



University of Belgrade, Technical Faculty in Bor
29th International Conference Ecological Truth
& Environmental Research



EcoTER'22

Proceedings



Editor

Prof. Dr Snežana Šerbula

21-24 June 2022, Hotel Sunce, Sokobanja, Serbia



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PREFACE

In today's world, the environment has been endangered by the use of outdated technology, fossil fuels and environmental law violations. Therefore, environmental and many other scientists all over the world have been concerned about finding sustainable technology in resolving these issues. That is why environmental research and ecological truth are at the focus of the 29th International Conference Ecological Truth & Environmental Research 2022 (EcoTER'22), which will be held in Sokobanja, Serbia, 21–24 June 2022. On behalf of the Organizing Committee, it is a great honor and pleasure to wish all the participants a warm welcome to the Conference.

We hope to convey the message of the conference, which is that a transformation of attitudes and behavior would bring the necessary changes. This is also an opportunity for the participants who are experts in this field to exchange their experiences, expertise and ideas, and also to consider the possibilities for their collaborative research.

The 29th International Conference Ecological Truth & Environmental Research 2022 is organized by the University of Belgrade, Technical Faculty in Bor, and co-organized by the University of Banja Luka, Faculty of Technology, the University of Montenegro, Faculty of Metallurgy and Technology – Podgorica, the University of Zagreb, Faculty of Metallurgy – Sisak, the University of Pristina, Faculty of Technical Sciences – Kosovska Mitrovica and the Association of Young Researchers, Bor.

These proceedings include 85 papers from the authors coming from the universities, research institutes and industries in 6 countries: Bulgaria, Italia, Albania, Bosnia and Herzegovina, Montenegro and Serbia.

As a part of this year's conference, the 4th Student section – EcoTERS'22 is being held. We appreciate the contribution of the students and their mentors who have also participated in the Conference.

Financial assistance provided by the Ministry of Education, Science and Technological Development of the Republic of Serbia is gratefully acknowledged by the Organizing Committee of the EcoTER'22 conference.

The support of the Platinum donor and their willingness and ability to cooperate have been of great importance for the success of EcoTER'22. The Organizing Committee would like to extend their appreciation and gratitude to the Platinum donor of the Conference for their donation and support.

We appreciate the effort of all the authors who have contributed to these Proceedings. We would also like to express our gratitude to the members of the scientific and organizing committees, reviewers, speakers, chairpersons and all the Conference participants for their support to EcoTER'22. Sincere thanks go to all the people who have contributed to the successful organization of EcoTER'22.

Prof. Snežana Šerbula,

President of the Organizing Committee

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THE CONTENT OF DANGEROUS CONTAMINANTS PAHs IN THE SOIL AND ROOTS OF *HEDERA HELIX* IN SLATINA (BOR'S MUNICIPALITY)

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Abstract

The samples of roots and soil from the rooting zone of poison ivy (Hedera helix) were collected from the rural settlement of Slatina, near Bor town, with the aim to determine the content of 16 priority polycyclic aromatic hydrocarbons (PAHs); they were analyzed by gas chromatographic-mass spectrometric method. Generally, the concentrations of 16 PAHs in the sample of roots (from n.d. to 491.06 µg/kg) were much higher than in the soil (from n.d. to 98.88 µg/kg). The accumulation rates in the roots of the investigated plant species were determined using bio-concentration factor (BCF). The highest accumulation rates for 16 PAHs were found in the cases of acenaphthene, fluorene, fluoranthene and pyrene. For these compounds the investigated plant may be useful in the root phytoaccumulation, practically in the soil phytostabilization. Also, Hedera helix can be successfully used in phytostabilization of the compounds such as anthracene, dibenzo(a,h)anthracene, and the sum of benzo(k)fluoranthene and benzo(b)fluoranthene, because it accumulated these compounds very efficiently (the extraction from the soil was maximal). However more research in the future is needed for the formulation of more safe conclusions about the accumulation capacities of Hedera helix.

Keywords: GC/MS, *Hedera helix*, BCF, PAHs

INTRODUCTION

The Copper Mining and Smelting Complex Bor more than 100 years has had strong impact on the environment pollution of Bor's municipality by heavy metals [1].

