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Analysis of trees planted in vicinity of hospitals in Ljubljana as a source of pollen

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Abstract

The paper analyses woody plants growing in the vicinity of hospital buildings situated along Zalog Road, Korytko Street, Šlajmar Street, Bohorič Street and Njegoš Street in Ljubljana, Slovenia. Woody plants are an immediate potential source of allergenic pollen, affecting all park users such as patients, visitors and hospital employees. The most allergenic tree species in the park was found to be birch (*Betula pendula* Roth.), which accounts for 6.8% of all registered trees. The low allergenic maples (*Acer* sp.) and the low allergenic horse chestnut (*Aesculus hippocastanum* L.) account for 19.6% and 7.4%, respectively. Among the medium allergenic trees are ash (*Fraxinus excelsior* L.) (4.8%), plane (*Platanus x hispanica* Muenchh.) (4.2%), hornbeam (*Carpinus betulus* L.) (1.9%), and oak (*Quercus* sp.) and hazel (*Corylus avellana* L.) with less than 1%.

Key words: hospital green areas, pollen, urban trees, allergenic trees, Ljubljana

Analiza drevja kot vira cvetnega prahu ob kliničnih bolnišnicah v Ljubljani

Izvleček

V prispevku so predstavljene lesnate rastline, ki rastejo v bližini bolnišničnih zgradb na Zaloški cesti ter na Korytkovi, Šlajmerjevi, Bohoričevi in Njegoševi ulici v Ljubljani. Lesnate rastline v parku so bližnji vir alergogenega cvetnega prahu, ki so mu izpostavljeni vsi uporabniki parka, bolniki, obiskovalci in zaposleno osebje. V parku je najbolj alergogena vrsta breza, ki predstavlja 6,8 % vseh dreves, 19,6 % je nizko alergogenih javorjev in 7,4 % nizko alergogenega divjega kostanja. Srednje visoko alergogeni so še jesen (4,8 %), platana (4,2 %), gaber (1,9 %) ter hrast in leska z manj kot 1-odstotno udeležbo.

Ključne besede: *bolnišnične zelene površine, cvetni prah, urbana drevesa, alergogena drevesa, Ljubljana*

1 Introduction

1 Uvod

Several roles of urban forests and trees have been recognised recently (KONIJNENDIJK et al. 2005). It is well known that urban trees reduce air pollution (MILLER 1997). On the other hand, it is sometimes not taken into account that urban trees and other vegetation in urban open space are also a source of pollen. Pollen as a cause of allergies can seriously affect urban inhabitants (ALCAZAR et al. 1998, BRICCHI et al. 2000, GREGORY 2000, KONIJNENDIJK 2008, NEGRINI 1992). Pollen of allergenic plants is of significance if it occurs on a large scale in the atmosphere. It is important how it is dispersed, which, in turn, depends on the size and morphology of pollen grains. These facts reduce the number of plants capable of inducing an allergy to but a few families, whose individual genera have a different level of allergenicity. For less than a hundred plant species, allergenicity of pollen has been described and well documented (D'AMATTO et al. 1991, 1998). Pollen released in the air produces bioaerosol, which spreads in the environment according to physical laws of the atmosphere. Its occurrence in the air is seasonal; pollen of the same plant species occurs at approximately the same time every year. The beginning, duration and level of intensity of pollen occurrence depend on plant species, weather conditions prior to and during the flowering season and on the biorhythm of plants.

Trees are also an immediate source of pollen inside buildings that are aired (BURGE 1994), especially if trees are planted close to the buildings (YANKOVA 1991) and to ventilation devices. Horizontal and vertical movement of the air makes it possible for pollen to remain in the air for a longer period of time and to spread across a wider area. Due to the laws of gravitation, pollen descends in the still air (GREGORY 2000). Variations of concentration at different heights above the ground measured on buildings are reflection of local conditions in the atmosphere and depend on other parameters such as wind direction, eddies, building orientation, hight of the pollen source (ALCAZAR et al. 1998, LEUSCHNER 1999; MANDRIOLI et al. 2000,

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ALCAZAR / COMTOIS et al. 2000, HUGG / RANTIO-LEHTIMÄKI 2007).

