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The influence of Warsaw urban environment on the chemical substances in bark and wood of trunk and branches of lime (*Tilia cordata* Mill.)

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Abstract: *The influence of Warsaw urban environment on the chemical substances in bark and wood of trunk and branches of lime (Tilia cordata Mill.).* The chemical composition analysis of wood and bark of trunk and main branches of lime (*Tilia cordata* Mill.) was performed. The tree was grown in the Warsaw City centre. Samples were gained from the butt end and half-height stem sections, main branches and bark. Disks were cut from mentioned above stem sections. Samples were collected from three disks zones – outer wood, middle wood and heartwood. Analysis of extractives, cellulose, substances soluble in 1% NaOH and lignin content was performed.

Key words: lime wood, branch, bark, extractives, cellulose, substances soluble in 1% NaOH, lignin.

INTRODUCTION

All substances, which being present in the atmosphere might harmfully affect animals and plants, can be classified as pollutants. Solids (dusts, soots), liquids and gases can be distinguished among these substances (Dominik 1977).

Harmful impact of dusts depends on fall volume, break-up degree, chemical composition and water solubility. The effects of action increase with fall volume and break-up degree rise. The settlement of high dusts quantity on the soil surface might leads to the soil pH change. It causes difficulties for trees in nutrients (particularly phosphorus, potassium, nitrogen and micronutrient) receiving (Kopcewicz and Lewak 1998).

Soots are also the solid atmosphere pollutants. They might act on trees physically and chemically as well. Rademacher et al. (1986) stated that thick layer of soot on young spruces causes photosynthesis efficiency decrease, as well as annual ring in the next year. It also causes needles burn as a result of toxic substances acting.

According to Bratkowski (1975) soots and dusts settled on leafs plug respiration gaps and make the sunrays penetration to chloroplasts difficult. Insufficient functioning of respiration and assimilation systems leads to gas exchange and plants nutrition disturbance. It causes the decrease of plants vitality.

Sulphur and nitrogen oxides, ozone and hydrogen halogens are the most harmful pollutants for plants.

The action of particular substances high concentrations on plants is usually space-limited. For example, salt used to pavement defrosting, combustion gas and dusts from brake blocks are the substances which harmfully acts in the area of communication routes.

Susceptibility of plants (including trees) to pollutants attack and damages range caused by these pollutants depend on biotic and abiotic factors as well (Kopcewicz and Lewak 1998). Species affiliation, morphological qualities, age, activity phase (day or night), general plant condition, climatic conditions and also chemical nature, concentration, action time of the pollutant are these factors.

The industry and urban communication are the main sources of atmosphere and soil pollution in Warsaw. Cross-roads, where carbon oxide, nitrogen oxides and hydrocarbons concentrations exceed values acceptable by polish standards, are the most polluted places.

The aim of this paper is to specify the influence of urban environment on the chemical components concentration and spacing on the longitudinal and cross-section of lime (*Tilia cordata* Mill.).

MATERIALS

Samples were gained from the butt end and middle stem sections, main branches and bark of 50-year old lime (*Tilia cordata* Mill.), which were grown near Aleje Ujazdowskie St. in Warsaw. About 200 mm thick disks were cut from mentioned above stem sections. Samples were isolated from outer wood, middle wood and heartwood using drill. Zones were not specified on the cross-section of branches, because their diameters were only about 35 mm. Bark covering stem was scraped with a knife and ground in a mill. he undersize 1.2 mm and oversize 0.49-mm mesh fraction was taken in the study.

Analysis of following parameters was performed: density, content of extractives, cellulose, lignin and substances soluble in 1% NaOH. Substances content refers to absolutely dry wood.

The extractives content was determined using a Soxhlet apparatus with ethanol-benzene mixture (1:1) as a solvent. Content of cellulose was analysed using Kürschner – Hoffer method, substances soluble in 1% NaOH according to Krutul (2002), lignin according to polish standard PN-92/P-50092. Content of particular substances was determined with the accuracy of 0.01 – 0.02%.

