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# Leaf impact trends of silver birch (*Betula pendula* Roth.) by allochtonous elements at Nitra town urban vegetation

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Abstract: The town settlements have different load level by emmissions originated mostly from industry, transport and heating system. Their environmental and climate conditions are more or less changed that effect to human healthy, growth, physiology and healthy stage of woody plants at the city public vegetation areas. Highest stress load is occurred along with thoroughfares at tree alley.

Total content of chosen allochtonous elements and anionic components in leaf of silver birch (*Betula pendula* Roth.) has been analysed at urban vegetation area of Nitra town grown along with thoroughfare. To those elements belongs Ca, Mg, K, Na, Fe, Zn, Cu, Pb, Mn and $H_2PO_4^-$, $Cl^-$, $NO_3^-$, $(SO_4)^{2-}$ that were analysed from leaf samples collected in 1989, 1999 and 2005 years. Investigated leaf element content was compared with leaf one collected at relatively clean locality Arboretum Mlyňany SAV, 30 km NE from Nitra in distance. The cumulated leaf elements has been assessed to town air load by emmissions. The significantly increased element contents were analysed from birch leaf grown at Nitra as are: K, Fe, Zn, Cu, Pb, Mn, $Cl^-$, $NO_3^-$, $(SO_4)^{2-}$. Leaf element contents are comparable higher at Nitra locality than in Arboretum Mlyňany SAV one. Many analysed elements from Nitra locality are over the allowed natural growth limits.

Keywords: Urban vegetation, silver birch, immission load.

## Introduction

Within last 50s the number of town inhabitants were increased rapidly. In western European countries today almost 75% inhabitants live in typical towns, at Slovakia 55% inhabitants only. Many of cities have from 2 up to 5 million inhabitants, big built up area cover, but urban vegetation increased area cover also. In spite of modern technology incorporated to the industry, transport and energy heating system the environmental impact of big human settlements is comparable high, originated from those decision resources. Often occurrence of secondary component as are photooxidance and glass house gases are found in urban air at different concentration levels. Those are main sources of environmental load and city climate changes. In Slovakia town settlements, the air concentration level of selected immissions are today as follow (KLINDA et al. 2006): $SO_2$ = 30-100 $\mu g.m^{-3}$, $NO_x$ = 20-70 $\mu g.m^{-3}$, ground-floor ozone 25-150 $\mu g.m^{-3}$, dust fall 0.5-3.7 $t.km^{-2}.year^{-1}$, flitter dust 30-70 $\mu g.m^{-3}$. Increased of $CO_2$ and $NO_x$ immission level in urban air are very often measured, those are responsible for average air temperature increasing in process of climate changes. The town environment characteristic also in increasing of water evaporation, rainfall deficiency and general climate aridisation (GILBERT 1991, SUPUKA et al. 2000 and others).

Immission load and synathropicaly changed climate creates worsened living conditions for plants, animals and human body (LAZAR et al. 2000). Important ecological, environment improving, aesthetic and cultural functions in settlement conditions has urban vegetation in different forms and space compositions (FERIANCOVÁ 2003, 2004, KALISZUK & SZULCZEWSKA 2006, KUBIŠTA 2006, REHÁČKOVÁ & PAUDITŠOVÁ 2006, SUPUKA et al. 2004, SUPUKA, BIHUŇOVÁ & ŠTĚPÁNKOVÁ 2005).

Injury of leaves and other vegetation organs of woody plants are guided by increased accumulation of metals and allochtonous elements in those tissue organs. This situation was found in urban vegetation areas at woody plans e.g. *Acer pseudoplatanus* L., *Aesculus hippocastanum* L., *Betula pendula* Roth., *Corylus avellana* L., *Tilia cordata* Mill., *Pinus sylvestris* L. (HRDLIČKA & KULA 1988, KONTRIŠ & KONTRIŠOVÁ 2001, MITROVIČ et al. 2006, SUPUKA 2001, ŠOMŠÁK et al. 2000, TOMAŠEVIČ et al. 2005).

The aim of this paper is evaluation of allochtonous elements dynamic accumulation process in silver birch leaves (*Betula pendula* Roth.) grown at urban vegetation areas in Nitra and compare obtained results with values from Arboretum Mlyňany SAV locality that is as relatively unloaded experimental plot.

