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AIR QUALITY AND DISTRIBUTION OF LICHENS AS BIOMONITORS IN SOME SERBIAN TERRITORIES

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***Abstract**: This paper deals with using lichens as a bioindicators of the air quality. A bioindication and physical- chemical detection of air pollution in Zrenjanin has not been carried out. Over recent decades, air quality has become environmental problem worldwide due to industrial activities and road traffic. Atmospheric monitoring has been necessary to control air quality and reduce pollution sources. Air quality is a topic that attracts more and more attention especially with the problem of human health. Biomonitoring is based on the detection and monitoring of changes that occur on different levels of the biological organization for living organisms under the influence of air pollutants. It was noted that not all lichen species are equally likely to indicate different levels of air pollution. The assessment of lichen biodiversity was based on the calculation of lichenic abundance indices. This research work dealswith using lichens as a bioindicators of the air quality and it was conducted from various Serbia locations. Also, it is shown the relationship between the Serbian air qualities, and how lichens act as a bioindicator for the air quality, in some parts of Serbia such as in Sremska Mitrovica city, Fruska Gora mountine, Palic Lake and Silver Lake. The bioanalysis of the samples from investigated sites indicates the presence of different lichen taxa, which shows that these sites are rich in lichen species. Information about the air quality index of Zrenjanin city as an example of the Serbian cities which demonstrates the chemical pollutants, climate changes for example weather, wind and temperature This work also shows the distribution of the lichens which can be found in the investigated sites. The presence of lichen indicates that the air quality in these sites: Sremska Mitrovica city, Fruska Gora mountine, Palic Lake and Silver Lake is quite good. It was concluded that the presence of epiphytic lichens plays an important role in determining the air pollution in those sites. By the presence of these lichens, we have found that the most dominant lichen taxa were Rhizocarpon geographicum, Lecanora muralis, Lecanora muralis, Rhizocarpon geographicum,Xanthoria parietina and Xanthoria candelaria.*

***Keywords**: air quality; biomonitors; lichen biodiversity, Serbian locations*

INTRODUCTION

Over recent decades, air quality has become environmental problem worldwide due to industrial activities and road traffic. Atmospheric monitoring has been necessary to control air quality and reduce pollution sources [1]; [2]. The evolution of conventional measurement methods continues to advance the monitoring of air quality. A biomonitoring using living organism offers an interesting complementary tool to estimate the impact of atmospheric pollution [3].
The negative effects of air pollution on human health are well known [4]. On the basis of the available knowledge about the possible threats to air quality, there is a need to know the type and extent of the threat that has arisen [5]. The basis for improving air quality is detection and registration on time. This can be achieved by physico-chemical or biological monitoring [6].

A bioindication and physical-chemical investigation of air pollution in Zrenjanin has not been carried out. The air quality is getting worse all over the world. The presence and absence of lichens and different species around different pollution sources has been used for problems connected to air pollution. This type of investigation started in Serbia in last decade of 20th century [1], [7], [8].

Lichens are currently considered to be fungi that live in symbiosis with a photobiont, an autotrophic green alga (phycobiont), or cyanobacterium (cyanobiont) or, in some cases, both. The fungal partner (mycobiont) in most lichens (98%) belongs to Ascomycetes, and Zygomycetes and rare Basidiomycetes make up the remainder. The symbiotic relationship is often characterized as mutualistic, that is, both partners benefit. However, recent evidence suggests that, while the fungus is dependent on its autotrophic partner, the photobiont is often fully content to live alone [9]

Air pollution is one of the biggest and most important risk factors for health in the world. Worldwide approximately 7 million people died prematurely due to the pollution; within the European countries 400,000 people suffer a premature death. [10]

The substances that are affecting health the most are: nitrogen oxides (NO_2), sulphur oxides (SO_2), ozone and particulate matter with the latter – especially particulate matter below 2.5 microns ($PM_{2.5}$) – being of greatest concern, as these tiny particles penetrate deep into the lungs, affecting both the respiratory and vascular systems. Both extent and duration of the exposure influence health outcomes. The impact of air pollution on health is a big concern as research shows more connection between a number of serious diseases among various age groups and air pollution (e.g. diabetes, neurodevelopment, pre-term birth, low weight birth, etc.). According to the results of the air quality monitoring, Serbia is one of the most polluted countries in Europe and worldwide. Pollution in Serbia is in general, really high in past few years. Serbia's air pollution comes from a variety of sources, with Serbia's reliance on lignite and coal-fuelled power plants being a well-known cause of the energy sector in addition to burning solid fuels (such as coal and wood) to heat homes. Pollutant emissions from an aging transport fleet, industrial activities, landfills and emissions from agriculture make a significant contribution to this. The specific industrial sites that have been documented as causing air pollutants in Serbia include the petrochemical complex around the cities of Pančevo and NoviSad for example. The level of air pollution from different sources varies in different areas of Serbia. For example, in large urban areas such as Belgrade, Novi Sad and Niš, road traffic is a significant contributor to urban air pollution and increases. The emissions in Serbia are largely attributed to the country's relativelyold vehicle fleet, with an average car in the country estimated at 17 years. [11]

