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THE IMPACT OF MAN-MADE POLLUTION UPON ARBOREOUS PLANTS OF YEREVAN

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ABSTRACT

The article highlights a study of the impact of man-made pollution upon arboreous plants in conditions of Yerevan. The research included investigation of chlorine and heavy metal concentrations in the city's soils and plants, assessment of the level and spatial spread of plant pollution, investigation of cumulative properties of plants and the effect of toxicants on some physiological and biochemical indices of plants. Criteria for indication of ecological tolerance of plants were set up, as well.

Key words: *chlorine, heavy metals, pollution, trees, nitrogen metabolism*

INTRODUCTION

An essential factor to the health and safety of urban population is known to be a presence of green zones as besides recreational, structural and designing decorative and aesthetic role, green plantations perform a sanitary and hygienic function as well, reducing dust contents, mitigating the effects of noise and finally cleaning up the environment from pollutants. Due to their property to absorb harmful substances from the environment, plants may serve not only as natural phytofilters, but also as effective indicators for detection of harmful substances. However, urbanization has an adverse impact on vegetation. Major ecological factors in cities notably differ from those impacting plants in natural conditions. Climatic, hydrological etc. regimes in cities undergo considerable changes adding pollution of urban air basin and soil cover. All the noted factors affect metabolic processes in plants and are recognized as basic causes of disturbance of biota and reduction of biodiversity in cities [4, 10, 18].

Since recent years, the ecosystems of Yerevan have been displaying an intensively running process of desertification, changes in physicochemical properties of soil and its fertility decline. Such changes are mainly induced by unregulated site development, expansion of asphalt- and concrete-paved areas and a presence of high concentration of diverse environmental toxicants which affect vegetation against a background of dramatic reduction of green belts, steady deterioration of the status of green plantations and drastic reduction of specific diversity of plants [2, 7]. All this prove the value of researches aimed at indication of ecological tolerance and metabolic specificities of plants in conditions of Yerevan.

The goal of this research was studying the impact of man-made pollution upon arboreous plants in conditions of Yerevan. The research tasks to achieve the stated goal were to study of chlorine and heavy metal concentrations in the city's soils and plants, assess the level and spatial spread of plant pollution, investigate cumulative properties of plants and the effect of toxicants on some physiological and biochemical indices of plants, set up criteria for indication of ecological tolerance of plants and description of pollution levels of sites.

MATERIALS AND METHODS

The research was performed between 2005 and 2007. The studied objects were soils and leaves of the selected species the most widespread in the city: *Robinia pseudoacacia* L., *Fraxinus excelsior* L., *Populus alba* L., *Morus alba* L. and *Vitis vinifera* L. Soil and plant sampling and sample treatment were done consistent with the accepted methods [15].

In 2005 and 2006 soil and plants were sampled from 19 points scattered allover Yerevan: soils – once and plants – twice a year in the beginning and end of vegetation, May and November, respectively.

In 2007 sampling was done in the mid of vegetation (July-August). Chlorides were determined in soil water extraction by ISO 11464 [5] and the contents of total nitrogen – by the accepted methods [1]. The contents of total chlorine in plants were determined by titration with $AgNO_3$ [14] and those of total nitrogen – through the express method [9]. Heavy metal contents were determined by a method of atomic-absorption analysis (AAnalyst 800, Perkin-Elmer, USA). A qualitative assessment of heavy metals in depositing mediums (soil, plants) was done through a method of a comparative analysis between actual and background concentrations. Background concentration value were taken from

earlier performed researches [19]. For studying heavy metal intake by and accumulation in plants we used the following indices: Coefficient of man-made concentration (C_c) and a summary concentration index (SCI) [13].
The obtained results underwent statistical treatment with help of MS Excell и Statistica 6.0 programs. To map sampling points and reflect the data obtained, schematic maps were produced through ArcGIS software.

RESULTS AND DISCUSSION

Chlorine

In 2005 through 2007 we studied the dynamics of mean, minimal and maximal concentrations of chlorine in Yerevan soils. As indicated, for the studied period mean contents of chlorine exceeded the standard (0.02%) [17] almost on all the studied sites (*Fig. 1*).