RESULTS

Basing on density, lime wood can be classified to V class, as moderately light (density 410-500 kg/m^3). Density values of analysed samples are as follows: 490-522 kg/m^3 in the butt end section and 430-460 kg/m^3 in the half-height trunk section. It is generally accepted that wood density decreases from butt-end to the top section (Krzysik 1984). It is consistent with our results.

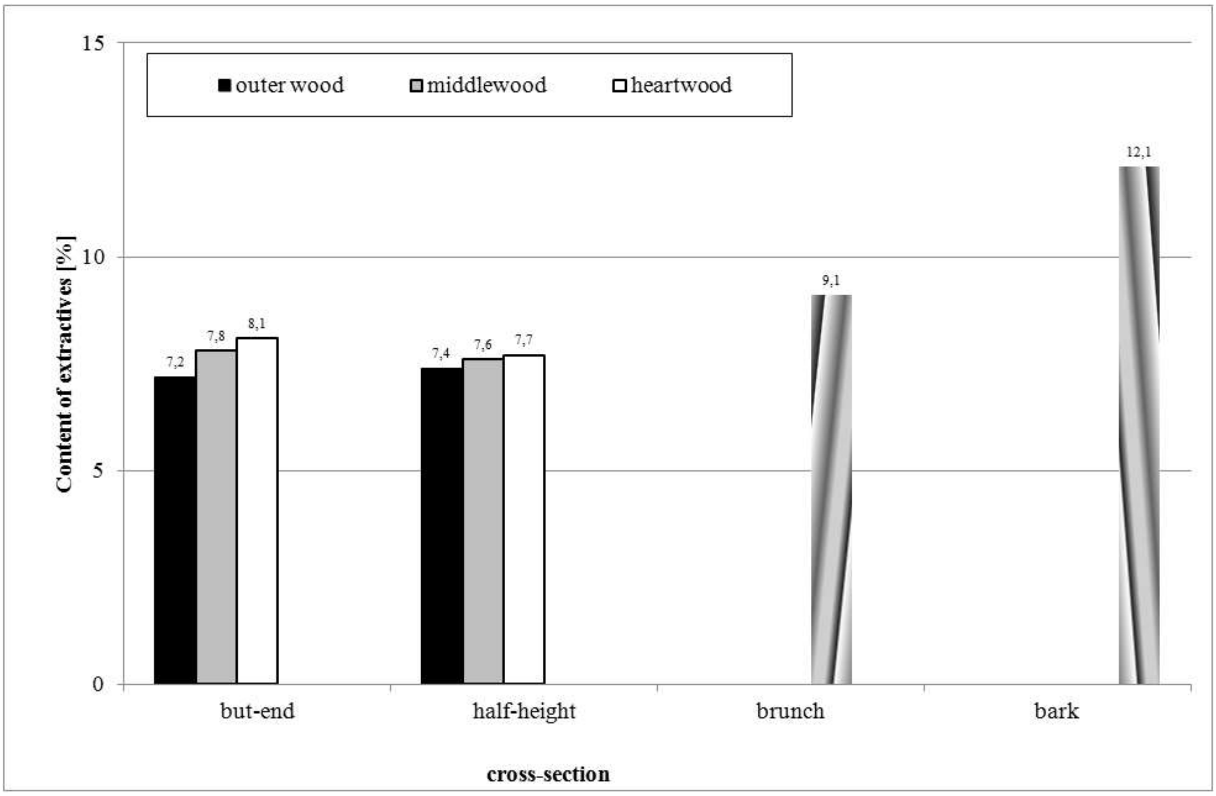

Figure 1. Content of extractives in bark and wood of lime

Extractives content in the lime wood decreases in the direction from the pith to the circumference, both in butt end and half-height section (Figure 1). Extractives content in heartwood is about 7% higher than in the middle wood and about 10% higher in relation to outer wood zone in butt-end section. It is cca. 4% higher in comparison to outer wood from half-height section. Research performed by Krutul et al. (2011) shows that extractives content in birch wood (*Betula pendula* Roth.) adjacent pith gained from trees which were grown 21 km from Kozienice heat and power plant is 10% higher in butt-end section, 45% higher in half-height, 35% higher in three quarters and 25% higher in the top part of the trunk in relation to outer wood zone.