## Materials and methods

Leaf samples from silver birch has been collected in Nitra town from trees grown along with thoroughfare at Štúrova street where heavy traffic of motor vehicles was identified (almost 8 thousand vehicles in both course per hour). The second experimental area has been selected Arboretum Mlyňany SAV, the locality of 30 km NE from Nitra town in distance. This area is considered as relatively clean without environmental loading. At both localities sampling was made from 5 silver birch tree in 40-45 years old from down third crown, south exposition, 3rd-5th leaf from top of branch, six time within growing season in 1989, 1999, 2005 years.

Average sample of non washed leaves was dried at 60 $^{o}$C, than milled to the powder. From this dry organic matter 2 g has been taken for mineralization by wet way with using of concentrated $HNO_3$ and $HClO_4$ at successive warming till to 150 $^{o}$C. Digested matter was filtered and than used for analyze of Ca, Mg, K, Na, Fe, Zn, Cu, Pb, Mn elements by using of atomic absorption spectrophotometer (AAS) with instrument type IL-12 (ALLEN 1984) in three parallel.

Water soluble anion compounds of $H_2PO_4^-$, $Cl^-$, $NO_3^-$, $(SO_4)^{2-}$ were analysed by method of liquid chromatography at using of ionic colons. Powdered dry leaf matter was extracted by deionised water in rate 1:40 and successively filtered over filter ANTROP 10. From this clean water extract were analysed anionic compounds (BENČAŤ, KAČÍK & KAČÍKOVÁ 1998).

Analysed results can be seen in Tab. 1, 2 and Fig. 1. Statistical significance of value differences were tested by t-test and results are shown in Tab. 3-6. Analysed amount elements has been compared with natural limit values according to BUBLINEC (1992).

## Results

In plant organism has been identified three classes of elements. For instance Ca, Mg, K, P, S (and C, H, O) are essential macro elements. Other elements belongs to trace elements, e.g. Cu, Zn, Fe, Mn, Na, Al. Third class represents ultra trace elements, e.g. As, Ba, Br, Cd, Fe, Hg, Pb, Sr, Ti, V, W, Zr. In some cases yet differences are obvious, because each plant including woody plant belongs to the certain ecological group of plants. It means, in natural ecosystems the plant species has been evaluated at concrete habitual conditions with characteristic hydro-pedology and climate phenomenon. The silver birch (*Betula pendula* Roth.) has been developed at poor soil and nutrition conditions, as pioneer type woody plant. The natural growing conditions are reflected in natural (standard) mineral elements content in leaves and other vegetation organs. Increasing or decreasing of element level in plant organs depends on either abundance or deficiency those elements in soil or in air. Town conditions are specific, where increased amount are found in air and soil as mark of environmental load. This situation has related to the element accumulation increasing in leaves, disturbing of phenology and physiology cycles and worsened healthy conditions of woody plants.

As is shown in our research results (Tab. 1, 2), the content of analysed elements are generally higher in birch tree leaves grown in Nitra town (later as N) urban vegetation than at Arboretum Mlyňany SAV (later as AM) over all investigated 3year. Within individual years as are 1989, 1999 and 2005s, we may observe certain variability in leaf element content what depends on different immission load of Nitra town and its urban vegetation. The rainfall distribution on both localities in relation to sampling dates is very important and has influence in analysed leaf element content. With regard to this reality we decided for six time leaf sampling within growing season to be partially eliminated variability in urban vegetation immission load. Over three years research activity we may show to leaf element content tendency within 16years at the territory Nitra town, where in that period social economy activities and environmental load has been changed.

The calcium (Ca) has achieved balanced leaf average content in 1989 and 1999 years but evident decreased content in 2005year at both localities (N & AM) that is connected with decreasing of dust fall amount. At Nitra locality Ca average annual content was 14.93-25.56 $mg.g^{-1}$, at locality AM 20.68-25.82 $mg.g^{-1}$. As critical level content of Ca for silver birch is considered 3.0-15.0 $mg.g^{-1}$ (BUBLINEC 1990). This limit has been overstepped at N & AM localities in 1989, 1999s and in coincidence in 2005year.

Content of magnesium (Mg) has fall down tendency from 1989 up to 2005s on both localities N an AM where levels are almost balanced. At Nitra locality within three investigated years was average amount Mg = 3.02-7.44 $mg.g^{-1}$, at AM locality Mg = 3.49-7.33 $mg.g^{-1}$. In comparison to natural limit content that is Mg = 2.0-4.0 $mg.g^{-1}$, accumulation levels of magnesium was overstepped only in 1989s both localities.

