MUNI | RECETOX

Phytoindication of the air contamination in high mountan habitats and in urban areas

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1. Phytoindication of the ecogenotoxic effects of vehicle emissions using pollen abortion test with native flora

Introduction/aims

This study aimed to evaluate the rate of genotoxicity caused by traffic emissions at sites in the vicinity of roads and at sites near planned highway construction using a pollen grain abortion assay with higher wild plant species. This method provided a view of overall rate of investigated environment contamination. The aim of this study was also to standardize applied fytoindicator species and to find the regions of the most intensive contamination of environment depending on the distance from the road. Twelve species of native flora were analyzed.

Selection of sampling sites

8 sampling sites

- **Urban area (Part A)** - 4 sites with high traffic density
- **Future highway area (Part B)** - 4 sites

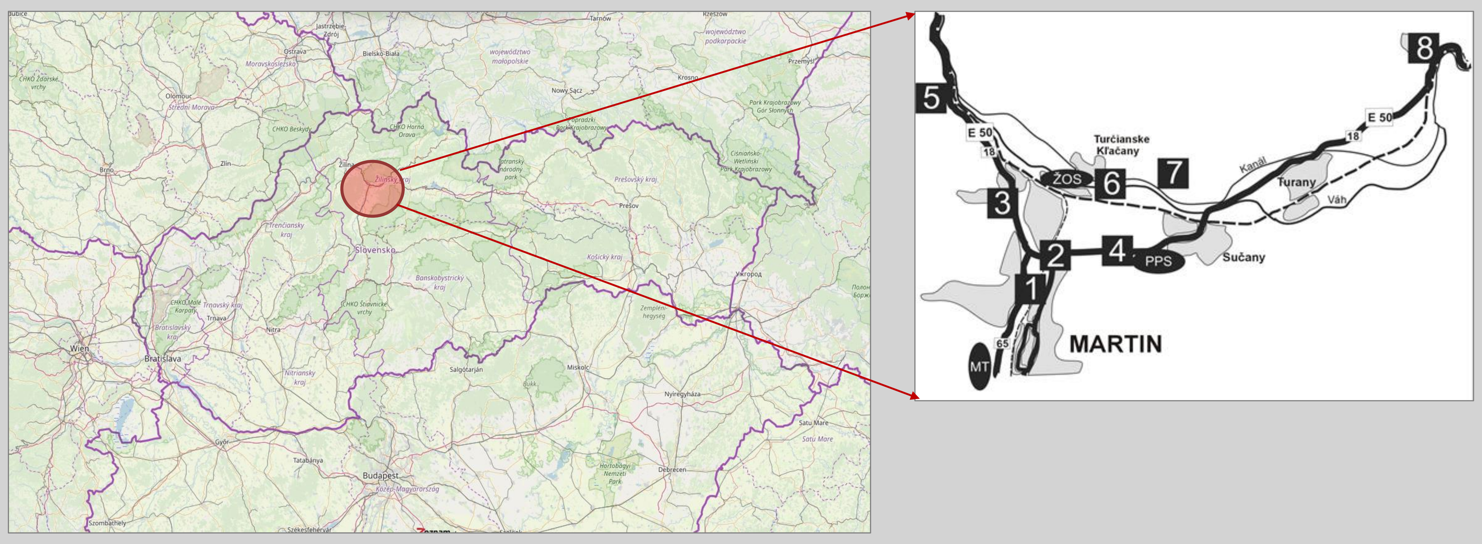

Fig. 1 Map of Martin town (Slovak republic) showing locations of sampling sites: 1. Tulip (below as T), 2. Košúty (K) and 3. SNP Cemetery (C) – 17,193 vehicles per hour, 4. Ring-road (R) – 14,859 vehicles/hour, 5. Dubná Skala (DS) – 14,784 vehicle/hour, 6. Váh (V), 7. Biele Brehy (BB), 8. Šútovo (S) – 11,618 vehicles/hour; stationary sources of emissions: calandria and machine plant, PPS: Sučany industrial area, ŽOS Vrútky: machine plant.

