DOI: 10.7251/QOL1801033M **UDC:** 551.588:551.506(497.6Banja Luka)

Original scientific paper

Impact of Air Pollution on Vegetation in Banja Luka

Tanja Maksimović[1], Predrag Ilić[2], Sanja Bajić[2]

[1]*University of Banja Luka, Faculty of Natural Sciences and Mathematics, Banja Luka, Republic of Srpska, BiH, tanja.maksimovic@pmf.unibl.org*

[2]*PSI Institute for Protection and Ecology of the Republic of Srpska, Banja Luka, Republic of Srpska, BiH, predrag.ilic@institutzei.net and sanja.bajic@institutzei.net*

Abstract: Atmospheric pollutants have a negative effect on the plants; they can have direct toxic effects, or indirectly by changing soil pH followed by solubilization of toxic salts of metals. Large number of studies have investigated the possible effects of ambient air pollution on vegetation and air pollution in stomata number and size and stomatal apparatus. The primary aim of this study was to impact air pollution from the aspect of presence SO_2, NO_X, CO_2, O_3 and PM10 on vegetation in the city of Banja Luka and stomatal response to air pollution, through a review of existing research.

Key words: air pollution, vegetation, Banja Luka

INTRODUCTION

Air pollution can be defined as the presence of toxic chemicals or compounds (including those of biological origin) in the air. Atmospheric pollutants particularly SO_2, halides (HF, HCl), ozone, carbon monoxide and per-oxiacetyl nitrate (PAN) produced from automobiles, industrial fumes and strong radiations are dangerous to plants. Balkan countries suffer the highest rate of the air contamination and air pollution related deaths throughout Europe. The problem of air pollution is largely present in the Republic of Srpska, BiH (Ilić et al., 2018). Bosnia and Herzegovina (BiH) is listed as the worst European performer and had European highest average of 55.1 μg particular matter per m^3. BiH in 2012 registered nearly 231 deaths per 100,000 people and had European highest death rate (WHO, 2017). The basis for plant damage by air pollution is very complicated. Persistent inversion layers, high temperatures and humidities, and the speed and direction of winds can influence the degree of damage (Caldwell, 1970). Atmospheric pollutants have a negative effect on the plants; they can have direct toxic effects, or indirectly by changing soil pH followed by solubilization of toxic salts of metals like aluminum. The particulate matters have a negative mechanical effect. They cover the leaf blade reducing light penetration and blocking the opening of stomata. These impediments influence strongly the process of photosynthesis which rate declines sharply (Gheorghe, 2011). Urban vegetation, also has the potential to contribute to the reduction of pollutant concentrations in cities. Coniferous trees are better at trapping pollutant particles than deciduous trees, because they keep their foliage throughout the year and have very high surface areas (Kerckhoffs, 2014). The majority of sulphur and nitrogen oxides reach plant leaves through stomata, thereby causing damage to the photosynthetic apparatus and photosynthesis inhibition (Miszalski and Mydlarz 1990; Jablanović et al. 2003). The relative amounts of the various pollutants can vary throughout the year, due to changes in traffic and heating, and industrial production. The action of one pollutant may be enhanced by the presence of an additional pollutant (synergism), thus lowering the concentration needed to damage vegetation (Caldwell, 1970). Hairy and rough leave surface seem to help with capturing particles. A planting scenario with planting trees on 25% of the available land in urban areas could result in bigger changes, ranging from an increase of 2-21% in deposition and a reduction of 7% of pollutant concentrations (Kerckhoffs, 2014). Numerous reports confirm that stomata number and size changes depending on the degree of air pollution by different types of pollutants, primarily sulphur and nitrogen oxides and ozone (Zelitch 1961; Mulgrew and Williams 2000; Shweta

2012). Stomatal response to air pollution is very complex and depends not only on air pollutant concentration and type, but is also very selective depending on plant species (Abeyratne & Ileperuma 2006).

Air pollution research in Banja Luka is significant (Ilić & Janjuš, 2008; Ilić et al., 2009; Ilić & Preradović, 2009; Lammel et al., 2010; Lammel et al., 2010; Gasic et al., 2010; Lammel et al., 2011; Preradović et al., 2011; Ilić et al., 2012b; Ilić et al., 2013; Ilić et al., 2014; Ilić, 2015). A large number of surveys were conducted in the Banja Luka in terms of impact intensity of transpiration and air pollution in stomata number and stomatal apparatus (Maksimović et al., 2008; Janjić et al., 2016; Janjić et al., 2017; Janjić & Maksimović, 2018).