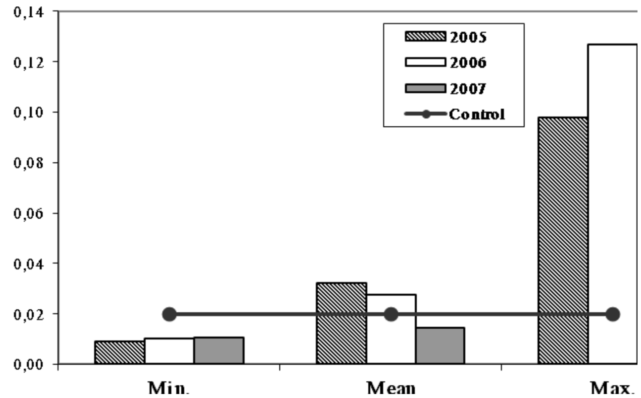

Fig. 1. Chlorine concentrations in the soils of Yerevan.

The obtained research results indicated that during the three years emphasizing 2006 chlorine contents in soils exceeded the control. Maximal concentrations of the element (0.127%) were detected in the southern part of the city.
We studied the dynamics of chlorine concentration in the leaves of the selected species in the beginning and the end of vegetation period in 2005-2006. The obtained results indicated chlorine accumulation by all the studied species. In 2006, in the end of vegetation period, chlorine accumulation was manifested best pronouncedly (*Fig. 2*).

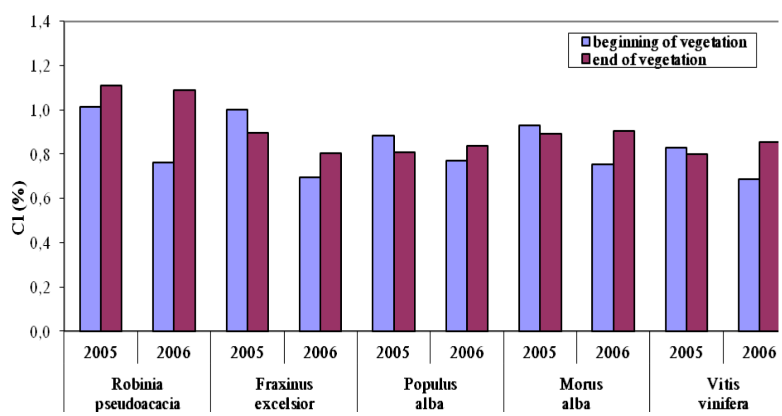

Fig. 2. The dynamics of mean chlorine concentrations in Yerevan arboreous plants during vegetation period in 2005-2006.

In 2007 mean concentrations of chlorine varied within 0.58-0.72%, whereas its maximal concentrations in the leaves of *Robinia pseudoacacia*, *Fraxinus excelsior*, white poplar exceeded the accepted value 0.4% [20] by 2.03-4.43; 2.03-4.43; and 2.23-2.8 times, respectively.
The research results for 2005-2007 indicated a presence of well high concentrations of chlorine in all the studied tree species which achieved their peaks in the end of vegetation. All the studied species readily absorbed and accumulated chlorine (*Tab. 1*).
The data obtained supported creation of schematic maps of spatial distribution of Cl contents in the soils and plants of Yerevan (*Fig. 3-4*). For mapping we selected data on soil and 3 decorative arboreous species, whereas the spread of the element was seen most distinctly in the variant with data on *Robinia pseudoacacia*.

Table 1. Minimal, mean and maximal concentrations of chlorine in diverse tree species in 2005-2007.