Extractives content in heartwood adjacent pith of oak wood (*Quercus robur* L.) is higher in relation to sapwood along trunk apart from the habitat (Krutul et al. 2014).

Extractives content in branch is about 11% higher than in heartwood from butt-end trunk section and about 15% higher than in heartwood from half-height section. Differences in relation between heartwood and bark are much higher: extractives content in bark is 33 % higher than in heartwood from butt-end trunk section and 36 % higher than in heartwood from half-height section. Extractives content in bark changes on its cross-section. Ohara and Hemingway (1989) state that in the bark (*Quercus falcata* Michx. *var. falcata*) of oak the content of substances extracted using acethone-water mixture is equal to 10,7% in inner bark, 14.8% in middle bark and 5.5% in outer bark. According to Krutul and Sacharczuk (1997) the extractives content (ethanol : benzene 1:1) in the bark of oak (*Quercus robur* L.) range from 6.7% to 15.2%. Extractives content in examined lime bark is equal to 12.3 % (Figure 1).

It can be stated that environment pollution did not influence the extractives spacing in the cross-section and along stem length as well. There is no such an influence in bark and branches too. According to Krutul et al. (2014) the extractives content in bark is 13% higher in butt-end, 36% higher in the half-height part and 12% higher in the top of the trunk of oak (*Quercus robur* L.) from unpolluted area in relation to the trunk from polluted one. The extractives content in Scots pine bark (*Pinus sylvestris* L.) in the distance of 1 km and 21 km from heat and power plant "Kozienice" is lower in relation to bark obtained from unpolluted environment (Krutul et al. 2006).

Cellulose content in trunk, bark and branch is presented in the Figure 2. It increases in the direction from the pith to the perimeter both in the butt-end and half-height sections. Cellulose content in heartwood in the half-height section is about 3 % higher than in butt end section, whereas in other zones values are similar in both sections.

Similar relations were obtained for 90-year old oak wood gained from unpolluted environment (Krutul et al. 2006). Results are moreover consistent with those obtained by Krutul et al. (2011). It was stated that cellulose content in particular zones along the birch trunk does not change. In outer wood it is from 3 to 5% higher in comparison to pith adjacent wood. According to Krutul et al. (2017) the cellulose content in outer wood of trunk of single-seeded hawthorn (*Cratageus monogyna* Yacq.) is only 4% higher than in pith adjacent wood, regardless the cross-section height. Cellulose content in particular sections along the trunk does not change.

Cellulose content in branch is 3.5 % lower in relation to heartwood and 8.5 % lower in relation to outer wood in butt-end stem section. Differences between branches and half-height section are even more significant.

According to Krutul et al. (2017) cellulose content in outer wood of main branches of single-seeded hawthorn (*Cratageus monogyna* Yacq.) is 44.9% and 43.3% in pith adjacent wood zone.

Cellulose content in bark is about 29 % lower than in heartwood and about 35 % lower in relation to outer wood in butt-end section and correspondingly 32 % and 34 % lower in relation to wood zones in half-height section.

Krutul et al. (2007) claim that oak heartwood contains 1.5 time more cellulose and sapwood 2 times more in relation to bark. According to Fengel (1984) cellulose content in the bark of beech is equal to 23.8 %. According to Krutul et al. (2017) cellulose content in bark of the single-seeded hawthorn trunk is cca. 3 times lower in relation to outer and pith adjacent wood from 0.1 m height and 2.5 times lower in samples gained from the height of 2.4 and 5 m.