Potassium (K) content in silver birch leaves has achieved this levels according to localities in annual averages 1989, 1999, 2005: Nitra, K = 13.10-19.61 $mg.g^{-1}$, Arboretum Mlyňany SAV, K = 7.99-16.82 $mg.g^{-1}$. On both localities has decreasing tendency within measured years but absolute contents are comparable higher at N locality. The limit value 3.5-10.0 $mg.g^{-1}$ was overstepped at Nitra locality in all years.

Natrium (Na) leaf content was analyzed at Nitra in average values Na = 0.111-0.230 $mg.g^{-1}$, at Arboretum Mlyňany SAV, Na = 0.062-0.175 $mg.g^{-1}$. Both localities had decreasing tendency in natrium content within followed years 1989-2005. Natural leaf limit content Na = 0.100 $mg.g^{-1}$ was most often overstepped at Nitra locality.

Iron (Fe) content in assimilation organs was analysed at Nitra, Fe = 0.207-1.271 $mg.g^{-1}$, at Arboretum Mlyňany, Fe = 0.07-0.154 $mg.g^{-1}$, where natural leaf limit content Fe = 0.2-2.0 $mg.g^{-1}$ was not overstepped on both localities. The higher iron content was significant at Nitra locality.

Content of zinc (Zn) as accessory element was analysed in annual average at Nitra, Zn = 0.084-0.258 $mg.g^{-1}$, at Arboretum Mlyňany SAV Zn = 0.078-0.114

mg.g$^{-1}$, when on both localities zinc amount was over natural limit, Zn = 0.015-0.080 mg.g$^{-1}$.

Copper (Cu) has in leaf content average levels at Nitra Cu = 0.008-0.033 mg.g$^{-1}$, Arboretum Mlyňany SAV Cu = 0.004-0.041 mg.g$^{-1}$. In both cases limit value 0.006-0.014 was overstepped.

Lead (Pb) was long time originated from industry and transport vehicles sources and increased values in air pollutants. At Nitra locality analysed leaf content was Pb = 0.001-0.0042 mg.g$^{-1}$, at Arboretum Mlyňany SAV, Pb = 0.005-0.036 mg.g$^{-1}$. The leaf amount of lead at both localities is very close, but they are over of natural limit for silver birch, where Pb = 0.002-0.006 mg.g$^{-1}$.

Manganese (Mn) in assimilation organs was found in content at Nitra, Mn = 0.057-0.119 mg.g$^{-1}$, at Arboretum Mlyňany SAV, Mn = 0.094-0.176 mg.g$^{-1}$, what means that at comparable locality was higher content. The values are under natural limit content, Mn = 0.50-4.00 mg.g$^{-1}$.

From anionic components, average annual leaf content $H_2PO_4^-$ = 0.73-2.94 mg.g$^{-1}$ at Nitra locality, and $H_2PO_4^-$ = 0.69-3.89 mg.g$^{-1}$ at Arboretum Mlyňany SAV. The content of $Cl^-$ = 3.59-7.90 mg.g$^{-1}$ at Nitra, and $Cl^-$ = 1.66-7.58 mg.g$^{-1}$ at AM locality. The content of $NO_3^-$ = 0.15-1.15 mg.g$^{-1}$ at Nitra, and $NO_3^-$ = 0.05-0.31 mg.g$^{-1}$ at AM locality. The leaf content of $(SO_4)^{2-}$ = 0.93-5-27 mg.g$^{-1}$ at Ntra, and $(SO_4)^{2-}$ = 0.42-3.28 mg.g$^{-1}$ at Arboretum Mlyňany SAV.

The three anionic components as are: $Cl^-$, $NO_3^-$, $(SO_4)^{2-}$ were analysed in silver birch leaves in higher content at Nitra town locality then Arboretum Mlyňany SAV what was due to higher pollutants load of urban environment.

According to statistical evaluation of analysed element contents in silver birch leaves, the significant differences when higher levels at Nitra town locality has been identified in case of: K, Fe, Zn, Cu, Pb, Mn, $Cl^-$, $NO_3^-$, $(SO_4)^{2-}$ elements and components. I should be considered as consequence of higher environmental load of urban vegetation by immissions.

## Discussion

Increased element contents in woody plant leaves at the urban vegetation areas is due as reflection of immission load from industry, transport and heating systems. It was confirmed by many authors in their papers (e.g. BENČAŤ 1995, HRDLIČKA & KULA 1998, KONTRIŠ & KONTRIŠOVÁ 2001, KOZLOWSKI et al. 1991, SUPUKA 2001, TOMAŠEVIČ et al. 2005).