Concentrations of chlorine (%)	The studied arboreous species				
	Robinia pseudoacacia	*Fraxinus excelsior*	*Populus alba*	*Morus alba*	*Vitis vinifera*
Minimal	0.41	0.44	0.43	0.56	0.44
Mean	0.93	0.77	0.83	0.87	0.79
Maximal	1.65	1.40	1.36	1.43	1.47

High contents of chlorine (0.019-0.03%) were detected in the soils of the southern part of the city (nearby the Yerevanian Lake, water cleanup station and a RPC “Nairit”) (*Fig. 3*). The analysis of the schematic maps reflecting data on robinia pseudoacacia indicated that wholly mean contents of the element (0.64-0.81%) were prevalent, whereas high concentrations (0.81-1.77%) were detected on plots located in the southern part of the city (close to a water cleanup station and a RPC “Nairit”) and in some points in direction of the wind rose (in River Hrazdan gorge) (*Fig. 4*) The noted species may serve as an effective indicator for detection of levels of chlorine pollution of sites.

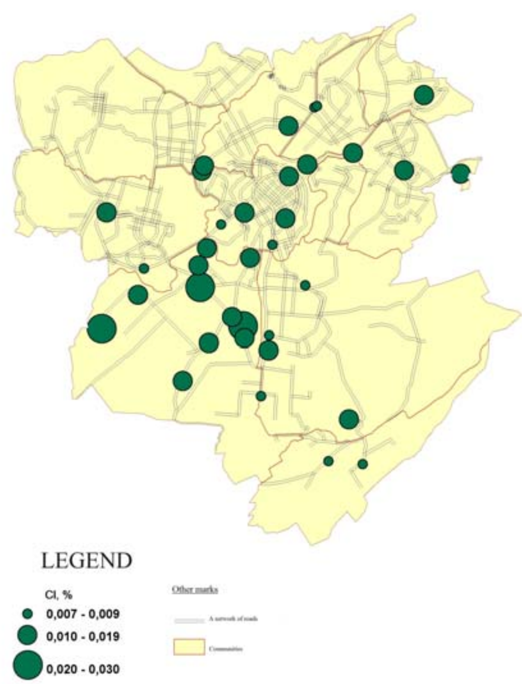

Fig. 3. A schematic map of chlorine spread in Yerevan soils.

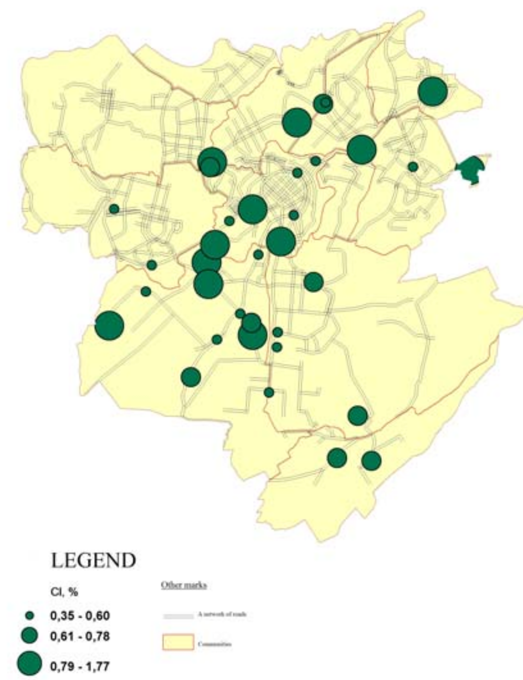

Fig. 4. A schematic map of chlorine spread according to data on *Robinia pseudoacacia.*

Heavy metals

We also studied the contents of heavy metals such as Cu, Mn, Pb, Ni, Mo and Zn in Yerevan soils and plants as those chemical elements hold a special position among dominating pollutants of the city [6, 10, 16].

Mean concentrations of elements in soils exceeded the background by 1.2-3.34 times (*Tab. 2*), whereas the highest contents of metals were detected mostly in the soils of the southern part of the city which homes the major part of industrial enterprises. The noted toxicants pollute the soils of some plots in the west and central parts of Yerevan, too.

Such distribution of heavy metals throughout the city’s territory may plausibly be associated with operation of industrial enterprises and basic directions of the wind rose, heavy traffic, load of domestic refuse and debris.

The studies indicated that background contents of heavy metals in plants, except lead, nickel and molybdenum **(***Tab. 3***)** were not high as compared with accepted concentrations [3, 20]. The concentrations of those elements exceeded the background values by 1.6-2.3, 4.6-5.25 and 3.34-9.7 times respectively, whereas mean values of Mn, Zn and Cu did not overstep the background.