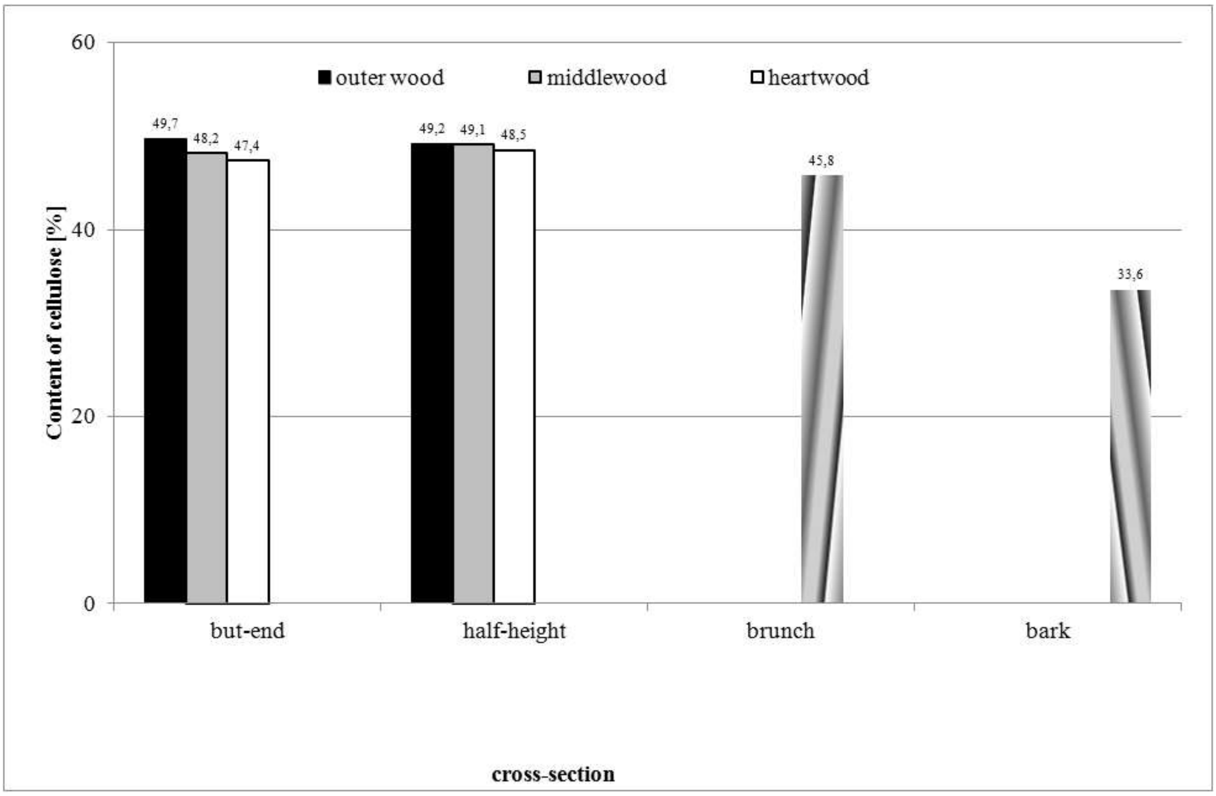

Figure 2. Content of cellulose in bark and wood of lime

Cellulose content in bark from birch trunk is about 50% lower in outer and middle wood from butt-end section and 40% lower in the top part of the tree (Krutul et al. 2011). On the basis on presented data it can be stated that urban environment pollution had no influence on spacing and content of cellulose in trunk, branch and bark of lime.

Data referring to the content of substances soluble in 1% NaOH in the trunk, branch and bark are presented in the Figure 3. It shows that these substances content in the trunk cross-section decreases in the direction from pith to perimeter, both in the butt-end section and half-height section. According to Harwood (1971), Uprichard (1971) and Krutul et al. (2006) the pentosanes content in the cross-section of scots pine wood decreases in the direction from the pith to the circumference. Presented data suggest that urban environment influenced the distribution of substances soluble in 1% NaOH in the cross-section.

According to Krutul et al. (2011) content of 1% NaOH soluble substances in 45-year old birch varies from 24.0 to 25.4 in outer wood, from 24.7 to 25.8 in the middle wood and from 25.0 to 26.1% in pith adjacent wood. Moreover, wood from the top part of the trunk contains more of these substances in relation to butt-end, half-height and three quarters height.

Changes in 1% NaOH soluble substances are irregular both on the cross- and longitudinal section of the 70-year old birch trunk (*Betula pendula* Roth.) As for butt-end section, these substances content in pith adjacent wood is 6% higher in comparison to outer and middle wood. In half-height and top section of the trunk the opposite relation was observed – outer wood contains 3-6% more of 1% NaOH soluble substances than pith adjacent wood (Krutul et al. 2017).