Material

Pollen grains of 12 plant species

- meets all basic criteria for selection of appropriate bioindicator species [1]
- easily determinable
- quality pollen grains with high sensitivity to air pollutants

Fig. 2 Pollen grains of *Salix capraea* - vital and abortive (bottom right).

Control site:
Záhorska lowland where pollen abortivity over the last 70 years has not exceeded 5% [2].

Fig. 3 Vehicle emissions

Methods

- At each site, 10-20 young and closed flowers and flower buds from 10 individuals from each species were collected
- fixed in a mixture of ethanol (96%) and acetic acid (3:1)
- stained with 0.05% aniline blue in lactophenol [1]
- evaluated set - 3,000 pollen grains per sample (per species)
- **Microscopy analysis**
- the abortion pollen grains - determined on the basis of form (altered form, unformed, undeveloped), size and staining deficiency [2]

Results

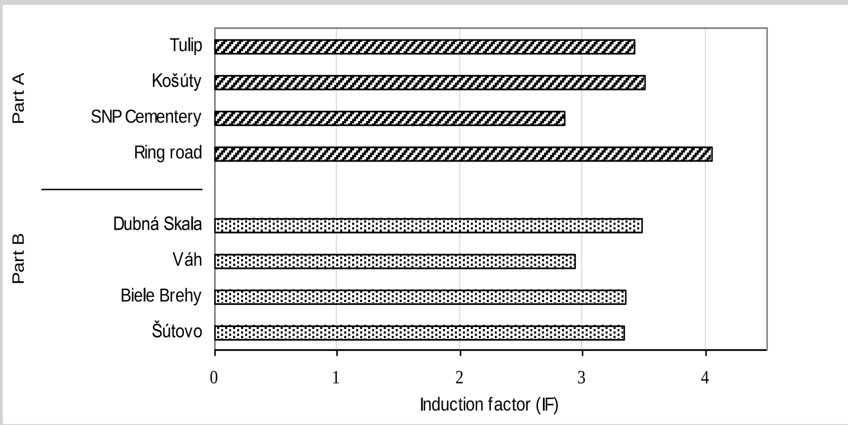

Fig. 4 Average induction factors of the evaluated sites.

Table 1
The average pollen abortion (% and SEM) - Part A

species/ locality	T	K	C	R	Control	B
Artemisia vulgaris	12.4±0.8 **	7.8±0.9 **	8.1±0.6 **	9.4±0.8 **	2.4±0.7	VII-VIII
IF	5.2	3.3	3.4	3.9		
Barbarea vulgaris	2.5±0.4	3.2±0.4 **	4.3±0.6 **	8.2±1.1 **	1.4±0.4	V-VIII
IF	1.8	2.3	3.1	5.8		
Chelidonium majus	4.2±0.5 **	3.2±0.3 **	4.3±0.6 **	6.8±0.7 **	2.0±0.3	V-VIII
IF	2.1	1.6	2.15	3.4		
Cichorium intybus	9.9±0.8 **	5.3±0.5 **	4.0±0.5 **	4.6±0.4 **	1.0±0.2	VII-X
IF	9.9	5.3	4	4.6		
Daucus carota	5.6±0.5	17.1±2.2 **	2.2±0.3	5.6±0.9	4.4±1.2	VI-XI
IF	1.3	3.9	0.5	1.3		
Lamium maculatum	1.4±0.2 **	1.6±0.2 **	2.1±0.3	7.0±0.6 **	2.8±0.2	IV-IX
IF	0.5	0.6	0.75	2.5		
Lactuca serriola	1.8±0.3 *	2.3±0.3 **	3.0±0.4 **	5.7±0.9 **	0.9±0.2	VII-IX
IF	2	2.6	3.3	6.3		
Melilotus albus	5.1±0.8 **	10.4±1.1**	7.2±1.3 **	7.7±1.5 **	1.0±0.3	VI-IX
IF	5.1	10.4	7.2	7.7		
Pastinaca sativa	9.7±1.1 **	5.5±0.5 **	4.3±0.4	3.5±0.5	3.4±0.4	VII-VIII
IF	2.85	1.6	1.3	1		
average IF	**3.42**	**3.51**	**2.85**	**4.05**		

