11th International Conference on Renewable Electrical Power Sources

PROCEEDINGS

Editor Dr Milica Vlahović

Belgrade, November 02–03, 2023

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on Renewable Electrical Power Sources

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on Renewable Electrical Power Sources

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FOREWORD

The conditions created by the development of technologies in which modern man lives have led to a complex and paradoxical effect: that by removing obstacles on the way to a more comfortable, simpler, faster and more efficient life and way of working, man also generates numerous misfortunes, attracting dark clouds of threats to the survival of the planet and humanity. The question that concerns and affects all of us - all people, all living beings, systems in which life takes place, large and small, strong and weak - boils down to the problem of the negative impact of man on the environment; this issue invites us to an urgent solution by looking at the causes, proposing solutions, evaluating them, changing approaches and ways of thinking, as well as drawing correct conclusions. Simply put, by adapting nature to one's own needs, man threatens and damages it. That is why, with the joint efforts of all of us, individuals, organizations and states, it is necessary to take all possible measures to immediately prevent the negative effects that are ahead of us.

The importance of renewable sources of electricity, which this international conference focuses on, is noticeable from two angles: the first - it is certain that fossil fuels as a resource will disappear and it is necessary to find alternative sources, the second - the use of renewable energy sources by its essence implies "clean" technology that significantly contributes to reducing CO_2 emissions and thus mitigating climate change and reducing pollution, while encouraging social and economic development in all spheres of life.

The 11th International Conference on Renewable Electrical Power Sources is organized by the Society for Renewable Electrical Power Sources (DOIEE) at SMEITS, with co-organizers: The Institute of Architecture and Urban & Spatial Planning of Serbia (IAUS) and the Chamber of Commerce and Industry of Serbia, with the support of the Ministry of Science, Technological Development and Innovation of the Republic of Serbia.

The registered participants designed their papers according to the given conference topics:
- Energy sources and energy storage;
- Energy efficiency in the context of use of renewable energy sources (RES);
- Environment, sustainability and policy;
- Applications and services.

Eminent authors - scientists, teachers, experts in this field from fifteen different countries: Algeria, Belgium, Bosnia and Herzegovina, China, Croatia, Greece, Hungary, India, Portugal, Saudi Arabia, Serbia, Slovenia, Spain, the United Arab Emirates, and Ukraine, contributed to the conference through sixty-nine papers that were reviewed by the Scientific Committee of the Conference, and after the review process were accepted for presentation at the conference and for publication in the proceedings.

At the end of this short message and at the beginning of the proceedings I believe that it can be proudly said that scientists, researchers, policy makers and industry experts gathered in one place, in order to exchange experiences and knowledge with the aim of promoting scientific and professional ideas and results of research, technology improvement for the use of RES, promoting the rational use of electricity, affirming and proposing inventive solutions in the field of sustainable sources of electricity.

Belgrade, *Milica Vlahović*
November 2023

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RAZMATRANJE PRISUSTVA FENANTRENA U OPŠTINI BOR NA BAZI NJEGOVOG SADRŽAJA U LIŠĆU I STABLJIKAMA HEDERA HELIX L.

A CONSIDERATION OF PHENANTHRENE PRESENCE IN BOR'S MUNICIPALITY BASED ON ITS CONTENT IN LEAVES AND STEMS OF HEDERA HELIX L.

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Sažetak

U ovom radu analizirani su neoprani uzorci listova i stabljikama otrovnog bršljana, Hedera helix (Hh), koji prirodno raste na području grada Bora i okoline na sadržaj fenentrena (Phe), kao opasnog polutanta iz grupe policikličnih aromatičnih ugljovodonika (PAU). Koncentracije, tj. Σ Phe na svim ispitivanim lokacijama bila je značajno veća u listovima nego u stabljikama: 1084,28 mg/kg i 675,08 mg/kg, respektivno. Najveće koncentracije u listovima detektovane su na lokacijama: BN (107,42 mg/kg), SN (190,15 mg/kg), O (220,82 mg/kg) i NS (265,03 mg/kg). Na osnovu izračunatog faktora R i dobijenih Pearson-ovih korelacionih koeficijenata, pokazalo se da su izvori odgovorni za prisustvo Phe kod listova i stabljika Hh iz opštine Bor brojni - pored rudarskog metalurškog kompleksa (sa topionicom i gradskom toplanom, kao glavnim izvorima zagađenja), ostali izvori su najverovatnije: induvidualna ložišta i saobraćaj. Konačno, Phe (kao jedan od nisko-molekularnih PAU), mogao je doći u ispitivane biljne delove ne samo iz atmosfere već i iz zemljišta.