OBJECTIVES

The primary aim of this study was to determine impact air pollution on vegetation and intensity of transpiration in stomata number and size and stomatal apparatus in the city of Banja Luka (Republic of Srpska, Bosnia and Hercegovina (BiH)), through a review of existing research, from the aspect of presence SO_2, NO_X, CO_2, O_3 and PM10.

MATERIAL AND METHODS

Subject of the research is impact air pollution on vegetation in Banja Luka, which is located in the northwestern part of BiH and in one of the two entities in BiH. We searched all available publications included in the electronic databases for city of Banja Luka. We searched for combinations of either of the key words "air pollution" or "pollution" with any of the following: "Banja Luka", "impact on vegetation", "stomata" etc.

RESULTS AND DISCUSSION

Air pollution does not represent only ''privilege'' of the present, but its history goes back to the period before Christ. Ancient Greeks and Romans had problems with air pollution in their cities, when they considered coal smoke to have ''harmful influence on human health'' (Ilić et al., 2012a). The environmental situation is not at a high level in Republic of Srpska. The current situation in the area of air protection is caused by different factors, such as the social and economic circumstances, whose execution is a prerequisite for solving environmental problems (Ilić et al., 2014). Monitoring of air quality in the area of Banja Luka has started the eighties, when analyzes of sulfur dioxide (SO_2) and soot (black smoke) were made. First automatic equipment is installed on 29th August 2005, for monitoring of sulfur dioxide (SO_2), nitrogen oxides (NO, NO_2 and NO_X), ozone (O_3), particulate matters under 10 μm (PM10), carbon monoxide (CO) and meteorological parametres (Ilić et al., 2006).

Sulfur dioxide is considered one of the indicators of air quality. It is formed primarily from the combustion of sulfur-containing fuels and can affect the health of people and have a negative impact on the environment (Ilić et al., 2018). Sulfur dioxide is a major component in acid rain. One of the byproducts of sulfur dioxide is sulfuric acid, and both can be extremely damaging to plants that are exposed to these chemicals. Exposed leaves can begin to lose their color in irregular, blotchy white spots. Some leaves can develop red, brown or black spots. When the pigments in enough tissue are damaged or killed, plants can begin to lose their leaves. Crop output is greatly reduced and growth can be stunted. This is especially noticeable in young plants (Gheorghe & Ion, 2011). Measured average values of sulfur dioxide are 12 $\mu g/m^3$ (Ilić et al., 2006), 39,35 $\mu g/m^3$ (Ilić et al., 2010b), 10,41 $\mu g/m^3$ (Ilić et al., 2012b), 10,23 $\mu g/m^3$ (Ilić et al., 2011), 26,51 $\mu g/m^3$ (locality Center) (Ilić et al., 2014) and 21.81 $\mu g/m^3$ (Ilić et al., 2018). In some cases, exposure to pollutant gases, particularly SO_2, causes stomatal closure, which protects the leaf against further entry of the pollutant but also curtails photosynthesis (Gheorghe & Ion, 2011). Therefore, the synergistic effect of SO_2 with increased concentration of CO_2 is considered to be the most harmful, leading to inhibition of stomatal closing (Majernik & Mansfield, 1972).

Nitrogen dioxide mostly affects the leaves and seedlings. Its effects decrease with increasing age of the plant and tissue. Conifers are found to be more sensitive to this gas during spring and summer than in winters. Older needles are more sensitive to the gas than young ones. Injury symptoms: The gas causes formation of crystalloid structures in the stroma of chloroplasts and swelling of thylakoid membrane. As a result the photosynthetic activity of the plant is reduced. Most common visible injury symptoms are chlorosis in angiospermic leaves and tip burn in conifer needles (Gheorghe & Ion, 2011). Measured average values of nitrogen dioxides are 39 μg/m^3 (Ilić et al., 2006), 57,09 μg/m^3 (Ilić et al., 2010b), 46,08 μg/m^3 (Ilić et al., 2012b) and 24,82 μg/m^3 (locality Center) (Ilić et al., 2014). For example, when plants are exposed to air containing NO_X, lesions on leaves appear at a NO_X concentration of 5 ml/l, but photosynthesis starts to be inhibited at a concentration of only 0.1 ml/l. These low, threshold concentrations refer to the effects of a single pollutant. However, two or more pollutants acting together can have a synergistic effect, producing damage at lower concentrations than if they were acting separately. In addition, vegetation weakened by air pollution can become more susceptible to invasion by pathogens and pests (Gheorghe & Ion, 2011).