T - Tulip, K – Košúty, C – SNP Cementery, R – Ring road, B - blooming period (months).
* Statistical significance (P≤0.05)
** Statistical significance (P≤0.01)
IF, induction factor - pollen abortivity at the contaminated site/ pollen abortivity at the control site.

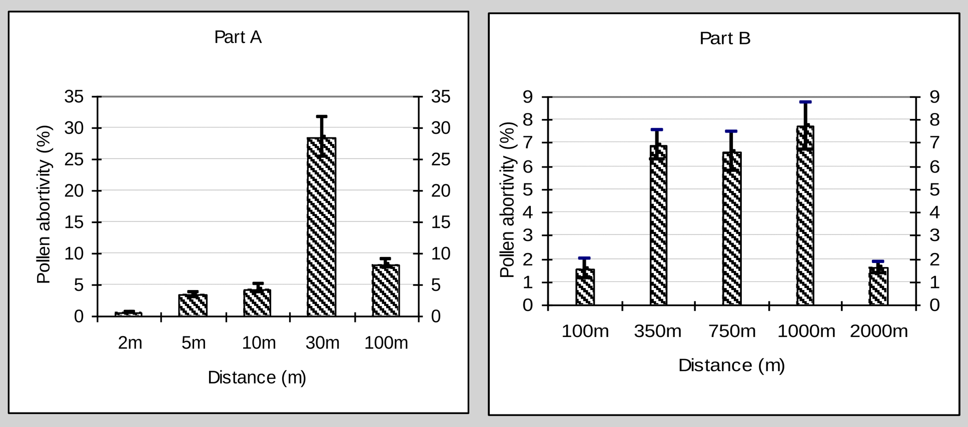

Fig. 5 The results of percentage of pollen abortivity with ± SEM in *Salix caprea* in relation to distance from the road in different prevailing wind directions (blowing parallel to the road in Part A and away from the road in Part B). At the control site a value of 3.9±1.1 was found.

The highest values were found at a distance of 30m, where the prevailing wind direction was parallel to the road. Wind blowing away from the road shifted this boundary to a distance of 350m (Fig. 5). The results showed the highest genotoxicity at the "Ring road" site, where the frequency of abortive pollen grains was 4.05 times higher than at the control site (Table 1), and at the "Dubná Skala" site, with induction factor 3.48.

Conclusions

According to results of the present study, the use of a pollen abortion assay with native flora in *"in situ"* conditions provides valuable information about the rate of contamination of the monitored environment. *Melilotus albus, Cichorium intybus* and *Chelidonium majus* may be considered the most suitable of the species applied for detection of air quality in an urban area highly contaminated by traffic and industrial emissions. Markedly higher values of pollen abortivity were observed at sites with a significant impact of traffic emissions in comparison with sites away from their effects. Thus it can be concluded that vehicle traffic is one of the major sources of air pollution.

More details: This study was published in *Polish Journal of Environmental Studies*. 22(4): 1069-1076
For part B, analyzes were also performed during the highway construction and other sampling is planned after several years of its start-up.

References
[1] Murín, A. 1995. Basic criteria for selection of plant bioindicators from regional flora for monitoring of an environmental pollution. *Biologia* (Bratislava), 50: 37-40.
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Fig. 6 The most suitable bioindicator species - *Melilotus albus, Cichorium intybus* and *Chelidonium majus* (from the left).