Besides meadowy and ruderal sites, which are to a great extent colonized by neophytes containing also high allergenic species, trees are a major source of allergenic pollen in a town. They are present in urban forests, parks, gardens, along avenues and roads, in car parks, and along waterways. Hospital green areas are especially sensitive places, where plant allergenicity should be taken into account carefully as they perform another task as well. They have an agreeable effect on the wellbeing of patients, promoting their medical treatment.

The aim of the study was to examine local sources of allergenic pollen in parks and avenues that occur in the direct vicinity of the hospital complex in Ljubljana and to theoretically assess its possible effect on patients, visitors and employees on account of their additional local exposure. Beside a list of species of woody plants, the study presents spatial distribution of birch (*Betula pendula* Roth.) trees as one of the most allergenic tree species in northern hemisphere and thus in Slovenia as well.

2 Materials and methods

2 Material in metode

2.1 Study area

2.1 Raziskovalno območje

In the Ljubljana hospital complex situated along Zalog Road, Korytko Street, Šlajmar Street, Bohorič Street and Njegoš Street, plants and shrubs planted in parks and along streets were examined and recorded. Zalog Road divides the hospital complex into two parts. In the southern part with the prevailing pavilion design, green areas spread between the buildings, flanked by the river Ljubljanica in the south. On account of the reconstruction of old buildings and the construction of the Institute of Oncology and Neurology Unit, the green area has been reduced over the last years. The hospital complex continues on the other side of Zalog Road, where multi-storey buildings prevail. Next to the University Medical Centre, which was built in 1970, the building of the Medical Faculty was constructed on Korytko Street in 1984, the Maternity Hospital on Šlajmar Street in 1997, and a multi-storey car park in 1996. Besides, a new Department of Paediatrics was constructed in 2009 and a new building of the Emergency Centre was just commenced to be built. The construction of all these buildings has reduced the physical space available for green areas, which are now trapped between streets, pavements and delivery roads. More often than not, they are confined to the space available between asphalt belts and concrete. There is no natural biotope in the complex.

2.2 Tree inventory

2.2 Popis dreves

All the trees growing in green areas within the hospital complex were inventoried in the field. The area in which the inventory was taken constitutes a polygon stretching from Rozman Street, Croatian Square, Njegoš Street, Bohorič Street and Japljeva Street to the Vodmat Kindergarten, to Zalog Road and to the Mortuary Bridge across the River Ljubljanica. The study site measures 28.88 ha.

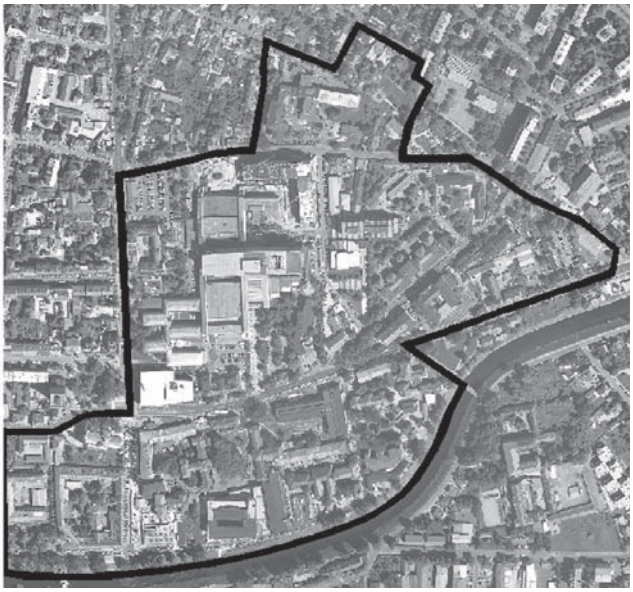

Figure 1: Study area

Slika 1: Študijsko območje

The study site linked the green belt between the buildings and the belt close to the buildings. Most of the trees recorded were determined according to species and some of them just according to genus, which suffices for an assessment of local sources of allergenic pollen. To assess the level of allergenicity, *http://www.pollenwarndienst.at/* was used as a source. Allergenicity was determined according to three main stages: low, medium, and high, and two transitional stages: low to medium and medium to high (Table 1).