According to State Healthy Institute in Nitra, immission load measured close to leaf sampled silver birch trees was in 1999 year are as follow: dust fall 6.6-11.2 g.m$^{-2}$ within 30 days in dependent to months of year, flitter dust 3.5-8.1 µg.m$^{-3}$, $NO_x$ = 16.2-27.2 µg.m$^{-3}$ (1999 year) and 9.0-43.0 µg.m$^{-3}$ (2005 year), $SO_2$ = 7.71-16.7 µg.m$^{-3}$ (in 2000 year), $O_3$ = 10.7-42.1 µg.m$^{-3}$ (POKORNÝ & ANDRLÍK 2000).

Results of measured immission levels in Nitra town air from 2005 year are as follow: $SO_2$ = 7-21 µg.m$^{-3}$ (with maximal occurred value 64 µg.m$^{-3}$), $NO_x$ = 35-111 µg.m$^{-3}$ (maximum 252), CO = 500-1600 µg.m$^{-3}$.

Other published paper (LAZOR, TOMÁŠ & TÓTH 2000) presents this values of immission load for Nitra town: $SO_2$ = 13.5-25.4 µg.m$^{-3}$ (in 1998s) and 6.0-22.7

μg.m$^{-3}$ (in 1999s), $NO_x$ = 7.0-14.6 μg.m$^{-3}$ (in 1998 year) and 9.0-12.5 μg.m$^{-3}$ (in 1999 year).

The hygienic allowed limits according to law No. 705/2002 Z.z. approved by Slovak parliment for individual components in polluted air with emphasize to woody plants sensitivity are follow: $O_3$ = 60 μg.m$^{-3}$, $SO_2$ = 20 μg.m$^{-3}$, $NO_x$ = 30 μg.m$^{-3}$. In many cases those limits were overstepped in investigated periods at Nitra town.

The content of measured anionic components in leaves of Norway maple (*Acer pseudoplatanus* L.) at locality Nitra town was identified 0.15-6.17 mg.g$^{-1}$ (SUPUKA 2001). The content of allochtonous elements in leaves of silver birch (*Betula pendula* Roth.) was measured in similar levels (HRDLIČKA & KULA 1998) as we analysed in Nitra town.

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**Tab. 1. Total content of elements in silver birch leaves (*Betula pendula* Roth.) from urban vegetation of Nitra town. Development trends according to years 1989, 1999, 2005 (elements in $mg.g^{-1}$ dry matter)**