2. Bioindication of chemical elements deposition in the High Tatra mts. (Slovakia) based on Calluna vulgaris (l.) Hull; comparative levels after the improvement of emissions

Introduction/aims

Calluna vulgaris was collected on the south slope of Lomnický štít peak in Skalnatá dolina valley (The High Tatra Mts) between 1987 - 1988 and repeat sampling took place in 2011, following reduction of emissions. Cu, Cd, Zn, Pb, Cr, Mn, Mo, Fe, S and F concentrations were determined in the samples. The following questions are addressed in this paper:
1. How are accepted measures aimed at emission reduction reflected in environmental contamination?
2. How do the emissions correlate with altitude?

Material and Methods

- ***Calluna vulgaris* L.** - collected: autumn 1987-1988 and autumn 2011 - on vertical transect, approximately every 50 -250 m, starting at 1,030 m a.s.l. - up to the 2,022 m a.s.l. (Fig. 1).
- each sample contained 10 randomly chosen stems from 3 to 5 plants
- samples were washed in distilled water and dried at 70°C

1987-1988
- copper, cadmium, zinc, lead, chrome, manganese and molybdenum - **AAS**
- iron - **Photometry method with sulphosalicylic acid**
- sulphur and fluorine - **gravimetric method.**

2011- **XRF spectrometry** [1, 2]

- ***Soil samples***

This study was published in *Carpathian Journal of Earth and Environmental Sciences*, 2014, 9 (2): 5 - 14

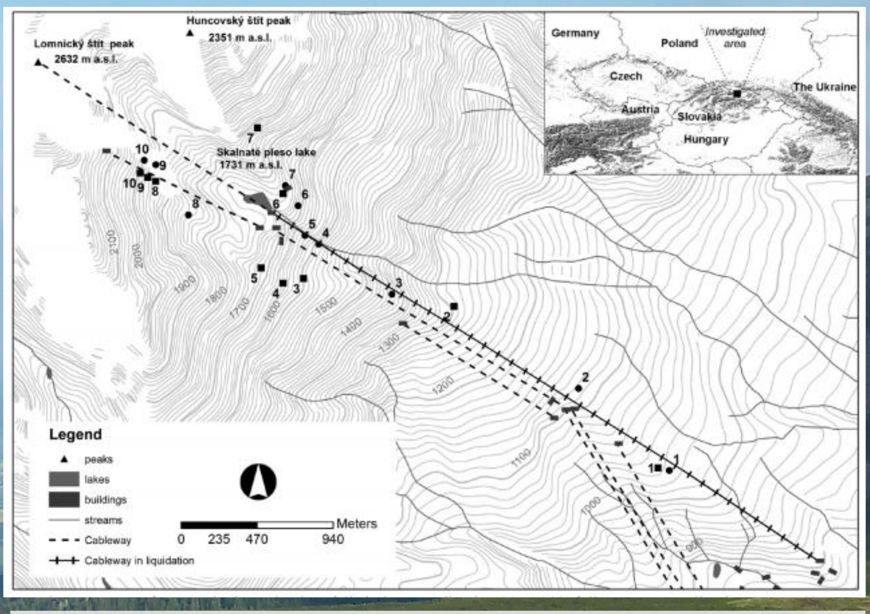

Fig 1. Map of area under investigation, full circles-sampling in 1987-1988, full squares-sampling in 2011. Vertical gradient.