AIR QUALITY INDEX (AQI)

As in Table (1), the air quality index is used to report daily air quality. It is used to find information of how the air is polluted, or clean, also which health effects might be of a concern in that place. [12]

Table 1. Air Quality Index information

Air Quality Index (Aqi) Values	**Levels Of Health Concern**	**Colours**
AQI RANGE:	Air Quality Conditions	Symbolized By Colour:
0-50	Good	Green
51-100	Moderate	Yellow
101-150	Unhealthy For Sensitive Groups	Orange
151-200	Unhealthy	Red
201-300	Very Unhealthy	Purple
301-500	Hazardous	Maroon

As in Figures (1 and 2), based on IQAir's "2019 World Air Quality Report", which aggregated air quality data for over 4000 cities globally, Serbia ranked as the 32nd most polluted country worldwide, of a list of 98 ranked countries for $PM_{2.5}$ pollution. [11] The country's annual average $PM_{2.5}$ concentration, when weighted by population, emerged as 23.3 μg/m^3, which represents a twofold exceedance of the WorldHealth Organization (WHO)'s international guideline limit for $PM_{2.5}$ as 10 μg/m^3. [13]

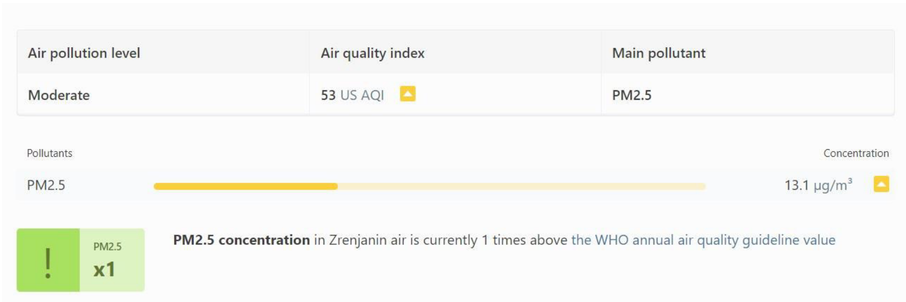


Figure 1. AQI Zrenjanin during the Summer (August 2021) [14]

Figure 2. AQI Zrenjanin (September 2021) [14]

In the Figures above, it is shown that the Air Quality Index (AQI), on first one in August 2021 (data found during the day), and on second report from the September 2021 (data found during the night). AQI values can be varied depending on the time of day.

Fine particulate matter ($PM_{2.5}$) is an air pollutant that may be a difficulty for popular health when its level in air is high. $PM_{2.5}$ is tiny particle with inside the air that reduces visibility and it is a reason for air to seem hazy while levels are increased. Outdoor $PM_{2.5}$ levels are maximum probable to be increased on days with very little or no wind or air mixing. The New York State Departments of Health (DOH) and Environmental Conservation (DEC) alert the general public through issuing a $PM_{2.5}$ Health Advisory whilst $PM_{2.5}$ concentrations in outdoor air are predicted to be dangerous for touchy groups.

There are outdoor and indoor sources of fine particles. Outside, fine particles in most cases come from car, truck, bus and off-road vehicle (e.g., construction equipment, snowmobile, locomotive) exhausts, different operations that contain the burning of fuels inclusive of wood, heating oil or coal and natural sources inclusive of wooded area and grass fires. Fine particles additionally form from the response of gases or droplets with inside the surroundings from sources inclusive of power plants. These chemical reactions can arise miles from the authentic supply of the emissions. Some indoor sources of fine particles are tobacco smoke, cooking (e.g., frying, sautéing, and broiling), burning candles or oil lamps, and operating fireplaces and fuel-burning space heaters (e.g., kerosene heaters). [15]

