPANT.
2. It is complemented by critical evaluation of their concentration in relation to limit values from Norway and by the data on the concentrations from polluted region in Ural Mountains. The impact of polluted air on forest ecosystems is a major question of the presence and future.

References

Frontasyeva, M.V., Pavlov, S.S.,2000: Analytical investigation at the IBR-2 reactor in Dubna. Proceedings of the VII International Seminar on Interaction of Neutrons with Nuclei, Dubna, May 17-20, 2000, E3-2000-192. p.219-227.

Frontasyeva, M.V., Steinnes,E.,1997: Epitermal neutron activation analysis for studying the environment. Proc. Int. Symposium M. V. on Harmonization of Health Related Environmental Measurements Using Nuclear and Isotopic Techniques (Hyderabat, India, 4-7 November, 1996), IAEA 1997, p.301-311.

ICP 1994 Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forest. 3rd edition, Programme Coordinating Centre West, BHF, Hamburg, Germany 173p.

Hunter,R., 1994. Results from the Interlaboratory sample exchange. IUFRO, Working Group S1.02-08 Foliar Analysis. Natural Resources Institute, Kent, 31 pp.

Maňkovská, B., 1984: The effects of atmospheric emissions from the Krompachy, Nižná Slaná, Rudňany iron ore mines on forest vegetation and soils. Ekológia (ÈSSR) 3, 3, s.331-344.

Maňkovská, B., 1988: The accumulation of atmospheric pollutants by Picea abies Karst. Ekológia (ČSSR) 7,1, s. 95-108.

Maňkovská , B., Huttunen, S., Peura, R.,1989: The effect of air pollution from Krompachy and Rudòany smelteries on Picea abies Karst. Ekológia (ČSSR) 8, 1, p.49-58.

Markert, B., Herpin, U., Maòkovská. B., et al., 1996: A comparison of heavy metal deposition in selected Eastern European countries using the moss monitoring method, with special emphasis on the "Black Triangle". Sci Total Environ. 193, 85-100.

Maňkovská, B.,:2000: Chemical composition of deciduous and coniferous vegetation, mosses and humus as environmental indicator in Slovakia. The role of research. Proceedings of XXI. IUFRO World Congress, 7-12 August 2000, Kuala Lumpur, Malaysia . Poster Abstracts, Vol.3, p.380-381.

Maňkovská, B., Bytnerowicz A., Karnosky D.F., 2000: Geochemical mapping of elements in the Carpathian Mountain forests using foliar analysis of white fir (Abies alba Mill.) The role of research. Proceedings of XXI. IUFRO World Congress, 7-12 August 2000, Kuala Lumpur, Malaysia . Poster Abstracts, Vol.3, p.381-382.

Maňkovská, B.,1996: Geochemical atlas of Slovakia. Forest biomass. Geological Service of Slovak republic,Bratislava. ISBN 80-85314-51-7, 87 pp.

Peresedov, V.F., Atmospheric aerosols and possibilities of their analysis for elemental content at the IBR-2 reactor. JINR Rapid Communications, No. 5[85]-97, Dubna, 43-50 (1997).

Ruhling ,A., Bargali, R., Maňkovská, B., et all. 1994: Atmospheric Heavy Metal Deposition in Europe-estimation based on moss analysis. NORD 9, ISBN 92 9120 427 7, Nordic Council of Ministers, Copenghagen, 53 s.

Stefan, K., Fűrst, A., Hacker, R., Bartles, U., 1997: Forest Foliar Condition in Europe. Technical Report. EC and UN/ECE, Brussels, Geneva, 207 pp.