A study of specificities of heavy metal intake and accumulation by plants indicated that the leaves of robinia pseudoacacia accumulated predominantly Mo, Pb and Ni, of white poplar – Mo, Mn, Ni, Zn, whereas those of European ash tree accumulated almost the whole range of elements.

Table 2. Minimal, mean and maximal concentrations of heavy metals in Yerevan soils (*mg/kg*).

Element	Background	Min	Min / Background	Mean	Mean / Background	Max	Max / Background
Cu	60	70	1.17	89.6	1.49	150	2.5
Mn	350	750	2.14	793.5	2.27	850	2.43
Pb	40	25	0.63	38.9	0.98	50	1.25
Ni	35	80	2.29	117	3.34	180	5.14
Mo	1.2	3.0	2.5	3,6	3	4.5	3.8
Zn	100	9	0.09	122	1.22	900	9.0

Table 3. Mean concentrations of heavy metals in the leaves of Yerevan trees (*mg/kg*).

Elements	Kind of species					
	Robinia pseudoacacia		*Fraxinus excelsior*		*Populus alba*	
	Background	Mean	Background	Mean	Background	Mean
Cu	10.71	20.30	15.84	22.41	12.06	22.46
Mn	75.47	72.70	75.12	74.55	81.25	83.82
Zn	23.8	29.09	23.76	31.38	26.8	26.8
Pb	2.0	4.64	2.5	3.94	2.0	4.61
Ni	1.07	4.92	1.06	4.78	1.07	5.54
Mo	0.62	1.59	0.3	1.88	0.41	1.92

On a base of summary concentration indices (SCI) of heavy metals in plants, schematic maps of plant pollution were produced (*Fig. 5*).

Data analysis indicated that wholly in plants concentrations of heavy metals exceeded the background by 2-3 times, whereas threefold and higher excesses were detected in all the plants and particularly in white poplar and ash tree on sites located mostly in the southern, southwestern, central and northeastern parts of the city.

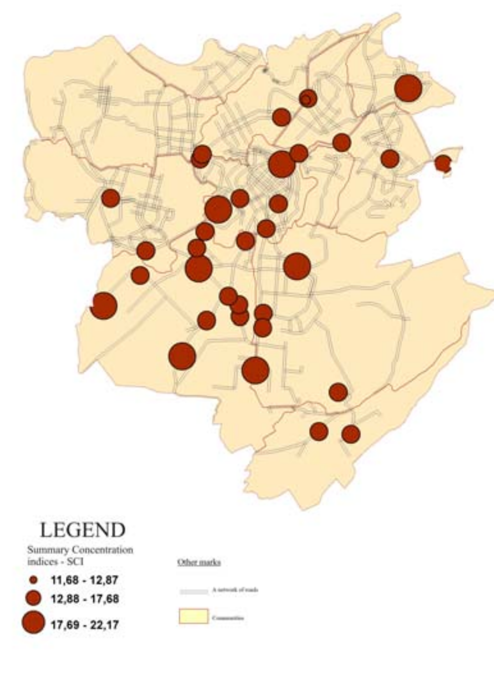

Fig. 5. Heavy metal pollution of *Populus alba* L. in Yerevan.

The impact of man-made pollution upon plants

To identify complex pollution sites, we performed a comparative analysis of plant pollution with chlorine and heavy metals. Data on the three studied plant species helped single out 6 sites of complex pollution, on which phenological studies of the status of plants were carried out. Visible morphological injuries were detected only in trees found in a radius of 1 km from industrial enterprises "Nairit" and 'Pure Iron' and in the vicinities of municipal waste disposal site. The leaves of plants growing on that plots displayed the highest concentrations of elements: chlorine – over 1.2%, heavy metal SCI – over 15.0. Visible injuries of leaves were best seen in the mid of vegetation (June-July).

Ash tree and robinia pseudoacacia exhibited high tolerance to chlorine and heavy metal pollution, whereas severely weakened and drying specimens of white poplar were found only among old specimens.