The higher the AQI the higher the air pollution and the higher level of concern for health. "For each pollutant the AQI value of 100 generally corresponds to an ambient air concentration that equals the level ofshort-term national ambient air quality standard for protection of public health. AQI values at or below 100 are generally thought of as satisfactory. When AQI values are above 100, air quality is unhealthy: at first for
certain sensitive groups of people, as AQI values get higher. There are six categories ranging from good with little to no risks to hazardous with emergency conditions. [16]

Table 1, AQI Basics for Ozone and Particle Pollution [17]

Daily AQI Color	Levels of Concern	Values of Index	Description of Air Quality
Green	Good	0 to 50	Air quality is satisfactory, and air pollution poses little or no risk.
Yellow	Moderate	51 to 100	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.
Orange	Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is less likely to be affected.
Red	Unhealthy	151 to 200	Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.
Purple	Very Unhealthy	201 to 300	Health alert: The risk of health effects is increased for everyone.
Maroon	Hazardous	301 and higher	Health warning of emergency conditions: everyone is more likely to be affected.

Particles in the $PM_{2.5}$ size range are able to travel deeply into the respiratory tract, reaching the lungs. Exposure to fine particles can cause short-term health effects such as eye, nose, throat and lung irritation, coughing, sneezing, runny nose and shortness of breath. Exposure to fine particles can also affect lung function and worsen medical conditions such as asthma and heart disease. Scientific studies have linked increases in daily $PM_{2.5}$ exposure with increased respiratory and cardiovascular hospital admissions, emergency department visits and deaths. Studies also suggest that long term exposure to fine particulate matter may be associated with increased rates of chronic bronchitis, reduced lung function and increased mortality from lung cancer and heart disease. People with breathing and heart problems, children and the elderly may be particularly sensitive to $PM_{2.5}$ (Figure 3).

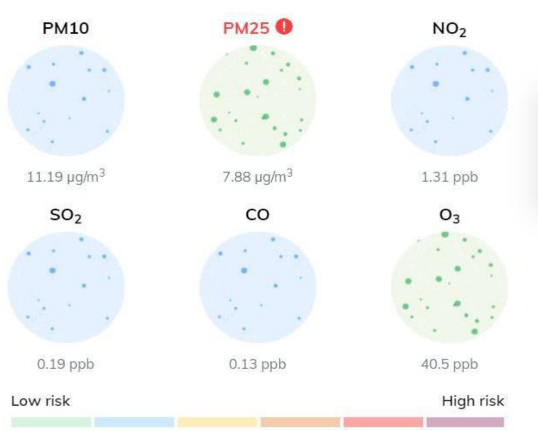


Figure 3. Chemical pollutants in Zrenjanin

AIR CHEMICAL POLLUTANTS IN SERBIA ESPECIALLY IN ZRENJENIN

AIR Pollutants:

Ozone (O_3): O_3 is a powerful oxidant and has many industrial and consumer applications related to oxidation. It can damage mucous and respiratory tissues in animals, and plants.

Particulate matters:
PM_{10}: Inhalable particles, with diameters that are generally 10 µm and smaller. These particles come in many sizes and shapes and can be made up of hundreds of different chemicals.
PM_{25}: Inhalable particles, with diameters that are generally 2.5 µm and smaller. Some are emitted directly from a source, such as construction sites, unpaved roads, fields, smokestacks or fires.
Carbon monoxide (CO): CO is a colourless, odourless gas that can be dangerous when inhaled in large amounts. Sources of CO are cars, trucks and other vehicles or machinery that burn fossil fuels.
Sulfur Dioxide (SO_2): SO_2 is one of a group of gases called sulfur oxides. The largest source of SO_2 in the atmosphere is the burning of fossil fuels by power plants and other industrial facilities.
Nitrogen dioxide (NO_2): NO_2 primarily gets in the air from the burning of fuel. NO_2 forms from emissions from cars, trucks and buses, power plants, and off-road equipment.'' [17]

CLIMATE CHANGES IN ZRENJANIN (IN LIMITED TIME)

Figure (4) shows those months with the largest precipitation are June, May, July with 209 mm precipitation. Most precipitation occurs in June with an average precipitation 83 mm. The annual amount of precipitation in Zrenjanin is 619 mm. The average annual temperature is 16°C in Zrenjanin. The warmest month of the year is July, with an average temperature: 28°C. January is the coldest month in Zrenjanin, with average temperature 2°C. The difference between the hottest month: July and the coldest month: January is: 26°C. The difference between the highest precipitation (June) and the lowest precipitation (February) is 48mm. The lowest temperature recorded (monthly average) was -10°C in February 1956 in Zrenjanin. The highest temperature recorded (monthly average) was 26°C in August 1992 in Zrenjanin. The year 2017 was the warmest in Zrenjanin, average temperature was: 14°C. 1956 was the coldest year (Figure 5), with average temperature was: 10°C. [18]