These substances content in branch is about 8% higher than in sapwood and middle wood and about 10% higher in relation to heartwood in the butt end stem section and correspondingly about 8% higher in relation to zones in the half-height section. Content of 1% NaOH soluble substances in bark of lime equals 15.4%. Presented data shows that 1% NaOH soluble substances content is 36% lower in relation to outer wood and cca. 35% lower than in heartwood. Content of these substances is cca. 30% lower in comparison to data given by Krutul et al. (2011) for birch (*Betula pendula* Roth.) bark.

According to Fengel (1984) the content of these substances in bark of oak (*Quercus robur* L.) is equal to 9.3%.

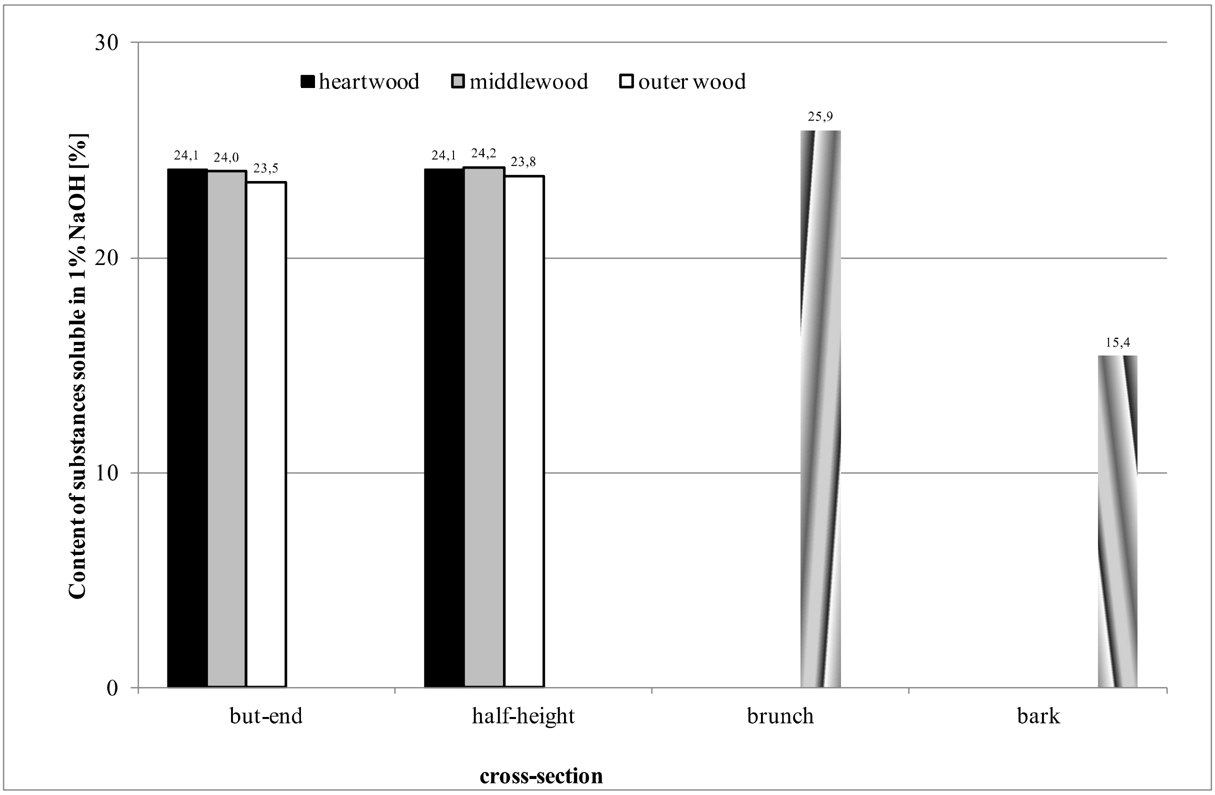

Figure 3. Content of substances soluble in 1% NaOH in bark and wood of lime

Content of total pentosanes and hexosanes in bark of birch trunk equals cca. 11.8% (Prosiński 1984). Significant difference between this value and results obtained in this paper may be caused not only by raw material diversity and disintegration degree, but also by different analytical methods.