Polluting gases such as SO_2 and NO_X enter leaves through stomata, following the same diffusion pathway as CO_2 (Gheorghe & Ion, 2011).

CO produces epinasty, chlorosis and abscission. However, concentration of over 1000 times that of ethylene is needed to produce same degree of damage. No injury to plants occurs below exposure of 100 ppm for 1 week (Gheorghe & Ion, 2011). Measured average values of carbon monoxide are 3,42 mg/m^3 (Ilić et al., 2006), 7,05 mg/m^3 (Ilić et al., 2010b), 2,15 mg/m^3 (Ilić et al., 2012b) and 1,40 mg/m^3 (locality Center) (Ilić et al., 2014).

Ozone (O_3) is released into the atmosphere from the burning of fossil fuels and is one of the most harmful pollutants to plants. It can be carried for long distances and is readily absorbed as a part of the photosynthetic process. Plants exposed to large amounts of ozone can develop spots on their leaves. These spots are irregular and often tan, brown or black. Some leaves can take on a bronze or red appearance, usually as a precursor to necrosis. Depending on the concentration of ozone in the environment, plants can show different amounts of discoloration before the leaves begin to die. Ozone is presently considered to be the most damaging phytotoxic air pollutant in North America. It has been estimated that wherever the mean daily O_3 concentration reaches 40, 50, or 60 ppb (parts per billion or per 109), the combined yields of soybean, maize, winter wheat, and cotton would be decreased by 5, 10, and 16%, respectively. Ozone is highly reactive: It binds to plasma membranes and it alters metabolism (Gheorghe & Ion, 2011). Measured average values of ozone in Banja Luka are 29 μg/m^3 (Ilić et al., 2006), 25,73 μg/m^3 (Ilić et al., 2010b), 40,93 μg/m^3 (Ilić et al., 2012b) and 56,70 μg/m^3 (locality Center) (Ilić et al., 2014). Tropospheric ozone is believed to be a very toxic pollutant for plants, also known as "photochemical smog", generated from primary atmospheric pollutants, nitrogen oxides and volatile hydrocarbons, especially under intensive luminosity conditions (Janjić et al., 2017).

Particulate matter such as cement dust, magnesium-lime dust and carbon soot deposited on vegetation can inhibit the normal respiration and photosynthesis mechanisms within the leaf. Dust pollution is of localized importance near roads, quarries, cement works, and other industrial areas (Gheorghe & Ion, 2011). Measured average values of PM10 are 90 μg/m^3 (Ilić et al., 2006), 81,71 μg/m^3 (Ilić et al., 2010a), 202,26 μg/m^3 (Ilić et al., 2010b), 81,76 μg/m^3 (Ilić et al., 2012b) and 32,42 μg/m^3 (locality Center) (Ilić et al., 2014).

In the research (Maksimović et al., 2008), results are shown of examining number (density) and size of stoma, and intensity of transpiration in *Spireae bumalda*, *Spiraea vanhouttei*, *Mahonia aquifolium*, *Cornus alba* and *Pterostyrax hispidu* in the area of the “Petar Kocic” park in Banja Luka. A narrow correlation between the number of stoma and intensity of transpiration has been found, namely, the more number of stoma, the more intensified transpiration, by which better regulation of water regime is provided.

In Banja Luka was carried out study, which objective was to determine the differences in stomata number and stomatal apparatus size between these selected plant species (*Tilia cordata* and *Betula pendula*) sampled in an urban area of Banja Luka and a suburban forest estate over two seasons. Based on analysis of stomata characteristics in the examined species, conclusion is that *T. cordata* and *B. pendula* possess different strategies for adaptation to urban conditions with increased concentrations of atmospheric pollutants. Betula pendula has shown to be a more sensitive species, since a significant reduction in stomata number was observed in leaves taken from the urban area in comparison with control samples from the suburban area. Also, microanatomic changes in the size of stomatal apparatus were noticed in the examined species on samples taken from the urban zone. On the other hand, no significant changes were noticed in T. cordata in the majority of analysed stomata characteristics, indicating that this species possesses higher degree of resistance to atmospheric pollutants common in urban areas (Janjić et al., 2017). Species of *Tilia cordata* Mill. and *Tilia platyphyllos* Scop. are reacted differently to aeropolutants. A larger number of smaller stoma was found in *Tilia platyphyllos*, while at *Tilia cordata* recorded reverse distribution (Janjić & Maksimović, 2018). In the research (Janjić et al., 2016), the impact of certain pollutants (SO_2, NO_X, O_3, soot) was investigated in the number and size at *Aesculus hippocastanum* L. (Horse chestnut) stomatal cells at four locations in the Banja Luka city. Obtained results show us certain changes caused by pollutants in relation to the characteristics of stomatal apparatus in *Aesculus hippocastanum* L.