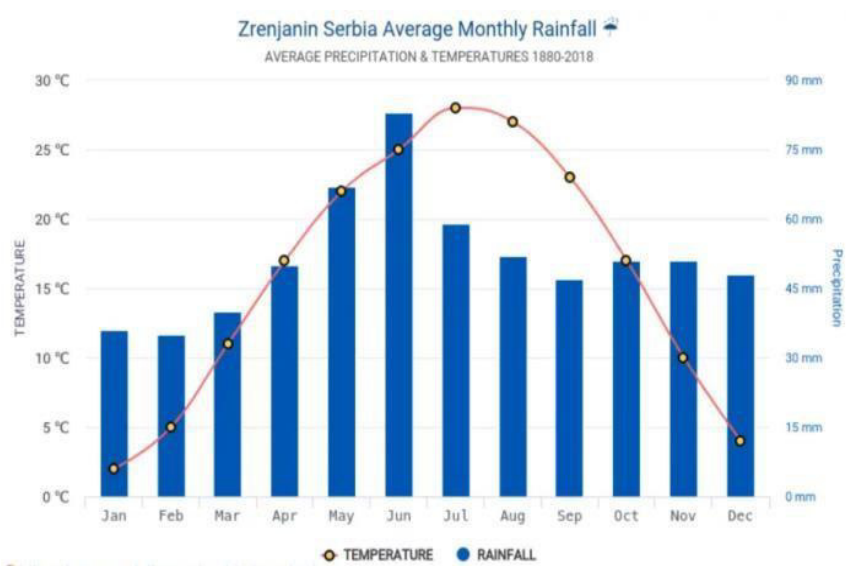


Figure 4. Climograph of monthly averages climate data
Temperature and precipitation in Zrenjanin, a basic climate data set 1880-2018 for Zrenjanin [18]

In Zrenjanin, in general, summers are warm, the winters are dry and cold, and during the year is usually partly cloudy. Over the year, the temperature was variants from 2°C to 28°C, and it rarely goes under -10°C and above 33°C [5].

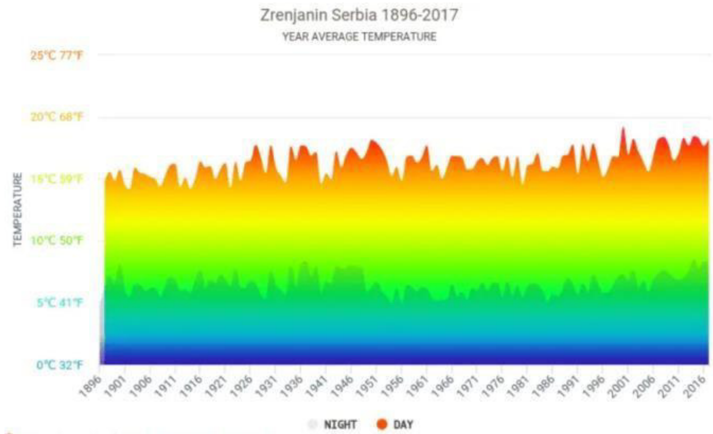


Figure 5. Average temperature in Zrenjanin over the years
Average Weather in Zrenjanin, Serbia Climatological information about changes of temperature over the years in Zrenjanin

Figures (6) and (7) illustrate the different climatic parameters such as temperature, relative humidity and wind as well as the $PM_{2.5}$ and PM_{10} at various times, August and September, respectively.