Summarizing, environmental pollution influenced the content of 1% NaOH soluble substances in wood and bark of lime.

Lignin content in the trunk cross-section decreases in the direction from pith to perimeter in butt-end and half-height sections as well (Figure 4). Its value is almost the same in branch and in outer wood from both sections. Lignin content in bark is about 50 % higher than in sapwood and about 47 % higher in relation to heartwood. There are no significant differences in lignin content along the stem, when comparing particular zones.

Krutul et al. (2010) stated that oak wood (*Quercus robur* L.) in pith adjacent wood contains more lignin than outer wood zone. Krutul et al. (2011) stated that in 45-year old birch trunk lignin content in pith adjacent wood is about 4% higher in comparison to outer wood and only in the top part of the trunk this value is similar in all zones. Lignin content in outer wood of cca. 70-year old birch (*Betula pendula* Roth.) is 3% higher in comparison to pith adjacent wood from butt-end section, but 6.5% lower in half-height and the top part (Krutul et al. 2014).

These results are consistent with data presented by Krutul et al. 2017, where no changes of lignin distribution on the longitudinal section of single-seeded hawthorn (*Crateegus monogyna* Yacq.) was stated.

Data referring to lignin content in lime bark are similar to data obtained by Fengel (1984) for lignin content in oak bark, which was 38.1 %.