Ključne reči: *Fenantren; Hedera helix; PAU; faktor R; Pearson-ova corelaciona analiza*

Abstract

In this work, unwashed samples of leaves and stems of poison ivy, Hedera helix *(Hh), which grows naturally in the area of the town of Bor and its surroundings, were analyzed for the content of phenanthrene (Phe), as a dangerous pollutant belonging to the group of polycyclic aromatic hydrocarbons (PAHs). The concentrations of Phe at all investigated sites were significantly higher in leaves than in stems: 1084.28 μg/kg and 675.08 μg/kg, respectively. The highest concentrations in the leaves were detected at the sites: BN (107.42 μg/kg), SN (190.15 μg/kg), O (220.82 μg/kg) and NS (265.03 μg/kg). Based on the calculated factor R and Pearson's correlation coefficients, it is turned out that the sources of Phe for leaves and stems in Hh from the municipality of Bor were numerous - in addition to the emissions from the mining and metallurgical complex (with the smelting and city heating plant, as the main sources of pollution), the other sources are most likely: the domestic heating and traffic. Finally, Phe (as one of the low-molecular weight PAHs) may come in the investigated plant parts not only from the atmosphere but also from the soil.*

Key words: *Phenanthrene;* Hedera helix*; PAHs; factor R; Pearson's correlation analysis*

1 INTRODUCTION

Phenanthrene (Phe) is one of 16 priority polycyclic aromatic hydrocarbons (PAHs) listed as priority pollutants by the United States Environmental Protection Agency (US EPA) [1-3]. It is a low molecule weight (LMW) PAH compound, which is composed of three benzene rings. Phenan-

threne is not classified as a possible carcinogen by the US EPA, but, at the same time, it is considered as a probable carcinogen to humans with extremely low potential [4].

Like most other PAHs, Phe is released into the environment by natural activities such as volcanic eruptions and forest fires, as well as by anthropogenic activities, especially the burning of fossil fuels and derived products [4-6].

In the area of Bor's municipality, the possible sources of Phe may be the main economical activities - mining and metallurgy, the city heating plant, but also the domestic heating in the rural zones, as well as the traffic [2,6,7]. Due to these reasons, the investigation of Phe, was carried out at the locations at different distances from the city heating plant, as one of the main sources to hold responsible for Phe' presence in the environment. Practically, the sampling was carried out at nine locations; the urban-industrial (UI) zone included four sampling sites: the flotation tailings pond (FJ), Bolničko naselje (BN), Slatinsko naselje (SN) and Naselje Sunce (NS), while the rural (R) zone included five rural settlements: Oštrelj (O), Slatina (S), Borsko jezero (BJ), Krivelj (K) and Gornjane (G) (Fig. 1).

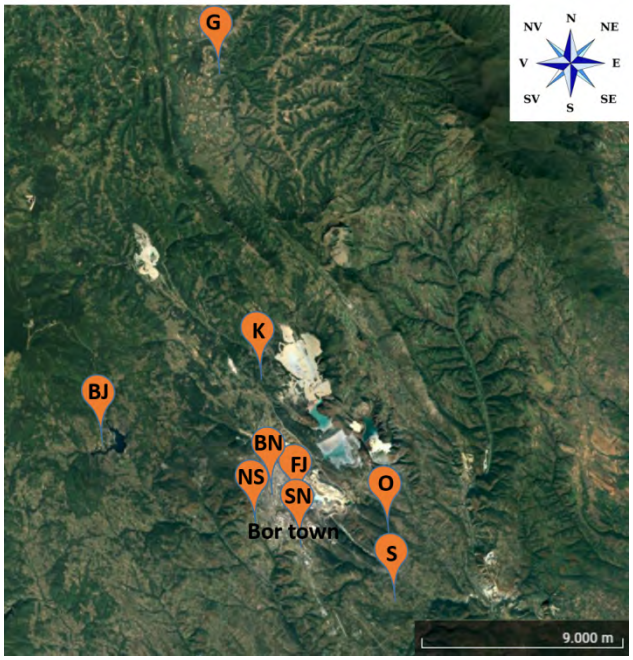

Fig. 1 Map of the investigated territory

2 MATERIALS AND METHODS

2.1 Sample collection, preparation and analysis

In September 2020 the samples of leaf and stem of Hh were collected from the named selected locations. At each site, 3 plants were taken to obtain representative samples for both analyzed plant parts. The unwashed plant material was transported to the laboratory for further analysis. Samples of leaves and stems were air-dried for a period of few months until a constant weight was reached, and then they were homogenized in a laboratory mill. The prepared samples were kept at a temperature of 4 □C until chemical analysis. The QuEChERS (Quick, Effective, Cheap, Easy, Rugged, Safe) method was used for Phe extraction from the prepared samples, after which the samples were purified. Finally, determination of Phe was performed by the gas chromatographic-mass spectrometric (GC/MS) method on 7890/7000B GC-MS/MS triple quadripole instrument equipped with a Combi PAL autosampler and HP-5MS capillary column [6].