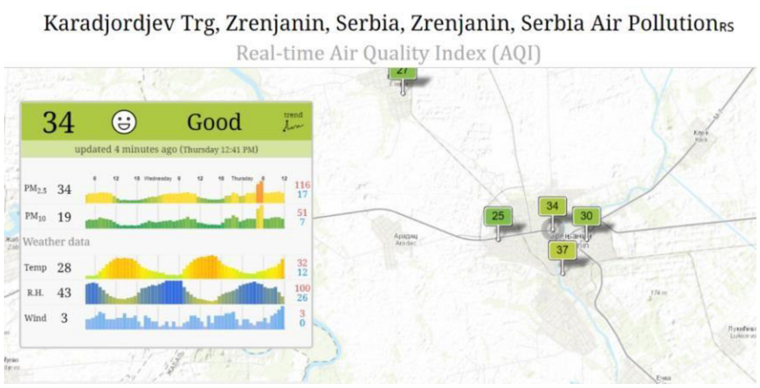


Figure 6. Data in Zrenjanin in Summer time (August)

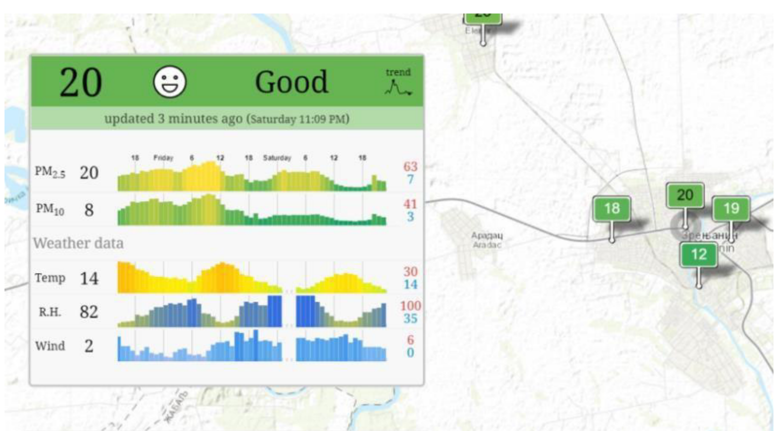


Figure 7. Data about Zrenjanin, in September [19]

Such a picture of the different air pollution levels in Zrenjanin is a logical consequence of air pollution and the mixed influence of microclimate, substrate and geo-physical features, as well as the distribution of "green" areas and objects. According to the qualitative and characterization of lichens, a qualitative assessment of lichen sensibility to air pollution has been made.

LICHENS AS AIR POLLUTION BIOMONITORS IN SERBIA

Biological monitoring is based on the detection and monitoring of changes that occur on different levels of the biological organization for living beings under the influence of pollutants [20]. Lichens are indicator organisms that have significant use in the bioindication of air quality. Not all lichen species are equally likely to indicate different levels of air pollution. Previously conducted studies have shown that certain species of lichens are sensitive to air pollutants in the atmosphere while other ones are resistant to them [21], [22].

Epiphytic lichens are defined as "permanent control systems" for estimating air pollution [23]. They are extremely sensitive to environmental changes because of their physiologies [24]. Lichens are the most used species in bioindication to detect and monitor air quality. The sensitivity of lichens is related to their biological characteristics due to the lack of cuticle and stomata which allows pollutants to penetrate the whole surface of the organism [1], [25]; [26]; [27]; [28].

Bioindication techniques have been established based on the composition of the lichenic flora [29], mainly the Shannon diversity index (H') [30], the lichen diversity value index (LDV) [31] and the atmospheric purity index (IAP) [32]. These indices are used to estimate air pollution levels that affect lichen diversity [25]; [28], [33]; [34], so that some environmental sources of pollution can be identified [3]; [35].

Loppi & Corsini [25] mentioned that lichen growth can be affected by different gaseous air pollutants such as: high sulfur dioxide concentration, carbon compounds in smoke, fluorides, car fumes (carbon monoxide, oxides of nitrogen, lead containing compounds, hydrocarbons) and dust, photochemical smog (ozone, peroxyacetyl nitrate, nitrogen oxides etc.), heavy metals (iron, lead, zinc, and copper), radioactive isotopes of metals (radionuclides), agricultural chemicals (such as pesticides, especially fungicides, and fertilizers).

Generally, it's thought-about that the most reasons for categorization of lichens as vulnerable organisms are disappearance and contamination of their environments primarily caused by humans, because of pollution of the atmosphere, industrialized agriculture, unfavourable biology practices and phylogeny alterations of huge habitat areas. All of those problems have led to the degradation of lichen habitats. In Serbia there are currently around 586 species of lichens. [10]

Lichenoflora in Vojvodina, including bank region of the River Tamiš and the Danube-Tisza-Danube Canal hydrosystem has been explored randomly [38], [39], [40], and more systematically within the study of former Yugoslavia lichen flora [41], [42], [43].