It is necessary to conduct regular monitoring of atmospheric pollutants in urban areas and additional studies of effects air pollution and natural stress factors on the condition on vegetation. Air quality biological monitoring methods have seen increasing use, possibly because they provide valuable data on the interaction of chemical pollutants with living systems (Janjić et al., 2017).

CONCLUSIONS

The results of the conducted measurements and analyses showed that the problem of air pollution in the City of Banja Luka is a very realistic for vegetation. Results suggest the importance of such research, and need for additional research regarding the relation between pollutants in air and impact on vegetation, especially impact in stomata number and size and stomatal apparatus. A special emphasis is on vegetation and research show that greens significantly decreas influence of pollutants, which makes urban conditions possible for living.

REFERENCES

Abeyratne, V.D.K., Ileperuma, O.A. (2006). Impact of ambient air pollutants on the stomatal aperture of Argyreia polulifolia. *Ceylon Journal of Science*. 35(1):9–15.

Caldwell, Roger L. (1970). Effects of Air Pollution on Vegetation. Progressive Agriculture, 22(2) 10-12.

Gasic, B., MacLeod, M., Klanova, J., Scheringer, M., Ilic, P., Lammel, G., Pajovic, A., Breivik, K., Holoubek, I. & Hungerbühler, K. (2010). Quantification of sources of PCBs to the atmosphere in urban areas: A comparison of cities in North America, Western Europe and former Yugoslavia. *Environmental Pollution*, *158*(10), 3230-3235.

Gheorghe, I. F., & Ion, B. (2011). The effects of air pollutants on vegetation and the role of vegetation in reducing atmospheric pollution. In T*he impact of air pollution on health, economy, environment and agricultural sources*. InTech. DOI: 10.5772/17660.

Ilić, P. (2015). *Pollution and control of air quality in the function of environment protection*. Independent University, Banja Luka.

Ilić, P., Ilić, S., Janjuš, Z. (2013). *Environmental protection in Republic of Srpska, status end perspectives*. Scientific-professional conference with international participation “Environment protection between science and practice – status and perspectives”, Banja Luka, Republic of Srpska, Bosnia and Herzegovina.

Ilić, P., Ilić, S., Janjuš, Z. (2014). *Air protection in Republic of Srpska*. IX International Conference Risk and Safety Engineering, Kopaonik, Serbia.

Ilić, P., Janjuš, Z. (2008). *Air quality assessment regarding the presence of SO_2*. Scientific-professional Conference with international participation "Modern technologies for cities' sustainable development", Banja Luka, Republic of Srpska, Bosnia and Herzegovina.

Ilić, P., Kojović, J., Tepić, S., Erić, Lj. (2006). *First data about the work of the automatic station for air quality monitoring in Banja Luka*. Collection of papers. First scientific-professional conference with international participation ''Air protection and health'', Banja Luka.

Ilić, P., Marković, S., Janjuš, Z. (2012a). History and sources of air pollution. *Skup*. 4(2):19-31.

Ilić, P., Marković, S., Janjuš, Z., Račić-Milišić, S. (2009). *Importance and role of vegetation in protection from air pollution*. Scientific-professional conference with international participation "Safety and health in work and environmental protection", Banja Luka, Republic of Srpska, Bosnia and Herzegovina.

Ilić, P., Marković, S., Račić, M., Janjuš, Z. (2012b). Municipal noise and air pollution in urban part of Banja Luka. *Skup*. 4(2):32-42

Ilić, P., Nešković Markić, D., & Stojanović Bjelić, LJ. (2018). Variation concentration of sulfur dioxide and correlation with meteorological parameters. *Archives for Technical Sciences*. 18(1), 81-88.

Ilić, P., Preradović, Lj. (2009). Simulation of pollution, i.e. modelling levels of nitrogen dioxide and meteorological parameters. *grkg/Humankybernetik*. 50(3):146-150.