For the processing of Hh samples taken from the investigated locations, i.e., in order to assess the degree of Phe pollution, the ratio of metal concentrations between aboveground plant parts (factor R) was used. This ratio is commonly calculated using the equation: $R_{leaf/stem}=C_{leaf}/C_{stem}$, where C_{leaf} and C_{stem} represent the concentrations of the pollutant (in this case, Phe) in the corresponding

samples of leaf and stem. A value of factor R greater than 1 indicates pollution of atmospheric origin [8,9].

In order to determine the possible relationship between the content of Phe in plant parts and the distance from the main sources of pollution in the whole region (the vicinal heating and smelting plants placed in the mining-metallurgical complex in the town of Bor), the statistical method of Pearson's correlation analysis was performed in IBM SPSS program, version 20 [10-12].

3 RESULTS AND DISSCUSION

The concentrations of Phe in the leaves and stems samples of Hh are given in Table 1. At all investigated locations, the concentrations of Phe in the leaves of Hh ranged from 42.18 μg/kg at the site BJ to 265.03 μg/kg at the site NS, while in stems of Hh the concentrations of Phe ranged from 25.61 μg/kg at the site NS to 156.84 μg/kg at the site BN.

Comparing the concentrations of Phe at all examined sites, the sum was significantly higher in leaves (1084.28 μg/kg) than in stems (675.08 μg/kg). The highest concentrations were detected in the leaves at the following locations: BN (107.42 μg/kg), SN (190.15 μg/kg), O (220.82 μg/kg), and NS (265.03 μg/kg).

Interestingly, the concentration of Phe was the highest in the leaves at the site NS of Hh, while the lowest was in the stems at the same site.

Table 1 The concentration of Phe (μg/kg, dw) in the leaf and stem samples of Hedera helix L. together with the calculated factor R

Location	The distance from the smelter and heating plants (km)	Leaf	Stem	R (C_{leaf}/C_{stem})
FJ	0.7	78.82	79.66	0.99
BN	1.3	107.42	156.84	0.68
SN	3.2	190.15	63.12	3.01
NS	3.6	265.03	25.61	10.35
O	4.5	220.82	46.85	4.71
S	6.5	60.64	75.41	0.80
BJ	7.0	42.18	91.21	0.46
K	8.0	75.17	62.46	1.20
G	19.0	44.05	73.93	0.60

In Table 1, the values of the calculated factor R are given too. The values greater than 1 were obtained at 4 out of 9 locations: SN (3.01), NS (10.35), O (4.71) and K (1.20), which supported the assumption of pollution of atmospheric origin at many sites. However, for 5 other sites, factor R was not provided such evidence, which was a first confirmation of previous investigations, namely, that:

1) plants may absorb LMW PAHs not only from the atmosphere but also through roots, from the soil [1,2], and

2) in Bor's municipality the mining-metallurgical complex cannot be considered as the only source of PAH/Phe pollution [2,7].

The cofirmation of the second allegation can be found in the results of Pearson's correlation analysis, which showed that the concentrations of Phe in both plant parts were in negative correlations with the distance from the main sources of pollution, which means that with distance increasing, the concentrations of Phe decreased. In some sense, it was expectable and it can be said that the

concentrations of Phe were in some connection with the emissions from both plant facilities. However, given that only the concentrations in leaves were in a good correlation (p = -0.440) with the distance (but still not at the statistically significant level) it can be supposed that the influence of plants' emissions was more significant in the case of Phe in leaves, than in the case of Phe in stems (p = -0.150, very weak, insignificant correlation).

4 CONCLUSION

The combination of the results for factor R, and for Pearson's correlation coefficients, offered a clear picture of Phe pollution in the region of Bor. Namely, it was obvious that the origin of Phe in leaves and stems in Hh from Bor's municipality was different and cannot be associated only with the main sources, such as the two plants in the mining-metallurgical complex in the town of Bor. The other sources are the most probably: domestic heating and traffic. The results of this work also confirmed that the origin of Phe (as one of LMW PAH compounds) in Hh leaves and stems may be not only from the atmosphere but also from the soil.

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ABBREVIATIONS

Hedera helix - Hh
Phenantrene - Phe
Polycyclic aromatic hydrocarbons - PAHs
Low molecule weight PAH - LMW PAH compound
United States Environmental Protection Agency - US EPA
Quick, Effective, Cheap, Easy, Rugged, Safe - QuEChERS
Gas chromatographic-mass spectrometry - GC/MS
R factor - the ratio that is commonly calculated using the equation: $R_{leaf/stem}=C_{leaf}/C_{stem}$, where C_{leaf} and C_{stem} represent the concentrations of the pollutant in the corresponding samples of leaf and stem
IBM SPSS – a statistical program

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