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A complex approach to the development of green infrastructure of Armenia's cities

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Abstract

This research was designed to develop a complex program of scientifically grounded greening of Armenia's cities and her capital – Yerevan with a view of assuring ecological tolerance, longevity and a functional use of urban plants. It comprised a study of levels and character of pollution of different environmental compartments, examination of condition of plants and determination of species composition of urban trees and their ecological tolerance.

A complex urban greening program prepared by us in the result of this research allows to efficiently manage the quality of urban environment as proved on the example of Yerevan.

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1. Introduction

Today, dramatically increasing levels of manmade loads on environment make it essential to properly manage the urban greening issue, solution of which requires a complex, scientifically sound approach. It is known that urban plants play a recreational, aesthetic and extremely important sanitary and hygienic function reducing levels of environmental pollution dust, gas, heavy metal pollution of urban environment [6-8, 12-13, 16]. However, under the impact of a number of factors including that produced by different toxicants, condition of urban plants steadily deteriorates in form of weakening and untimely aging, deformation and necrosis of their vegetative organs, growing

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vulnerability to diseases and pests. This all inevitably brings to reduction of green areas in cities[9, 12, 17, 24, 30]. So, to maintain urban plants, it is essential to develop assortment of ecologically tolerant park and street tree and shrub species taking into consideration their decorativeness and longevity, specificities and functional predestination of sites, natural and climatic conditions, character and levels of environmental pollution.

Recent years have been marked by sharp reduction of both green spaces and species diversity in assortment of urban plants in Armenia's cities and particularly Yerevan- her capital[10-11]. These processes are determined by mismanaged cutouts and site development, high levels of environmental pollution with different toxicants, poor soil fertility, expansion of asphalt- and concrete-paved areas, piled debris and domestic garbage and so on.

A geochemical survey of the site implemented in the frames of this research showed presence of different toxicants in Yerevan soils and atmosphere. It should be mentioned that for years the city has been exposed to heavy vehicular and dust load, priority pollutants of environmental compartments being heavy metals, and that chlorine compounds, too, are detected in plants and soils of several districts of the city [18-21, 27-28, 31].

Such a situation urges to develop a proper strategic and complex approach to management of the issue that would help build ecologically favorable living environment for urban population.

The proposed complex approach includes

- Functional zonation of sites using satellite images,
- Geochemical survey of study sites,
- Assessment of existing plants,
- Studying dust- and gas- accumulation properties of urban plants,
- Compilation and complex analysis of a database.

The goal of this research was to develop a complex, scientifically sound greening program for Armenia's cities and particularly Yerevan in order to assure ecological tolerance, longevity and a functional use of green plantations.

To develop a research program, we selected the Abovyan Square -one of green recreation spots and study sites in Yerevan.

2. Research Material and Methods.

2.1. Study site

The study site is located in the heart of the city and has been under increasing vehicular impact. Despite its small area (0,8 hectares), the Square is notable for wide diversity of plant species. The Square is surrounded by three streets: Teryan Street - from the north, Abovyan Street- from southeast, and a beltway with a bus stop in the corner of a crossroad - from the northwest. To the southwest the Square borders on the National Agrarian University of Armenia (NAU) (Fig.1).

Figure 1. A satellite image of the Abovyan Square

2.2. Research methods

Field studies

In the frames of this research we studied species composition and condition of basic tree species growing on the study site. Trees were examined separately. Condition of trees was estimated through a 5 point grading scale: I- normal to excellent, II – good, III – poor, IV- extremely poor, V- dead. Prior to assessment we selected a series of visible symptoms of a pressure on a specimen: injuries of assimilation apparatus, dried branches, canopy and trunk deformation and so on. Also, based on visible morphological features we did a dendrometric estimation of trees and determined the age and diameter of trunks[3-4] Leaf dust contents were measured by weighing.