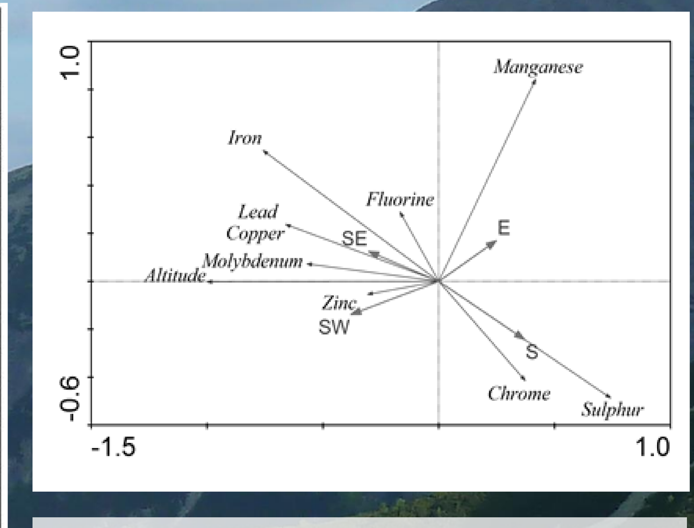

Fig. 2 Principal component analysis (PCA), biplot, relationship between supplementary environmental variables and heavy metal concentrations including altitude. SE south-east, SW south-west, E east, S south. Sampling in 1987-1988.

Table 1. Comparison of element content in samples collected in 1987-1988 and in 2011, mean values (mg.100g-1)

Element	Sampling in 1987-1988	Sampling in 2011	Difference, ($mg.100g^{-1}$)
Cu	0.91	1.49	0.58
Zn	4.84	5.10	0.26
Pb	0.82	2.00	1.18
Cr	0.21	1.40	1.19
Mo	0.34	0.62	0.28
Fe	66.92	36.93	-29.99
S	82.26	122.2	39.94

Table 2. Correlation coeficients between heavy metals (including sulphur) and altitude, 2011

	S	Fe	Mo	Cr	Pb	Zn	Cu	Altitude
Altitude	0.6253	0.4784	0.4900	0.0199	*0.7306	0.6417	*0.9266	1.0000
Cu	*0.7570	0.4017	0.5107	0.1522	0.5381	*0.6459	1.0000	
Zn	0.3498	0.2846	0.4200	-0.4534	0.4689	1.0000		
Pb	0.4428	0.1763	0.1847	0.3326	1.0000			
Cr	0.5319	-0.0792	-0.1947	1.0000				
Mo	0.3243	0.1038	1.0000					
Fe	0.4287	1.0000						
S	1.0000							

* Indicates significance

Results

The results of ordination analysis and correlation analysis show a positive significant correlation of Pb, Fe and Cu (r=0.6320-0.9519) with rising altitude and negative significant correlation of S (r=-0.7398) (Fig. 2). Due to reduced emissions the sulphur correlation with rising altitude became positive not significant in 2011 (Table 2). In 1987-1988, Mo, Mn, Cr, Cd and Zn did not show any significant correlations with altitude. In 2011, Fe, Mo, Cr, Zn and Mn also showed no significant correlation with altitude. Pb and Cu retained a positive significant correlation with rising altitude (Table 2). There was a significant change correlated to S. In 1987-1988 the highest S concentrations had been recorded up to 1300 m a.s.l. (>109.8 mg.100g-1), whereas in 2011, the lowest S concentrations were recorded at these altitudes (<87 mg.100g-1) due to reduction of emissions. Despite the reduction of emissions, the accumulated heavy metals remain in the ecosystem for a long time and acceptable concentrations are mostly exceeded, approximately 2-4 times, in the case of chromium up to 10 times.

Conclusions

We have compared the data sets from 2 decades ago, at the height of contamination, with recent contamination levels. Despite the fact, that industrial plants have accepted measures to reduce emissions, in 2011 we have recorded approximately the same elemental contents in the plant tissues in comparison with 1987-1988. Following SO2 contamination, the ecosystem has recovered after 12 only a few years, however the metal contamination was evident for a longer period. Acceptable concentrations of emissions are mostly exceeded.

References
[1] **Richardson, D.H.S., Shoreb, M., Hartreeb, R. and Richardson, R.M.** 1995: "The Use of X-Ray Fluorescence Spectrometry for the Analysis of Plants, Especially Lichens, Employed in Biological Monitoring." *Science of the Total Environment*, 176 (1-3): 97-105.
[2] **Stephens, W.E. and Calder, A.** 2004: "Analysis of Non-Organic Elements in Plant Foliage Using Polarised X-Ray Fluorescence Spektrometry." *Analytica Chimica Acta*, 527 (1): 89-96.