Ilić, P., Preradović, Lj., Dejanović, R., Marković, S., Janjuš, Z. (2010a). *Modeling of air pollution (PM10) with meteorological parameters*. XVII Festival of Information Technology Achievements – INFOFEST 2010, Budva, Montenegro.

Ilić, P., Preradović, Lj., Dejanović, R., Marković, S., Janjuš, Z. (2010b). *Using the factor analysis in monitoring of air pollution and meteorological parameters*. 54th ETRAN Conference, Donji MIlanovac, Serbia.

Jablanović, M, Jakšić, P, Kosanović, K. (2003). *Introduction to ecotoxicology*. University of Priština, Faculty of Natural Sciences and Mathematics, Kosovska Mitrovica, Kosovska Mitrovica

Janjić, N., Hasanagić, D., & Maksimović, T. (2017). Stomatal apparatus response of Tilia cordata (Mill.) and Betula pendula (Roth.) to air quality conditions in the City of Banja Luka (Bosnia and Herzegovina). *Biologia Serbica*, *39*(2).

Janjić, N., Maksimović, T (2018). An Impact of Air Pollution on Characteristics of Stoma and Photosynthetic Apparatus of *Tilia Cordata* (Mill.) and *Tilia Platyphyllos* (Scop.) on Banja Luka Area *Bulletin of Faculty of forestry, University of Banja Luka (paper accepted)*.

Janjić, N., Maksimović, T., Boltić, D. (2016). The impact of some aeropollutants on the stomatal apparatus of Horse chestnut (*Aesculus hippocastanum* L.) on Banja Luka area. *Skup* 7(1): 219-225.

Kerckhoffs, J. (2014). A review of the effects of urban vegetation on air quality (Master's thesis).

Lammel, G., Klánová, J., Erić, L., Ilić, P., Kohoutek, J., & Kovacić, I. (2011). Sources of organochlorine pesticides in air in an urban Mediterranean environment: volatilisation from soil. *Journal of Environmental Monitoring*, *13*(12), 3358-3364.

Lammel, G., Klánová, J., Ilić, P., Kohoutek, J., Gasić, B., Kovacić, I., Lakić, N. & Radić, R. (2010). Polycyclic aromatic hydrocarbons in air on small spatial and temporal scales–I. Levels and variabilities. *Atmospheric Environment*, *44*(38), 5015-5021.

Lammel, G., Klánová, J., Ilić, P., Kohoutek, J., Gasić, B., Kovacić, I., & Škrdlíková, L. (2010). Polycyclic aromatic hydrocarbons in air on small spatial and temporal scales–II. Mass size distributions and gas-particle partitioning. *Atmospheric Environment*, *44*(38), 5022-5027.

Majernik, O, Mansfield, T.A. (1972). Stomatal response to raised atmospheric CO_2 concentrations during exposure of plants to SO_2 pollution. *Environmental Pollution*. 3(1):1–7

Maksimović, T., Petrović, M., Stanković, Ž. (2008). Examining number and size of stoma and intensity of transpiration in decorative bushes in the «Petar Kočić» park in Banja Luka. *Skup* 2: 209-213.

Miszalski, Z, Mydlarz, J. (1990). SO_2 influence on photosynthesis of tomato plants at different CO2 concentrations. *Photosynthetic*. 24:2–8

Mulgrew, A, Williams, P. (2000). Biomonitoring of air quality using plants. WHO Collaborating Centre for the Air Quality Management and Air Pollution Control, Berlin. *Air Hygiene Report* No. 10.

Preradović, L., Ilić, P., Marković, S., & Janjuš, Z. (2011). Meteorological parameters and pollution caused by Sulfur dioxide and their influence on construction materials and heritage. *Facta universitatis-series: Electronics and Energetics*, *24*(1), 9-20.

Shweta, T. (2012). Air Pollution Induced changes in Foliar Morphology of two shrub species at Indore city, India. *Research Journal of Recent Sciences*. 2(3):195–199.

WHO (2017) World health statistics 2017, Monitoring health for the SDGs, Sustainable Development Goals. Geneva, World Health Organization.

Zelitch, I. (1961). Biochemical control of stomatal opening in leaves. Proceedings of the National Academy of Sciences of the United States of America. 47(9):1423–1433.

Recived: 7.12.2017.

Accepted: 17.3.2018.