Based on the level and character of environmental pollution, condition and ecological tolerance of plants were studied and leaf sampling done. Leaf samples were collected and treated through the accepted methods[25] in the mid of vegetation period – July through August (in 2008- 2013). Leaves were gathered from 1.5 to 2 m high above the ground from minimum three–maximum five trees per sampling site, then placed in paper bags, and transported to the Central Analytical Laboratory CENS accredited by ISO IEC 17025.

Analytical methods

The collected samples were treated (washed, chopped into small pieces and air dried) at the Laboratory and then analyzed for heavy metal contents (Cu, Pb, Mn, Mo, Ni, Zn) through the atomic absorption method (AAnalyst 800, Perkin Elmer, US) (ISO-8288)[5]. A qualitative assessment of heavy metals in plants was done through a comparative analysis between actual and background concentrations[26].

The generated data were processed through a software and then collated with the accepted norm, tables and diagrams produced, data credibility verified by Quality Control Charts. Additionally, to verify comprehensiveness and credibility of information about quantitative and qualitative composition of Yerevan green spaces collation was done between remote sensing and field data.

3. Results and discussion

3.1. Assessing condition of plants

Phenological observations of every tree species growing in the Square allowed to reveal trees with dying branches and leaves, trunk and leaf injuries (chlorosis, necrosis, decoloration, reduction in size, deformation, etc.). There are a total of 273 trees in the Square. The assortment includes 9 tree species dominated by *Acer negundo L.* (37,7% from total quantity), *Ailanthus altissima (Mill.) Swingle* (15%) and *Robinia pseudoacacia L*. (13,6 %), and 2 shrub species: *Hibiscus syriacus L.* and *Cornus sanguinea L.* (Fig.2).

Figure 2. Assortment of trees in the Abovyan Square (% from total quantity of trees)

The overwhelming majority of trees such as *Morus alba L.* and *Styphnolobium japonicum (L.) Schott* are old, aged above 40 years; young specimens (under 10 years of age) are found, too, and include *Ailanthus altissima (Mill.) Swingle, Ulmus pumila L., Robinia pseudoacacia L.* and *Acer negundo L.* (Tab.1).

Table1. Distribution of different tree species by age (% from total quantity of the same species)

№	Species	Age of species				
		<10	**10-20**	**20-30**	**30-40**	**>40**
1	*Ailanthus altissima (Mill.) Swingle)*	53,7	31,7	7,3	7,3	0,0
2	*Fraxinus excelsior L.*	22,6	9,7	12,9	22,6	32,3
3	*Tilia cordata Mill.*	33,3	0	33,3	0	33,3
4	*Ulmus pumila L.*	50,0	41,7	0	0	8,3
5	*Acer negundo L.*	47,6	24,3	8,7	7,8	11,7
6	*Robinia pseudoacacia L.*	53,8	17,9	5,1	5,1	17,9
7	*Styphnolobium japonicum (L.) Schott*	0	7,1	21,4	28,6	42,9
8	*Ulmus laevis Pall.*	45,5	18,2	0	9,1	27,3
9	*Morus alba L.*	7,1	7,1	0	7,1	78,6

Of all the studied species in the best condition were elm-tree specimens (45,2% from total quantity of this species belong to the 1st group), two elm-tree species (*Ulmus laevis Pall*. and *Ulmus pumila L.*) (63,6-66,7%) were in good condition. The worst condition was detected in *Robinia pseudoacacia L.* species: 50% of specimens were attributed to the 3rd group, 13, 5% fell on dying specimens growing along the streets (Tab. 2).