Lichens are used as an environmental biological indicator or the bioindicators for the pollution worldwide. In case that air is a lot polluted with for example SO_2, there won't be any presents of lichen, only the green algae can be found. Because of their sensitivity to SO_2 they can be considered, and used as a bioindicatorsof air quality and pollution. On the other hand, in case that air is clean, and air quality is good, lichens become abundant, which means that in absence of pollution, lichens are presence. If the lichens are smaller and less variety, environment in more polluted. Lichens are sensitive to atmospheric pollution because they get their nutrients and water from wet and dry atmospheric deposition. [44]

Based on the sizes of lichens, they can be classified in two groups: Microlichens and Macrolichens.

Microlichens: are really small, and not so easily defined because of impossibility of seeing their structure and physical characteristic with the naked eye.

Macrolichens: Because of their size, they can be easily defined and observed only with the naked eye.

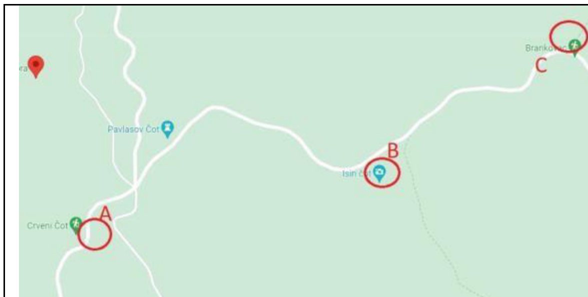
Based on their growth forms lichens can be: Crustose, Folios and Fruticose, and on the basis of substrate on which they grow, they can be classified as: Corticoloua, Ramicolous, Legnicolous, Saxicolous, Musicolous, Terricolous, and Follicolous. Methods which can be used for identification of lichens are:

- Microscopic Approaches: Morphology, Anatomy
- Chemical Approaches: Colour spot test, TLC, HPTLC, HPLC
- Molecular Approaches: PCR genotyping and DNA Barcoding [45]

Many studies on air quality are based on testing of lichens, in which a large number of papers have described the air quality level in urban areas [46], [47], [48], [49], [50], [51], [52]. Degtjarenko et al. [53] suggested that lichen growth form, reproductive strategy, and tolerance to substrate pH could serve as potential tools for indicating the effects of dust pollution. The study conducted by Szwed et al. [54] showed a high level of lichen sensitivity to air quality changes created by anthropogenic impact. In different studies of biomonitoring of air quality, the degree of urbanization and traffic density are the basic causes of pollution in urban areas [55], [56]. Lichenological study in Serbia is still developing. Basic groundwork must be comprehended in order to meet the nation's needs and also to strive towards the biotechnology industry.

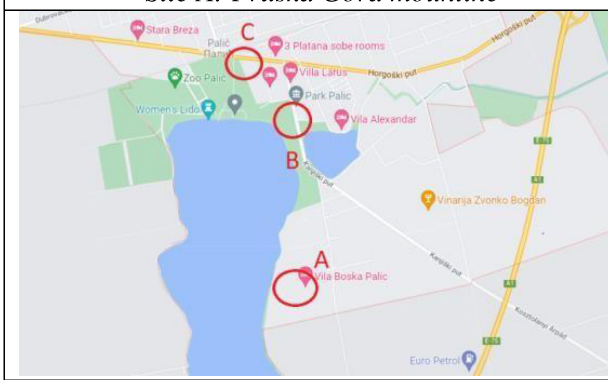
MATERIALS AND METHODS

Sites of collecting samples: The lichen samples were collected from four different climatic and topological conditions sites: Site A: Fruska Gora mountine, Site B: Silver lake, Site C: Palic lake and Site D: Sremska Mitrovica city as shown in the Figure (8).

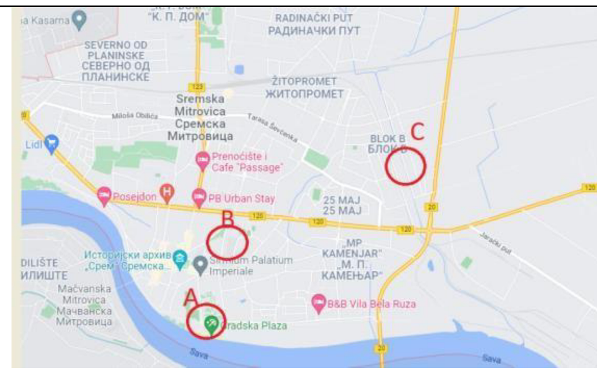


Site A: Fruska Gora mountine

Site B: Silver Lake



Site C: Palic Lake



Site D: Sremska Mitrovica city

Figure 8. The sites of lichen samples collections presented by red circles

Lichen samples in Sremska Mitrovica city, Fruska Gora mountine, Palic Lake and Silver Lake were collected from different trunk of various trees at different locations. The investigated sites are located in the urban part of Sremska Mitrovica, starting from the centre of town and close to Sava River (Figure 8).