Environmental impact is manifested not only as visible (morphological, physiological), but also as hidden, invisible injuries. High sensibility of plants to environmental impacts allows using the parameters of their vital functions as indicators of environmental status, whereas investigations into their stress metabolism helps define physiological and biochemical criteria of early diagnosis of plant injuries in conditions of man-made environment [17, 20].

With a view of setting such criteria, we studied seasonal and annual dynamics of total nitrogen in plants found on complexly polluted sites. In 2006 vs. 2005 nitrogen concentrations were particularly high in the leaves of *Robinia pseudoacacia* and *Morus alba* (*Fig. 6*).

Nitrogen concentrations in plants depended on pollution level of sites. On complexly polluted sites displaying high levels of chlorine and heavy metal pollution, we detected excessive contents of nitrogen (*Fig. 7*) that could apparently be associated with high contents of metals as some microelements are known to be actively involved in plant metabolism.

We calculated the values of total nitrogen- metals correlation. Tab. 4 gives values of nitrogen-metal and nitrogen-sum of metals(N/∑Cu, Zn, Mo, Pb, Mn, Ni) correlations in the leaves of plants on background, polluted and severely polluted sites in the mid of vegetation.

We established a decrease of values of nitrogen-metal correlations: N/Cu- by 1.2-5.7; N/Zn- by 1.1-1.9; $N/Z_{metal.}$- by 1.1-1.8; N/Mo- by 3.3-9.8 times. During appearance of visible injuries such decrease in N/Cu и N/Mo was sharper in the species noted above: by 3.7-5.7 и and 6.5-9.8 times, respectively (*Fig. 8*).

Changes in values of nitrogen-metal (emphasizing Cu and Mo) may be used for diagnosing pathologic processes in plants grown on man-altered sites and for assessing pollution level and ecological tolerance of species.

Tolerance of plant species in conditions of technogenesis may be established through studies of diverse forms of nitrogen, too. High concentrations of heavy metals in plants may lead to an increase in protein contents, which in turn have a property to bind metals, thus protecting cells from their toxic effects. In tolerant species under the impact of toxicants, an increase in protein nitrogen and in intolerant species – accumulation of non-protein forms of nitrogen [6, 8, 19] is detectable. Further investigation may help disclose both the mechanisms of the effect of toxicants on plants and metabolic peculiarities of tolerant species.

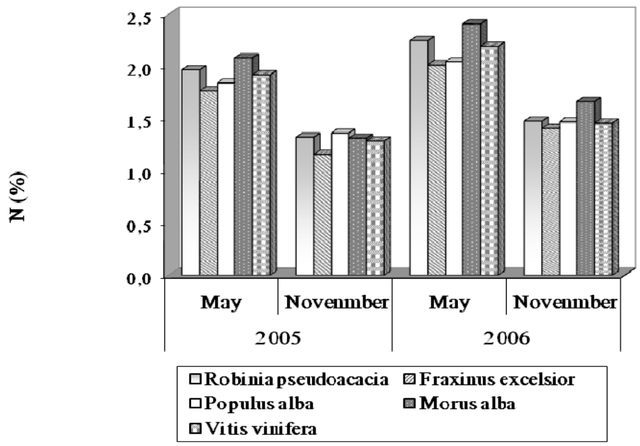

Fig. 6. The dynamics of nitrogen contents in the leaves of Yerevan trees.

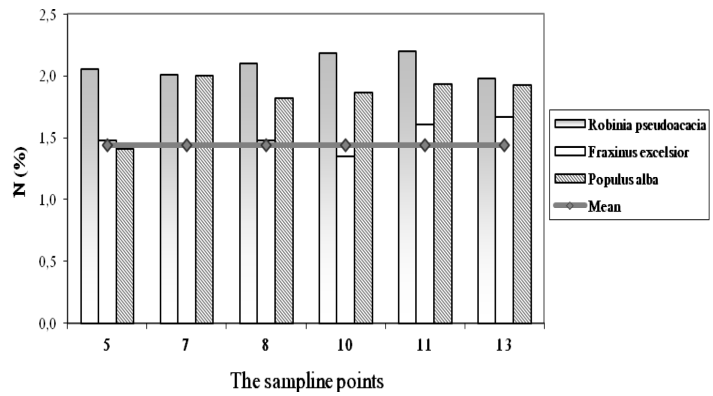

Fig. 7. The contents of total nitrogen in plants on strongly polluted sites.