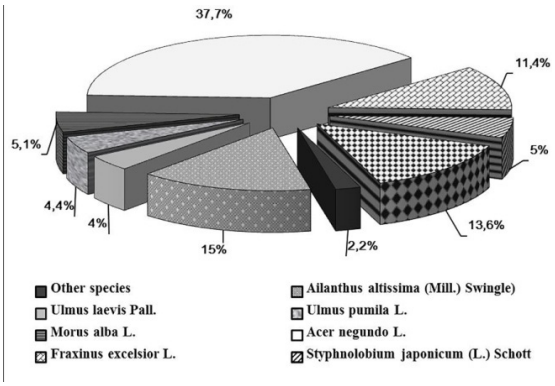
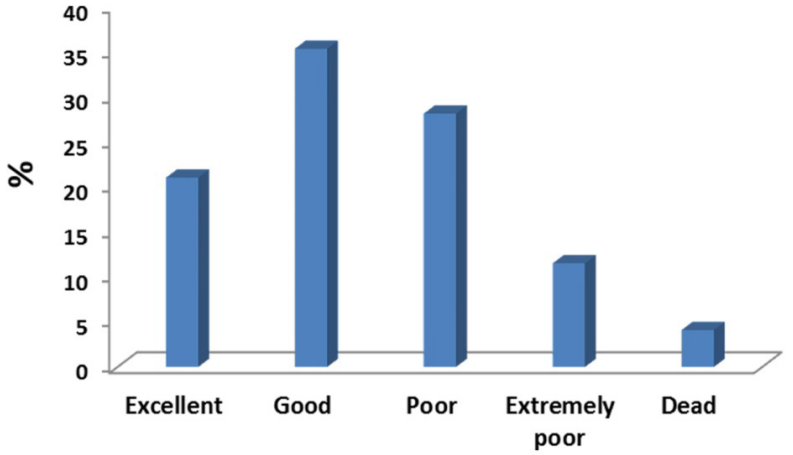


Table 2. Distribution of basic tree species by assessment scale groups (% from total quantity of the same species).



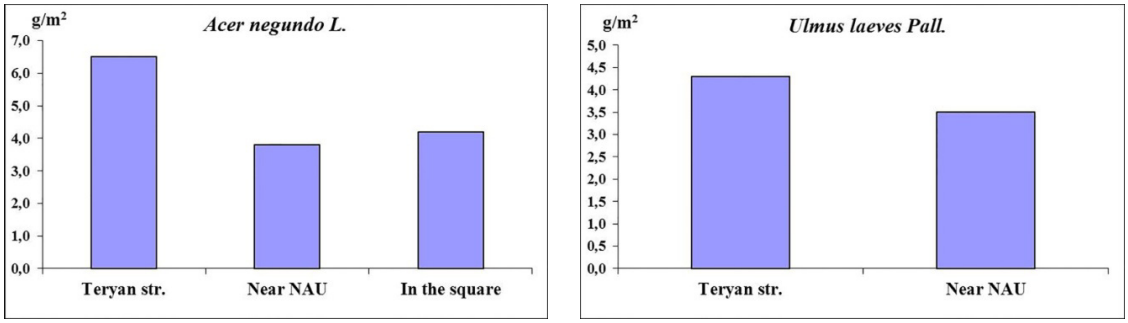
Species	Assessment category				
	Excellent	**Good**	**Poor**	**Extremely poor**	**Dead**
Ailanthus altissima (Mill.) Swingle	29,3	51,2	14,6	4,9	-
Ulmus laevis Pall.	-	63,6	18,2	18,2	-
Ulmus pumila L.	-	66,7	33,3	-	-
Morus alba L.	21,4	28,6	42,9	7,1	-
Acer negundo L.	26,2	36,9	21,4	13,6	1,9
Fraxinus excelsior L.	45,2	6,5	25,8	22,6	-
Styphnolobium japonicum (L.) Schott	7,1	42,9	50,0	-	-
Robinia pseudoacacia L.	2,7	21,6	48,6	13,5	13,5

Overall assessment of all the tree species in the green zone allows to judge about general condition of the Square. If total quantity of plants in poor condition (the 3rd group) does not exceed 15%, then condition of plantations is assessed as excellent, up to 30% - good, 31-50% - poor, over 50% - extremely poor[4].