RESULTS AND DISCUSSION

At four investigated sites, various lichen taxa from different genera were found. The most frequent and dominant as well as common taxa in these four sites of collections were *Rhizocarpon geographicum, Lecanora muralis, Lecanora muralis, Rhizocarpon geographicum, Xanthoria parietina and Xanthoria candelaria*.

The presence of lichens indicates that the air quality of the study sites (Sremska Mitrovica city, Fruska Gora mountine, Palic Lake and Silver Lake) which it illustrated a quite good. Also, it was concluded that the presence of epiphytic lichens plays an important role in determining the different degree in air quality. The following Figures (from 9 to 13) will demonstrate some common samples of collected lichens in the investigated sites.

SAMPLE COLLECTION OF LICHENS FROM FRUSKA GORA MOUNTINE SITE

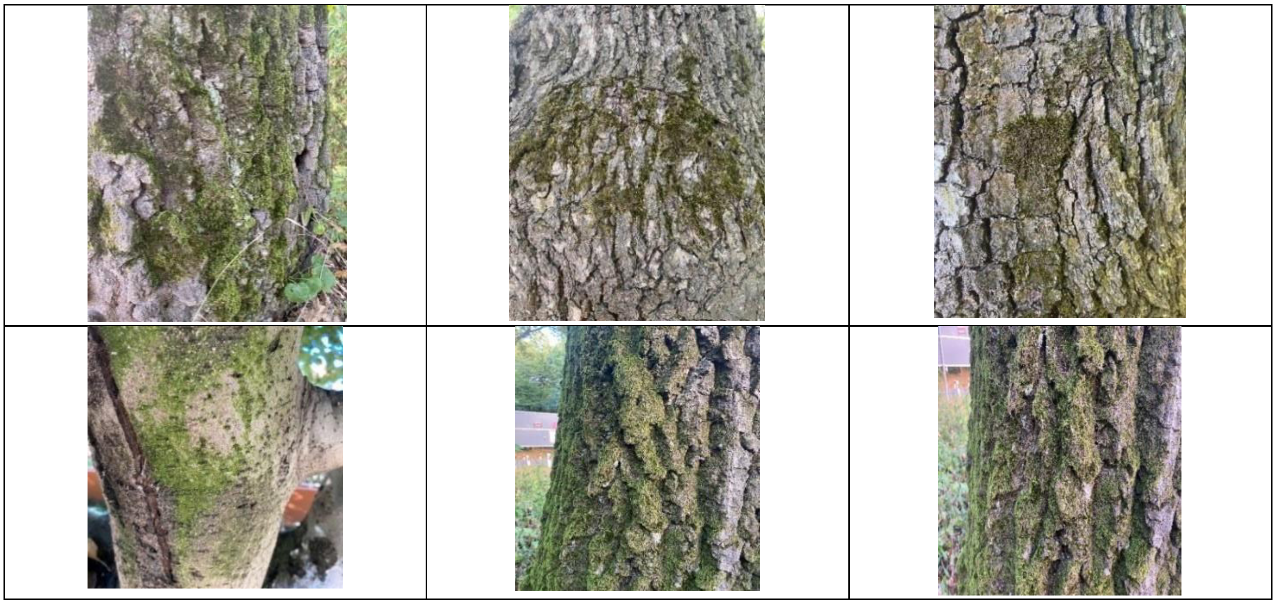


Figure 9. Lichens in Fruska Gora mountine

SAMPLE COLLECTION OF LICHENS FROM SREMSKS MITROVICA TOWN SITE

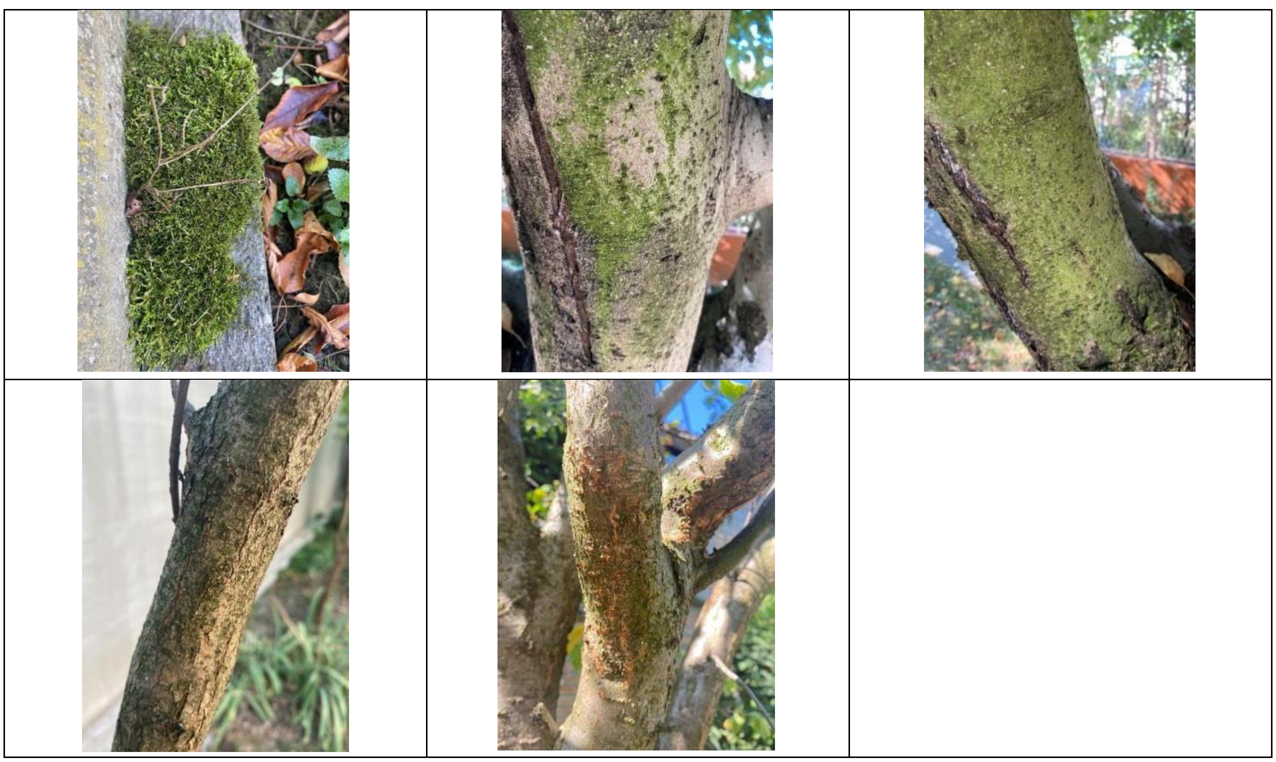


Figure 10. Lichen semples from Sremsks Mitrovica town

SAMPLE COLLECTION OF LICHENS FROM SAVA RIVER IN SREMSKA MITROVICA SITE

Figure 11. Lichens near Sava River in Sremska Mitrovica

SAMPLE COLLECTION OF LICHENS FROM PALIC LAKE SITE

Figure 12. Lichens close to Palic Lake

COLLECTION OF LICHENS FROM SILVER LAKE SITE

Figure 13. Lichens close to Silver Lake