| Elements<br>Leaf sampling dates | Ca | Mg | K | Na | Fe | Zn | Cu | Pb | Mn | $H_2PO_4^-$ | $Cl^-$ | $NO_3^-$ | $(SO_4)^{2-}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4.5. **1989** | 16.50 | 3.43 | 11.91 | 0.097 | 1.186 | 0.212 | 0.028 | 0.036 | 0.075 | 4.69 | 8.75 | 0.51 | 4.26 |
| 13.6. | 22.99 | 8.17 | 14.99 | 0.258 | 0.933 | 0.324 | 0.028 | 0.025 | 0.094 | 4.08 | 8.51 | 0.49 | 4.73 |
| 14.7 | 19.31 | 7.65 | 19.50 | 0.256 | 1.187 | 0.283 | 0.035 | 0.038 | 0.112 | 1.86 | 7.15 | 0.21 | 8.52 |
| 23.8. | 25.42 | 6.37 | 28.31 | 0.193 | 1.650 | 0.198 | 0.045 | 0.049 | 0.126 | 2.78 | 5.67 | 0.38 | 9.18 |
| 26.9. | 30.47 | 10.97 | 20.33 | 0.235 | 1.363 | 0.290 | 0.033 | 0.054 | 0.168 | 2.66 | 7.62 | 0.26 | 2.55 |
| 20.10 | 32.32 | 8.07 | 22.63 | 0.343 | 1.306 | 0.241 | 0.029 | 0.052 | 0.137 | 1.60 | 9.68 | 0.20 | 2.37 |
| **Average 1989** | 24.50 | 7.44 | 19.61 | 0.230 | 1.271 | 0.258 | 0.033 | 0.042 | 0.119 | 2.94 | 7.90 | 0.34 | 5.27 |
| 11.5. **1999** | 25.86 | 5.50 | 17.64 | 0.034 | 0.231 | 0.186 | 0.014 | 0.016 | 0.067 | 1.39 | 6.99 | 0.13 | 1.70 |
| 9.6. | 41.08 | 6.26 | 15.84 | 0.048 | 0.260 | 0.092 | 0.034 | 0.021 | 0.078 | 3.79 | 5.78 | 0.22 | 1.63 |
| 27.7. | 37.92 | 5.26 | 11.74 | 0.101 | 0.264 | 0.098 | 0.033 | 0.016 | 0.075 | 3.59 | 5.12 | 0.09 | 1.03 |
| 16.8. | 11.58 | 4.48 | 9.52 | 0.179 | 0.189 | 0.044 | 0.058 | 0.023 | 0.057 | 1.24 | 2.37 | 0.07 | 0.56 |
| 13.9. | 17.48 | 5.06 | 11.76 | 0.187 | 0.278 | 0.041 | 0.012 | 0.011 | 0.112 | 1.02 | 4.46 | 0.29 | 0.31 |
| 11.10. | 19.44 | 5.42 | 12.10 | 0.191 | 0.282 | 0.043 | 0.011 | 0.012 | 0.114 | 2.15 | 10.09 | 0.11 | 0.71 |
| **Average 1999** | 25.56 | 5.33 | 13.10 | 0.123 | 0.251 | 0.084 | 0.027 | 0.016 | 0.084 | 2.20 | 5.80 | 0.15 | 0.99 |
| 20.5. **2005** | 8.57 | 2.02 | 12.20 | 0.172 | 0.139 | 0.153 | 0.007 | 0.001 | 0.030 | 0.64 | 2.79 | 0.30 | 0.76 |
| 28.6. | 13.91 | 2.83 | 15.00 | 0.114 | 0.145 | 0.184 | 0.007 | 0.001 | 0.036 | 0.78 | 3.76 | 0.93 | 0.82 |
| 29.7. | 16.41 | 2.95 | 16.60 | 0.106 | 0.209 | 0.132 | 0.006 | 0.001 | 0.062 | 0.84 | 5.90 | 1.42 | 1.14 |
| 24.8. | 16.52 | 2.98 | 14.50 | 0.084 | 0.235 | 0.126 | 0.007 | 0.002 | 0.068 | 0.90 | 3.34 | 1.59 | 1.36 |
| 27.9. | 15.02 | 3.65 | 12.50 | 0.093 | 0.357 | 0.124 | 0.008 | 0.002 | 0.085 | 0.61 | 2.98 | 1.39 | 0.98 |
| 27.10 | 19.14 | 3.71 | 11.50 | 0.095 | 0.159 | 0.113 | 0.010 | 0.001 | 0.062 | 0.58 | 2.77 | 1.26 | 0.49 |
| **Average 2005** | 14.93 | 3.02 | 13.72 | 0.111 | 0.207 | 0.139 | 0.008 | 0.001 | 0.057 | 0.73 | 3.59 | 1.15 | 0.93 |

**Tab. 2. Total content of elements in silver birch leaves (*Betula pendula* Roth.) grown at comparable locality Arboretum Mlyňany SAV. Development trends according to years 1989, 1999, 2005 (elements in mg.g$^{-1}$ dry mater)**