Wholly, we assessed condition of the Square plants as poor because total quantity of severely weakened and dying specimens constituted 39, 6 % from total quantity of plants (Fig.3).

So, assessment of condition of the Square plants has indicated that best tolerant to conditions of the Square are *Ulmus pumila L.* и *Ulmus laevis Pall.* and that condition of plants is poor.

Figure 3. Distribution of basic tree species by categories (% from total quantity of trees)



3.2. Dust study

This research included a study of dust accumulation properties of different tree species.

The highest dust accumulation potential was detected in *Ulmus laevis Pall.* и *Acer negundo L.*: 4,3 and 6,5 g/sq.m, respectively (Fig.4).

Figure 4. Leaf dust contents in different tree species, g/sq.m

Besides, we studied leaf dust contents in these species found in different parts of the Square. As established, leaf dust contents depend on remoteness from streets: the more the distance, the lower the contents. This is nicely illustrated by *Acer negundo L.*: 6.5g/sq.m close to the street and almost twice as low in the center of the Square. (Fig.5).

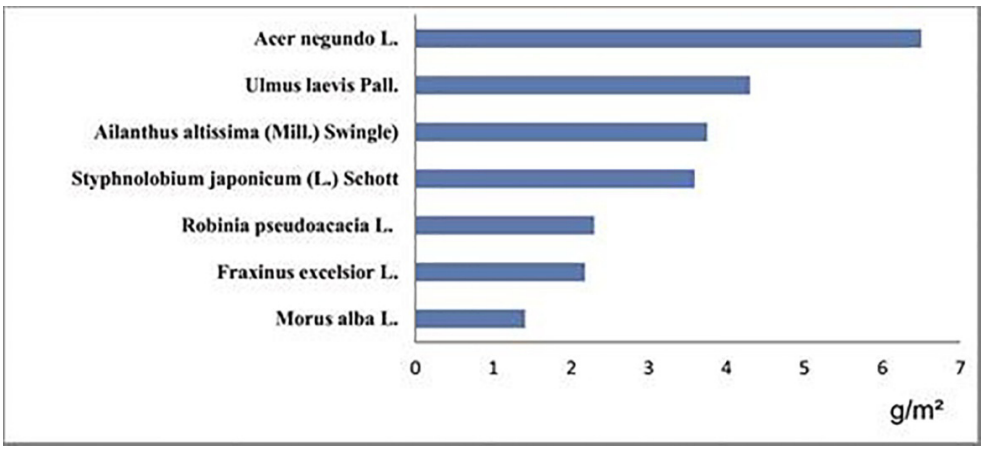


Figure 5. Leaf dust contents in tree species growing in different parts of the Abovyan Square g/sq.m

So, the highest dust accumulation potential was detected in *Ulmus laevis Pall.* and *Acer negundo L.* As found out, leaf dust contents depend on remoteness from motorways: the more the distance, the lower the contents.

3.3. Geochemical assessment of the site

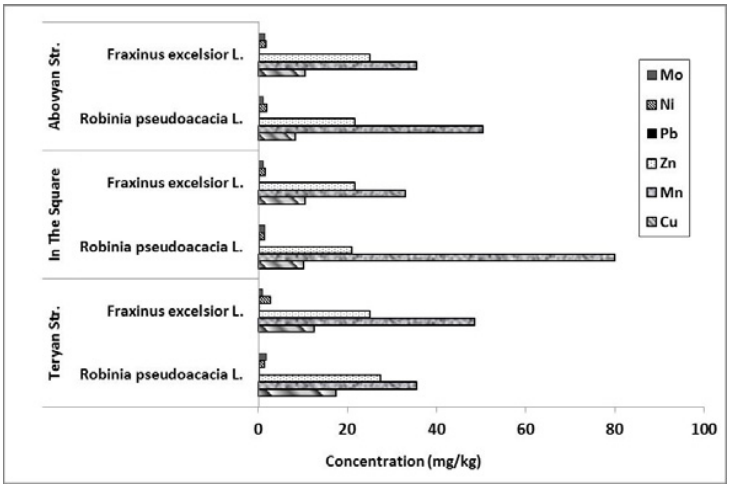
Prior to our research, geochemical assessment of the Square section was done.