The data were processed with the Excel programme. For on-screen digitizing and geocoding of trees recorded in the field and for measuring distances, the CartaLinx 1.2 programme was used, while a digital aerial photo of the study site was applied as a basis. Photos printed from the internet source Google Earth, which are slightly more recent, were also used in the field, apart from the printed digital aerial photo. For spatial distribution of birch trees, each tree was marked with a circle and geocoded with the Cartalinx 1.2 programme.

Table 1: Allergenicity of tree genera (Source: http://www.pollenwarndienst.at/)

Preglednica 1: Alergenost drevesnih rodov (Vir: http://www.pollenwarndienst.at/)

No.	Latin name	Genus	Allergenicity
1	*Acer*	Maple	low to medium
2	*Aesculus*	Horse chestnut	low to medium
3	*Ailanthus*	Tree of heaven	little known, probably low
4	*Betula*	Birch	high
5	*Carpinus*	Hornbeam	low to medium
6	*Chamaecyparis*	Lawson cypress	medium to high
7	*Corylus*	Hazel	medium to high
8	*Cupressus*	Cypress	medium to high
9	*Fagus*	Beech	low to medium
10	*Fraxinus*	Ash	medium to high
11	*Juglans regia*	Walnut	medium
12	*Juniperus*	Juniper	medium to high
13	*Platanus*	Plane	medium to high
14	*Populus*	Poplar	no data
15	*Quercus*	Oak	medium
16	*Salix*	Willow	low
17	*Thuja*	Thuja	medium to high
18	*Tilia*	Linden	no or low

3 Results

3 Rezultati

In the study site, 591 trees and 99 shrubs were recorded, a total of 690 specimens. From all the recorded genera, birch (*Betula pendula* Roth.), which accounts for 6.8%, is placed into the highest category of allergenicity. Slightly less allergenic genus is ash (*Fraxinus excelsior* L.), which accounts for 4.8%. It is followed by plane (*Platanus x hispanica* Muenchh.) with 4.2%, and hazel (*Corylus avellana* L.) with 0.6%. There were 73 medium to high allergenic trees recorded, totalling 10.6% of all trees.

The other tree species are placed into the low to medium category or they do not induce allergy at all. Due to a possible crosswise reaction between related plants, it is of interest to note as to what proportion tree species such as hornbeam (*Carpinus betulus* L.), oak (*Quercus* sp.) and beech (*Fagus sylvatica* L.) occur in the area: hornbeam accounts for 1.9% and beech 0.6%, while oak

Table 2 : Percentage composition of trees and shrubs genera in green areas within the hospital complex

Preglednica 2: Rodovi drevnine v odstotkih, zastopani na zelenih površinah v sklopu bolnišnic

Genus / Rod	%
Acer	19.6
Aesculus	7.4
Ailanthus	1.2
Betula	6.8
Carpinus	1.9
Corylus	0.6
Fagus	0.6
Fraxinus	4.8
Juglans	0.6
Pinus, Picea	12.8
Platanus	4.2
Populus	2.4
Rosaceae	2.3
Rhus	3.2
Tilia	4.2
Other	27.4