Table 4. Values of relations between nitrogen/metal and nitrogen/chlorine in the leaves of plants growing on polluted sites.

Tree species	Variant	N/Cu	N/Mo	N/Zn	$N/\sum_{т.м}$
Robinia pseudo-acacia	Background	1870	32258	840	176
	Pollution site	917.1	10645	614	145
	Strong pollution site*	330	4954	461	96.5
Fraxinus excelsior	Background	949	50000	631	126.5
	Pollution site	846.7	7022	775	130
	Strong pollution site*	259.5	5105	327	79.59
Populus alba	Background	833	36585	559.7	121
	Pollution site	670	7414	533.5	111.6
	Strong pollution site*	624	6496	364	113.9

* - a strongly polluted site with visible injuries of plants

CONCLUSION

Finally, the obtained research results enabled us to conclude that

- ❖ Chlorides accumulation in arboreous plants growing in Yerevan depend on the closeness of a pollution source, dominating direction of the wind rose and accumulative properties of a species. High chlorine contents that exceeded the standard by 2.0-4.43 times were detected in the vicinities of Nairit RPC, a water cleanup station and in River Hrazdan gorge.
- ❖ The leaves of the studied tree species accumulate heavy metals emphasizing Pb, Ni, Mo, mean concentrations of which were excessive against the background by 1.6-2.3; 4.6-5.25 and 3.34-9.7 times, respectively. The highest summary concentration indices (SCI) of heavy metals were detected in the south, south-west, central and north-east of the city.
- ❖ Element intake by and accumulation in plants depends on biological properties of a species: robinia pseudoacacia more actively accumulates Cl, Pb, Ni, Mo, white poplar - Mo, Zn, Mn, Ni, ash tree – almost all the elements.

- Within strongly polluted zones plants displayed increased contents of total nitrogen, whereas nitrogen/ metals correlation values in the mid of vegetation dramatically decreased.

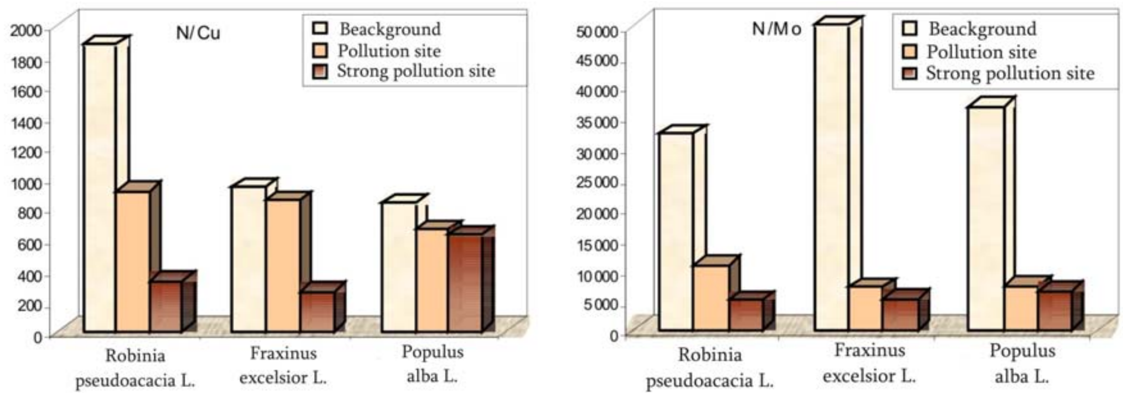

Fig. 8. Nitrogen/metal correlation values for leaves of plants growing on polluted sites.

Changes in ecological and biochemical indices of plants are detected prior to occurrence of visible injuries of leaves and may serve as indication features for early diagnosis of pathological processes in plants. The performed research allows recommending nitrogen/metal correlation values as criteria both for indication of specific tolerance and assessment of pollution level of territories.

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