Total contents of gaseous pollutants (CO- Carbon monoxide, CxHx, NOx) in near-earth layer of atmosphere of the study site were high (0,45tons/yr.)[1].

In the soils of the study site we detected high concentrations of heavy metals. For instance, Pb and Cu contents were excessive by 5 and 4,5 times respectively as compared with background concentrations. By Summary concentration indices of heavy metals the Square soils belong to the group of high level of metal pollution[29].

We studied concentrations of heavy metals in the leaves of the Square trees. The studied species were *Robinia pseudoacacia L.* and *Fraxinus excelsior L.,* because they grew in different parts of the Square. In the leaves of the Square trees we detected high contents of Pb, Ni and Mo which exceeded background concentrations. Cu, Zn and Mn contents varied within background values. High concentrations of Mo and Ni were detected in plants growing both in the center of the Square and close to streets, whereas Pb contents were high in leaves of trees growing along the streets, which was quite expectable in the leaves of *Fraxinus excelsior L.* and *Robinia pseudoacacia L.* growing close to Teryan Street we detected high concentrations of Pb and Ni, and Mo, Cu and Zn, respectively (Fig.6).

Figure 6. Mean concentrations of heavy metals in leaves of trees growing in the Abovyan Square, mg/kg.



Subsequent collation between field monitoring data obtained for the Abovyan Square and satellite IR image data verified the obtained results and enabled us to make a conclusion about a possibility of a complex use of different methods for assessment of pollution levels in plants[2].

Thus, geochemical assessment of the study site has indicated that soils and plants are high in heavy metals.

So, employing the complex approach to study the study site – the Abovyan Square of Yerevan – we obtained data on

- condition of plants,
- ecological status,
- priority pollutants,
- dust- and metal accumulation potential of plant species.

Using these data one may prepare recommendation for improvement of condition of the green zone of the site.

3.4. Developing a complex urban greening program

Studying the study site helped us develop a complex, scientifically sound program of functional greening of Armenia's cities which consists of the following stages:

- Functional zonation of the site,
- Geochemical assessment of the site, identification of priority pollutants,
- The obtained data mapping
- Assessment of condition of urban plants,
- Setting up the assortment of ecological tolerant plant species with good phytofiltration properties,
- Monitoring of urban green spaces.

The program was tested on the example of Yerevan in 2008 by the order of Yerevan Mayor's Office. We implemented functional zonation of Yerevan area and some districts, provided geochemical assessment of the sites, identified basic pollutants of soils, plants and atmosphere.

Finally, using ArcGIS geographic information software, maps were produced, by 3 per district: functional zonation of the site, heavy metal pollution of soils, and atmosphere pollution with gaseous toxicants.

Synchronously, we studied metal accumulation properties and dust resistance of plants, provided assessment of park, square and street species, identified ecologically tolerant tree and shrub species, set up the assortment of plants for each of districts taking into account the character and levels of pollution, natural and climatic conditions and functional predestination[32].

Subsequently, in 2009-2013 consistent with the developed program we implemented monitoring of green zones of Yerevan which included a study of condition of plants and tolerance of park and street species in different parts of the city[14-15, 19-23].

4. Conclusion

To conclude, the ecologically tolerant tree species having good phytofiltration properties selected in the result of this research have already been included by Yerevan Municipality in the list of plants used for greening most polluted districts of the city.

The complex program developed by us has already been suggested for assessing condition of green plantations and preparing the assortment of plants to be used in urban greening in Armenia taking into consideration natural and climatic conditions, character and level of manmade pollution.

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