| **Elements**<br>**Leaf sampling dates** | | **Ca** | **Mg** | **K** | **Na** | **Fe** | **Zn** | **Cu** | **Pb** | **Mn** | **$H_2PO_4^-$** | **$Cl^-$** | **$NO_3^-$** | **$(SO_4)^{2-}$** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4.5. | **1989** | 23.30 | 5.70 | 15.96 | 0.140 | 0.120 | 0.199 | 0.016 | 0.021 | 0.061 | 4.03 | 6.39 | 0.42 | 5.23 |
| 13.6. | | 20.50 | 5.50 | 16.28 | 0.090 | 0.160 | 0.113 | 0.021 | 0.015 | 0.075 | 3.92 | 7.46 | 0.36 | 5.06 |
| 14.7 | | 23.20 | 6.10 | 18.44 | 0.030 | 0.140 | 0.087 | 0.036 | 0.021 | 0.097 | 5.58 | 5.73 | 0.27 | 4.88 |
| 23.8. | | 30.70 | 6.30 | 18.25 | 0.175 | 0.154 | 0.075 | 0.058 | 0.065 | 0.114 | 4.39 | 6.61 | 0.24 | 1.18 |
| 26.9. | | 29.50 | 7.70 | 16.75 | 0.487 | 0.170 | 0.100 | 0.042 | 0.080 | 0.098 | 3.56 | 7.89 | 0.26 | 1.56 |
| 20.10 | | 27.70 | 12.70 | 15.25 | 0.125 | 0.178 | 0.110 | 0.072 | 0.015 | 0.118 | 1.19 | 11.38 | 0.32 | 1.79 |
| **Average 1989** | | 25.82 | 7.33 | 16.82 | 0.175 | 0.154 | 0.114 | 0.041 | 0.036 | 0.094 | 3.89 | 7.58 | 0.31 | 3.28 |
| 11.5. | **1999** | 22.20 | 4.80 | 16.88 | 0.068 | 0.160 | 0.089 | 0.011 | 0.024 | 0.110 | 5.54 | 1.93 | 0.17 | 1.05 |
| 9.6. | | 18.89 | 5.54 | 16.16 | 0.059 | 0.146 | 0.098 | 0.014 | 0.016 | 0.165 | 1.28 | 1.79 | 0.18 | 1.28 |
| 27.7. | | 37.92 | 5.26 | 11.74 | 0.075 | 0.169 | 0.099 | 0.026 | 0.016 | 0.195 | 2.24 | 3.02 | 0.19 | 3.12 |
| 16.8. | | 24.18 | 4.54 | 9.76 | 0.104 | 0.097 | 0.081 | 0.054 | 0.017 | 0.259 | 4.14 | 1.45 | 0.20 | 1.06 |
| 13.9. | | 22.50 | 4.94 | 7.58 | 0.130 | 0.125 | 0.074 | 0.089 | 0.013 | 0.185 | 2.75 | 1.93 | 0.15 | 1.03 |
| 11.10. | | 23.58 | 4.34 | 9.14 | 0.149 | 0.163 | 0.024 | 0.015 | 0.011 | 0.141 | 1.26 | 1.87 | 0.13 | 0.97 |
| **Average 1999** | | 24.88 | 4.90 | 11.88 | 0.098 | 0.143 | 0.078 | 0.035 | 0.016 | 0.176 | 2.87 | 2.00 | 0.17 | 1.42 |
| 20.5. | **2005** | 12.25 | 2.55 | 10.00 | 0.058 | 0.061 | 0.070 | 0.006 | 0.002 | 0.069 | 0.90 | 0.84 | 0.06 | 0.76 |
| 28.6. | | 17.80 | 3.46 | 8.30 | 0.066 | 0.063 | 0.078 | 0.005 | 0.003 | 0.097 | 0.66 | 1.38 | 0.04 | 0.71 |
| 29.7. | | 20.91 | 3.51 | 9.20 | 0.069 | 0.074 | 0.107 | 0.004 | 0.004 | 0.120 | 1.09 | 2.32 | 0.05 | 0.43 |
| 24.8. | | 23.44 | 3.65 | 8.30 | 0.580 | 0.076 | 0.092 | 0.004 | 0.005 | 0.124 | 0.76 | 2.74 | 0.07 | 0.27 |
| 27.9. | | 29.66 | 3.40 | 7.10 | 0.052 | 0.067 | 0.079 | 0.003 | 0.005 | 0.133 | 0.44 | 1.51 | 0.04 | 0.21 |
| 27.10 | | 20.01 | 4.38 | 5.00 | 0.071 | 0.079 | 0.069 | 0.003 | 0.008 | 0.250 | 0.31 | 1.15 | 0.02 | 0.12 |
| **Average 2005** | | 20.68 | 3.49 | 7.99 | 0.062 | 0.070 | 0.082 | 0.004 | 0.005 | 0.132 | 0.69 | 1.66 | 0.05 | 0.42 |

**Tab. 3. Statistical significance of differences at average element contents in silver birch leaves (*Betula pendula* Roth.) at Nitra urban vegetation locality in comparated years, T-test**

| Elements<br>Statistical values | Ca | Mg | K | Na | Fe | Zn | Cu | Pb | Mn |
|---|---|---|---|---|---|---|---|---|---|
| | | | | **Comparated values, 1989-1999 years** | | | | | |
| **T - value** | -0.20 | 2.03 | 2.45 | 2.41 | 10.41 | 5.72 | 0.75 | 5.18 | 2.11 |
| **Pr - value** | 0.8492 | 0.0919 | 0.0341$^{+}$ | 0.0368$^{+}$ | 0.0001$^{+++}$ | 0.0002$^{+++}$ | 0.4795 | 0.0004$^{+++}$ | 0.0614 |
| | | | | **Comparated values, 1989-2005 years** | | | | | |
| **T - value** | 3.36 | 4.24 | 2.37 | 3.35 | 10.36 | 5.28 | 9.34 | 8.91 | 3.89 |
| **Pr - value** | 0.0073$^{++}$ | 0.0063$^{++}$ | 0.0544 | 0.0074$^{++}$ | 0.0001$^{+++}$ | 0.0004$^{+++}$ | 0.0001$^{+++}$ | 0.0003$^{+++}$ | 0.0030$^{++}$ |
| | | | | **Comparated values, 1999-2005 years** | | | | | |
| **T - value** | 2.15 | 6.64 | -0.42 | 0.39 | 1.18 | -2.16 | 2.59 | 7.75 | 2.08 |
| **Pr - value** | 0.0566 | 0.0001$^{+++}$ | 0.6852 | 0.7052 | 0.2767 | 0.0670 | 0.271 | 0.0001$^{+++}$ | 0.0650 |