Generally among the distribution of lichens throughout the four collected sites, the Site A: Fruska Gora mountine contained the highest amount of lichens. The distributions of lichens at the Site D: Sremska Mitrovica city were differentially found between the collected points. The C point showed the lowestlichens content than the other two points. A point was the site where the highest lichen population is found. Finally, it was found that the distribution of lichens at Site D: Sremska Mitrovica city was lower than in others sites. So, high ambient concentrations of pollutants have been associated by international epidemiological studies with various negative health impacts.

CONCLUSIONS

The areas from where lichens samples were collected are urban settlement and without much and large industry and traffic. A bioindication and physical-chemical investigation of air pollution in Zrenjanin has not been completed yet. At different investigated sites a lot of lichen taxa were collected from various genera. The most frequent lichen taxa are: *Rhizocarpon geographicum, Lecanora muralis, Lecanora muralis, Rhizocarpon geographicum, Xanthoria parietina and Xanthoria candelaria*. The presence of lichen indicates that the air quality in these sites (Sremska Mitrovica city, Fruska Gora mountine, Palic Lake and Silver Lake)is quite good. It was concluded that the presence of epiphytic lichens plays an important role in determining and distinguish between the air pollution at the different areas of collections. Finally, the need for further studies on lichens is suggested as a basis for their effective protection and conservation in relation with the climatic changes and air quality.

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