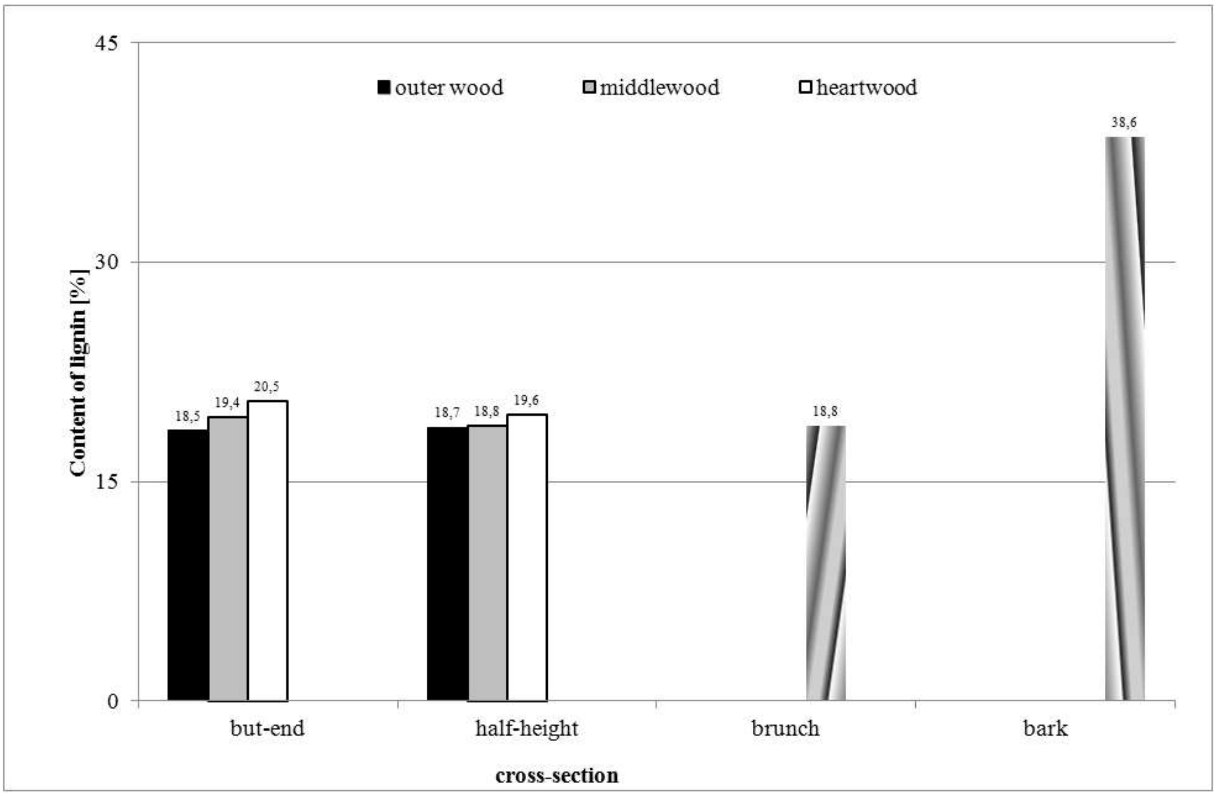

Figure 4. Content of lignin in bark and wood of lime

According to Krutul et al. (2011) lignin content in bark of cca. 45-year old birch trunk (*Betula pendula* Roth.) and branches and roots is more than a twice higher in relation to wood. It equals 46.0% in bark from the top part of the trunk, 47.9% in butt-end section, 48.0% in bark from main branches and 49.0 in bark from the main roots. Bark of cca. 70-year old birch (*Betula pendula* Roth.) contains 34.8% of lignin what is twice higher in comparison to wood (Krutul et al. 2014).

Bark from analyzed trunk contains about 70% lower amount of lignin than bark from single-seeded hawthorn (Krutul et al. 2017).

Urban environment did not influence on the lignin content and spacing in stem, branch and bark.

CONCLUSIONS

- The urban environment pollution had no influence on the content and spacing of extractives, lignin and cellulose in the stem, branch and bark of lime (*Tilia cordata* Mill.).
- The urban environment pollution influenced the spacing of 1% NaOH soluble substances in the stem cross-section.

- Extractives and lignin content in bark is higher in relation to the wood of trunk and branch.
- Content of 1% NaOH soluble substances and cellulose in bark is lower than in the trunk and branch.

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Streszczenie: *Wpływ skażenia środowiska wielkomiejskiego Warszawy na zawartość substancji chemicznych w korze i drewnie pnia oraz gałęzi lipy drobnolistnej (Tilia codata Mill.)* Przeprowadzono oznaczenia zawartości substancji ekstrakcyjnych, celulozy, substancji rozpuszczalnych w 1% NaOH, ligniny w drewnie pnia, w drewnie głównych gałęzi i w korze. Drzewo ok. 40-letnie wyrosło w Alejach Ujazdowskich miasta stołecznego Warszawy. Na przekroju poprzecznym pnia wyróżniono strefę drewna przyobwodowego, środkowego i przyrdzeniowego. Przekroje poprzeczne wycięto na wysokości 200 mm od podstawy gruntu i w połowie długości pnia.

Na podstawie uzyskanych wyników stwierdzono, że rozmieszczenie substancji ekstrakcyjnych na przekrojach poprzecznych pnia przebiega podobnie do ich rozmieszczenia w pniach sosnowych, dębowych, brzozowych i głogu jednoszyjkowego. Drewno głównych gałęzi charakteryzuje się od 11% do 20% większą zawartością substancji ekstrakcyjnych w stosunku do drewna pnia. W korze tych substancji jest od 35% do 40% więcej w stosunku do badanych stref drewna pnia i 25% więcej w odniesieniu do drewna gałęzi. Na przekrojach poprzecznych lipy drobnolistnej zawartość celuluozy zwiększa się w kierunku od rdzenia do obwodu. Kora charakteryzuje się ok. 30% mniejszą zawartością celulozy w stosunku do drewna strefy przyrdzeniowej i drewna gałęzi oraz ok. 35% mniejszą w odniesieniu do drewna strefy przyobwodowej.

Na podstawie uzyskanych wyników można stwierdzić, że skażenie środowiska wielkomiejskiego wpływa na rozmieszczenie substancji rozpuszczalnych w 1% NaOH na prekroju poprzecznym pnia oraz na zawartość tych substancji w korze. Zawartość ligniny w korze jest o 50% większa w stosunku do drewna strefy bielu, natomiast o 47% większa w odniesieniu do drewna strefy twardzieli pnia.

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