Significance: + $P \leq 0.05$; ++ $P \leq 0.01$; +++ $P \leq 0.001$

**Tab. 4. Statistical significance of differences at average element contents in silver birch leaves (*Betula pendula* Roth.) between Nitra and Arboretum Mlyňany SAV localities in comparated years, T-test**

| Elements<br>Statistical values | Ca | Mg | K | Na | Fe | Zn | Cu | Pb | Mn |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | **Comparated values, 1989 year** | | | | |
| **T - value** | 0.44 | -0.07 | -1.16 | -0.76 | -11.48 | -5.35 | 0.86 | -0.49 | -1.54 |
| **Pr - value** | 0.6737 | 0.9433 | 0.2738 | 0.4717 | 0.0001$^{+++}$ | 0.0003$^{+++}$ | 0.4123 | 0.6399 | 0.1596 |
| | | | | | **Comparated values, 1999 year** | | | | |
| **T - value** | -0.09 | -1.42 | -0.61 | -0.78 | -5.88 | -0.25 | 0.53 | -0.13 | 4.00 |
| **Pr - value** | 0.9289 | 0.1872 | 0.5542 | 0.4569 | 0.0002$^{+++}$ | 0.8067 | 0.6080 | 0.9028 | 0.0051$^{++}$ |
| | | | | | **Comparated values, 2005 year** | | | | |
| **T - value** | 2.14 | 1.35 | -5.33 | 0.44 | -4.06 | -4.64 | -4.52 | 3.63 | 2.80 |
| **Pr - value** | 0.0640 | 0.2078 | 0.0003$^{+++}$ | 0.6667 | 0.0023$^{++}$ | 0.0017$^{++}$ | 0.0012$^{++}$ | 0.0046$^{++}$ | 0.0186$^{+}$ |

Significance: + P ≤ 0.05; ++ P ≤ 0.01; +++ P ≤ 0.001



**Tab. 5. Statistical significance of differences at average element contents in silver birch leaves (*Betula pendula* Roth.) between Nitra and Arboretum Mlyňany SAV localities comprehensively in 1989, 1999, 2005 years**

| Elements | Ca | Mg | K | Na | Fe | Zn | Cu | Pb | Mn |
|---|---|---|---|---|---|---|---|---|---|
| **T - value** | 0.88 | -0.03 | -2.12 | -0.36 | -3.66 | -3.16 | 0.57 | -0.17 | 2.99 |
| **Pr - value** | 0.3835 | 0.9764 | 0.0414 | 0.7233 | 0.0008$^{+++}$ | 0.0033$^{++}$ | 0.5707 | 0.8667 | 0.0057$^{++}$ |

Significance: + P ≤ 0.05; ++ P ≤ 0.01; +++ P ≤ 0.001

**Tab. 6. Statistical significance of differences at average anion contents in silver birch (*Betula pendula* Roth.) at Nitra locality and between Nitra and Arboretum Mlyňany SAV localities comprehensively in 1989, 1999, 2005 years**

| Anionic elements | $H_2PO_4^-$ | $Cl^-$ | $NO_3^-$ | $(SO_4)^{2-}$ |
|---|---|---|---|---|
| **Statistical values** | **Comparated values, Nitra locality, 1989-1999 years** | | | |
| **T - value** | 1.06 | 1.74 | 2.86 | 3.52 |
| **Pr - value** | 0.3127 | 0.1133 | 0.0169 | 0.0146 |
| **Statistical values** | **Comparated values, Nitra locality, 1989-2005 years** | | | |
| **T - value** | 4.44 | 5.72 | -4.03 | 3.61 |
| **Pr - value** | 0.0064$^{++}$ | 0.0002$^{+++}$ | 0.0072$^{++}$ | 0.0148$^{+}$ |
| **Statistical values** | **Comparated values, Nitra locality, 1999-2005 years** | | | |
| **T - value** | 2.94 | 1.89 | -5.10 | 0.11 |
| **Pr - value** | 0.0148$^{+}$ | 0.1002 | 0.0005$^{+++}$ | 0.9189 |
| **Statistical values** | **Comparated values, Nitra and Arboretum Mlyňany SAV comprehensively in 1989, 1999, 2005 years** | | | |
| **T - value** | 0.93 | -2.18 | -2.95 | -0.91 |
| **Pr - value** | 0.3601 | 0.0369$^{+}$ | 0.0057$^{++}$ | 0.0369$^{+}$ |