Table 3: The number and percentage of individual tree species in the study area

Preglednica 3: Število in odstotek drevesnih vrst v študijskem območju

Species / *Vrsta*	Total / Skupaj	%
Acer platanoides L.	102	14,8
Acer negundo L.	5	0,7
Acer saccharinum L.	19	2,8
Acer palmatum Thunb. Ex Murr.	4	0,6
Acer pseudoplatanus L.	4	0,6
Acer sp.	1	0,1
Aesculus hippocastanum L.	51	7,4
Ailanthus altissima (Mill.) Swingle	8	1,2
Berberis sp.	1	0,1
Betula pendula Roth.	47	6,8
Buxus sempervirens L.	3	0,4
Carpinus betulus L.	13	1,9
Catalpa bignonioides Walt.	3	0,4
Cercidiphyllum japonicum Sieb et Zucc.	2	0,3
Cornus sp	7	1,0
Corylus avellana L. + var. *contorta*	4	0,6
Fagus sylvatica L.	2	0,3
Fagus sylvatica L. var. purpurea	2	0,3
*Forsythia * intermedia* Zab.	4	0,6
Fraxinus excelsior L.	33	4,8
Gleditsia triacanthos L.	11	1,6
Glicinia sp.	1	0,1
Juglans regia L.	4	0,6
Juniperus sp.	1	0,1
Larix decidua Mill.	4	0,6
Ligustrum vulgaris L.	1	0,1
Liquidambar styraciflua L.	1	0,1
Liriodendron tulipifera L.	9	1,3
Magnolia sp.	2	0,3
Picea omorika (Pančić) Purkyne	23	3,3
Picea abies (L.) Karsten	37	5,4
Picea pungens Engelm	2	0,3
Pinus nigra Arnold	8	1,2
Pinus wallichiana A. B. Jacks	11	1,6
Pinus sylvestris L.	7	1,0
*Platanus * hispanica* Münchh.	27	3,9
Platanus orientalis L.	2	0,3
Populus nigra L.	16	2,3
Populus tremula L.	1	0,1
Prunus avium L.	9	1,3
Prunus laurocerasus L.	15	2,2
Prunus cerasifera Erhr.	24	3,5
Prunus sp.	3	0,4
Pterocarya fraxinifolia Spach.	13	1,9
Pyracantha coccinea M. J. Roem.	4	0,6
Pyrus communis L.	3	0,4
Quercus sp.	1	0,1
Rhus typhina L.	22	3,2
Robinia pseudacacia L.	1	0,1
Rosaceae sp.	16	2,3
Salix sp.	2	0,3
Sambucus nigra L.	5	0,7
Sophora japonica L.	6	0,9
Spiroea sp.	20	2,9
Taxus baccata L.	14	2,0
Thuja sp.	6	0,9
Tilia platyphyllos Scop.	20	2,9
Tilia cordata Mill.	8	1,2
Tilia tomentosa Moench.	1	0,1
Tsuga canadensis (L.) Carr.	6	0,9
Ulmus carpinifolia Gled.	2	0,3
Viburnum rhytidophyllum Hemsl.	6	0,9
Total	690	

is represented with only one very young tree. Poplar (*Populus tremula* L.) with a low level of allergenicity accounts for 2.4% and willow (*Salix* sp.) for less than 1%. Horse chesnut (*Aesculus hippocastanum* L.), which is present to a larger extent (7.4%), has a low level of allergenicity.

Maples (*Acer* sp.) with a low level of allergenicity account for as much as 19.6%. Most maple species are pollinated by insects, except for Acer negundo, which is a wind-pollinated species. Pollen of spruce (*Picea abies* (L.) Karsten) and pine (*Pinus* sp.), which account for 12.8%, does not induce allergy. The same applies to sumach (*Rhus* sp.) and lime (*Tilia* sp.), which account for 3.2% and 4.2% respectively.

Pollen of plane trees (*Platanus x hispanica* Muenchh.) often induces allergy in south Europe, seldom in Slovenia. Since it is not indigenous to Slovenia, it is a source of pollen only in parks and alleys without original natural vegetation.

Mention should also be made of the Tree of heaven (*Ailanthus altissima* (Mill.) Swingle), which also propagates within the hospital complex, but causes no allergy.

In the next step we have carefully examined the spatial distribution of the birch. We estimated that 43 birch trees out of 47 grow less than 25 meters from the nearest hospital building, 21 of these even less than 15 meters from the nearest building.