Significance: + P ≤ 0.05; ++ P ≤ 0.01; +++ P ≤ 0.001

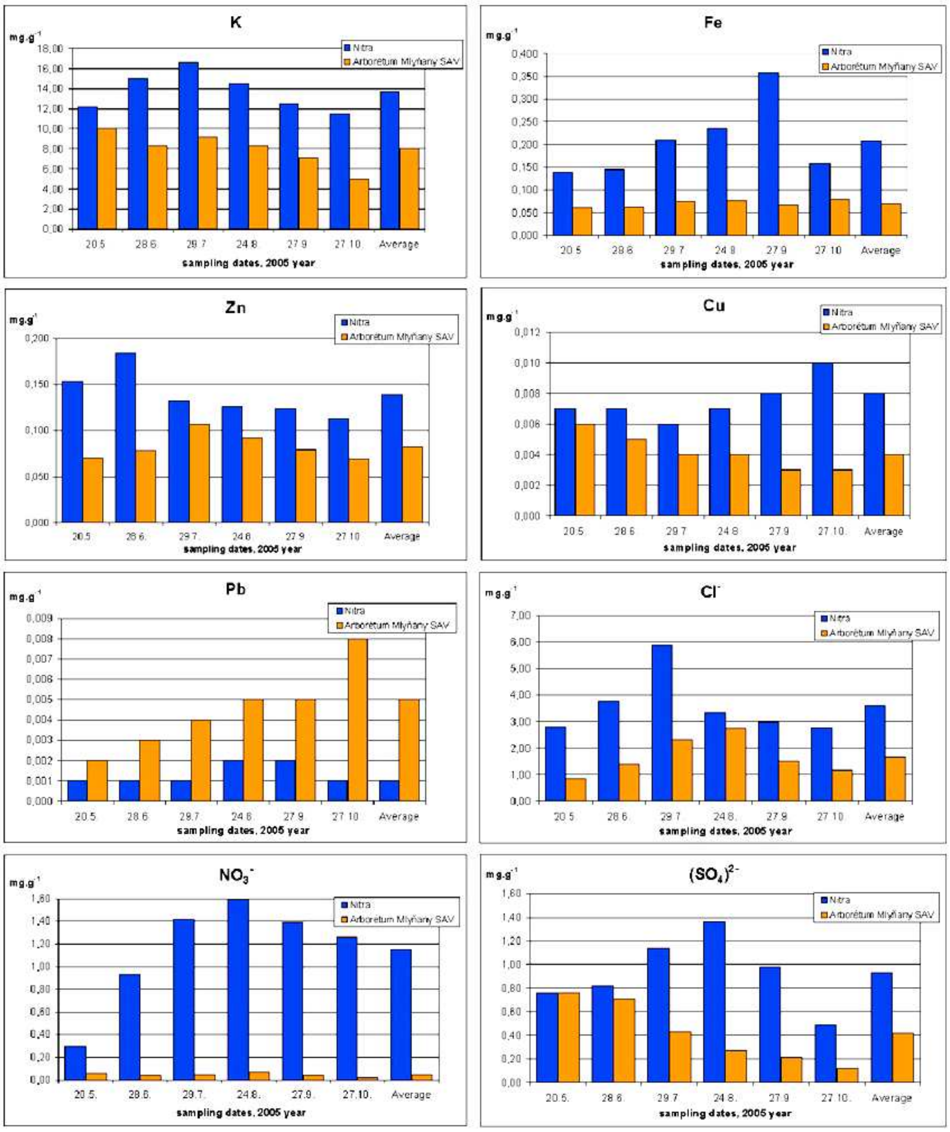


**Fig. 1. The course of accumulated elements and components in silver birch leaves (*Betula pendula* Roth.) at Nitra town and Arboretum Mlyňany SAV localities where differences were statistically significant**

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