Figure 2: Spatial distribution of birch (*Betula pendula* Roth.) (black) in the vicinity of hospital buildings (grey)

Slika 2: Prostorska razporeditev brez (Betula pendula Roth.) (črno) v bližini bolnišničnih stavb (sivo)

Table 4: Distance from each birch to the nearest hospital building (in meters)

Preglednica 4: Razdalje od posameznih brez do najbližje bolnišnične stavbe (v metrih)

Distance / *Razdalje*	No. of birch trees / *Število brez*
0 - 5.0	4
5.1 – 10	17
10.1 – 15	0
15.1 – 20	4
20.1 – 25	18
25.1 – 30	0
30.1 – 35	1
35.1 – 40	0
40.1 – 45	1
45.1 – 50	0
> 50	2
Total	47

4 Discussion

4 Razprava

Hospital gardens and parks have an agreeable effect on the wellbeing of patients, promoting their medical treatment. This sphere of research commenced in the early 1990s and the results substantiate a favourable influence. In a study by Barnes and Cooper Marcus (1999), the most positive qualities of nature are considered those perceived by sight such as the view of trees, green areas, flowers and water, which have a positive psychological impact. Similar benefit of natural environment has been recognised in recent research developed through Cost E39 action »Forest, Trees and Human Health and Well-being (GALLIS 2005). However, some plants may have an adverse effect on the well-being of patients or, in some cases, they may even bring about deterioration of health.

In case of Ljubljana, the size of parks and the number of trees in the vicinity of the Ljubljana hospital complex is decreasing on account of the construction of new buildings. As presented in Figure 1, green areas are trapped between hospital buildings with no options for a possible expansion. Therefore progressive replacement of single trees or group of trees is going to happen in a future, but it should be based not only on their possible low vitality but also on their allergological viewpoint. The results of the present study show that the number of high allergenic trees is not very high in hospital parks. The most allergenic tree species in the park was found to be birch, which accounts for less than ten percent of all the trees. The low allergenic maple and the low allergenic horse chestnut together account for one quarter of trees. Among the medium allergenic trees are ash, plane, hornbeam and oak together with around ten percent and hazel with less than 1%.

A study carried out during the COST E12 action (PAULEIT, 1998) has shown that in Ljubljana most common street and park trees are the Norway maple and other maple species, horse chestnut, London plane, lime, poplars and birch; others to be mentioned are: *Carpinus betulus, Acer platanoides, Catalpa bignonioides, Liquidambar styraciflua, Liriodendron tulipifera, Pterocaria fraxinifolia, Robinia pseudoacacia* and some others. Hospital parks and gardens are not significantly different to other green areas and parks of Ljubljana from the tree composition point of view in terms of tree structure and also in terms of tree replacement. Modern list of suggested city trees used also for consideration of tree replacement in Ljubljana (*www.baumpflege-schweiz.ch/pdf/strassenbaumliste_GALK.pdf*) is not addressing allergological issues. Therefore we believe that allergological point of view has not been studied in the past when urban tree species were chosen.

Beside allergological – tree species point of view, the distance from hospital buildings is important. Bacles and Ennos (2008) have stressed the importance of tree species, wind and landscape structure for analysis of pollen

flow distance. According to their estimation for *Fraxinus excelsior* in an open landscape the pollen dispersal curve is showing significant decrease after 100m distance from the source, though pollen has flown more than one kilometer away. In an urban environment it is nearly impossible to measure wind dispersal in the same way due to several buildings affecting the wind as obstacles. However, it is obvious that pollen flow from outside into the hospital buildings is not affected by trees and shrubs in the study area alone, trees just outside the study area and the background pollen load of the territory should not be neglected. Due to the urban conditions mentioned we may conclude that important source of pollen is produced within the parks.

In case of Ljubljana hospital area, birch trees were planted close to buildings, just two trees are growing at a distance greater than 50 meters to the nearest building, while all others are growing much closer! Therefore it is likely for pollen to be carried directly into the buildings and we may conclude that birch trees may quite likely have an important effect on pollen concentration inside hospitals.

Based on our results, we suggest the following recommendations. On account of their high level of allergenicity, birch trees should not be planted in groups in the vicinity of hospital buildings (i.e. along Zalog Road, Korytko Street, Šlajmar Street, Bohorič Street and Njegoš Street). When planning trees for a hospital garden, the most important factor to consider is the choice of trees. Their pollen should not be allergenic or should have just a low level of allergenicity. Such trees should be chosen that do not release a great amount of pollen into the air. They should have insect-pollinated flowers rather than wind-pollinated. If a new species or a cultivar is introduced, it should be taken into account that a new plant may prolong the season of pollen occurrence of the genus to which they belong. Such are trees of the family Rosaceae, maples except for *A. negundo*, spruces, firs, and pines and trees of the family Fabaceae, linden trees and, to a smaller extent, elms. Hornbeams are recommended for hedges.

5 Summary

5 Povzetek

V prispevku smo predstavili trenutno zasaditev lesnatih rastlin v bližini bolnišničnih zgradb na Zaloški cesti ter na Korytkovi, Šlajmerjevi, Bohoričevi in Njegoševi ulici v Ljubljani. Na obravnavanem območju je bilo zabeleženih 690 dreves in grmov.

Za oceno alergogenosti smo uporabili avstrijsko lestvico (http://www.polleninfo.org/index/). Cvetni prah lesnatih rastlin v parku je bližnji vir alergogenega cvetnega prahu, ki so mu izpostavljeni vsi uporabniki parka, bolniki, obiskovalci in zaposleno osebje. Je tudi dodaten, bližnji vir za cvetni prah, ki se z zračenjem bolnišničnih prostorov prenese v notranji zrak.

Po alergogenosti v najvišjo kategorijo uvrščamo med zabeleženimi rodovi brezo, nekoliko manj so alergogeni jesen, platana in leska, medtem ko so druge drevesne vrste nizko do srednje visoko alergogene ali pa sploh ne povzročajo alergije. Zaradi mogočih navzkrižnih reakcij med sorodnimi rastlinami z brezo, je zanimiv podatek, koliko je na tem področju gabra, hrasta in bukve: gaber je zastopan z 1,9 %, bukev 0,6 %, hrast pa s samo enim zelo mladim drevesom. Visoko alergogenost ima tudi jesen iz družine oljkovk. Nizko alergogeni so topoli in vrbe pa tudi divji kostanj; slednjega je nekaj več tudi v bolnišničnem parku.

Skoraj 20 % vseh dreves so javorji, njihova alergogenost je nizka. Večino izmed njih oprašujejo žuželke, razen vrste *Acer negundo*, ki je vetrocvetna. Smreke in bora je skupaj 12,8 %, njun cvetni prah ne povzroča alergij. Prav tako nista alergogena octovec s 3,2-odstotnim deležem in lipa s 4,2-odstotnim deležem.

Breza je z alergološkega stališča najmanj zaželeno drevo in zajema 6.8 % vseh dreves v raziskavi. Ker navadno rastejo tik ob stavbah, je tudi večja verjetnost, da se cvetni prah neposredno prenese v zgradbe. Zaradi visoke alergogenosti to drevo ni primerno za sajenje v skupinah blizu bolnišničnih zgradb. Ugotovili smo, da kar 43 brez od vseh 47 raste bliže kot 25 m od posamezne bolnišnične stavbe, 21 od tega celo le do 15 m od najbližje stavbe.

Pri izbiri dreves za sajenje v bolnišničnih vrtovih se je treba držati načela, da izberemo drevesa, katerih pelod ni alergogen ali je nizko alergogen. Izberemo tiste vrste, ki v zrak ne sproščajo velike količine cvetnega prahu, po možnosti žužkocvetne vrste, ne vetrocvetnih. Če uvajamo nove vrste oziroma kultivarje, lahko z novimi rastlinami podaljšamo sezono pojavljanja cvetnega prahu rastlinskega rodu, kateremu pripadajo. Tem pogojem ustrezajo drevesa iz družine rožnic, javorji (razen *A. negundo*), smreke, jelke, bori, drevesa iz družine metuljnic, lipe, v manjši meri bresti. Za žive meje so priporočeni tudi gabri.

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