The aim of this research was to determine the content of specific and dangerous organic pollutants such as 16 polycyclic aromatic hydrocarbons (PAHs) in the soil and roots of *Hedera helix* in the rural settlement of Slatina, which is located 6.5 km away from the Bor town and from the heating plant and the copper smelter, as possible sources of PAH pollution. Also, according to Alagić *et al.* [2], one of the main sources of pollution in the rural area is domestic heating based on wood combustion. Additionally, it was important to determine the level of soil pollution according to the classification given in Table 1, and to establish the related accumulation rates (which is important for phytoremediation).

In the United States Environmental Protection Agency (USEPA), 16 PAHs have been included in the list of pollutants of highest priority. It includes the following compounds:

naphthalene (Nap), acenaphthylene (Acy), acenaphthene (Ace), fluorene (Flr), anthracene (Ant), phenanthrene (Phe), fluoranthene (Flt), pyrene (Pyr), benzo(a)anthracene (BaA), chrysene (CHR), benzo(a)pyrene (BaP), benzo(k)fluoranthene (BkF), benzo(b)fluoranthene (BbF), indeno(1,2,3-c,d)pyrene (IcP), benzo(g,h,i)perylene (BgP), and dibenzo(a,h)anthracene (DhA). USEPA classified 7 PAHs as possible carcinogens: BaA, CHR, BaP, BbF, BkF, IcP and DhA [2–6].

Table 1 The level of soil pollution depending on the $\Sigma 16$ PAHs ($\mu\text{g}/\text{kg}$) [7]

Class of soil contamination	16 PAHs
Non-contaminated	<200
Weakly contaminated	200–600
Contaminated	600–1000
Heavily contaminated	>1000

MATERIALS AND METHODS

Sample collection, preparation and analyses

The samples of soils and roots of *Hedera helix* were collected from the chosen location at the end of September 2020. From the investigated site, 3 plants were taken; these samples were pooled to obtain a representative sample for roots and for the soil. All samples were placed into paper bags and transported to the laboratory. The roots were carefully cleaned from soil particles, and after that, they were washed with tap and distilled water. All samples were air-dried until constant weight, over a period of couple of months. In a laboratory mill were homogenized all dried samples. The samples of soils and roots were placed in sealed bags and stored at the fridge at 4°C until PAHs determination by gas chromatographic-mass spectrometric (GC/MS) method (before GC/MS analysis PAHs were extracted from the prepared samples using mixture water/acetonitrile and then all samples were purified).

The prepared samples of the soil and roots were analyzed on 7890/7000B GC-MS/MS triple quadrupole device equipped with a Combi PAL auto sampler and HP-5MS capillary column.

The bio-concentration factor (BCF) was used to estimate the accumulation rates of 16 PAHs in *Hedera helix* roots [2,3]. BCF was determined according to the equation (1):

$$BCF = \frac{C_{root}}{C_{soil}} \quad (1)$$

where C_{root} and C_{soil} are the concentrations ($\mu\text{g}/\text{kg}$, dry weight) of the compound in the root and in the corresponding soil. Namely, BCF values represent a first sign that the investigated plant may be useful for application in the root phytoextraction/phytoaccumulation.

RESULTS AND DISCUSSION

The total concentrations of 16 priority PAHs in the soil and root samples at the investigated site ranged from 4.27–98.88 $\mu\text{g}/\text{kg}$ and from 1.74–491.06 $\mu\text{g}/\text{kg}$, respectively

(Table 2). The concentrations of 16 PAHs for the soil from the sampling site S decreased in the order as follows: 98.88 µg/kg (Phe), 72.43 µg/kg (Nap), 36.96 (Flt), 32.17 (BaA), 19.54 (Flr), 10.15 (Pyr), 10.09 (BaP), 9.78 (Acy), 4.27 (Ace). Anthracene was not registered in the soil, as well as heavier compounds such as: CHR, Bkf+BbF, IcP, BgP and DhA.

The concentrations of 16 PAHs in the roots of poison ivy decreased in the order as follows: 491.06 µg/kg (Flr), 190.26 (Flt), 94.31 (DhA), 91.31 (Phe), 83.97 (Pyr), 30.77 (Nap), 16.39 (Ant), and 1.74 (BkF+BbF). The concentrations of Acy, BaA, CHR, BaP, IcP and BgP, were not registered in the roots.

The results of the obtained analyses clearly showed that the sum of 16 PAHs was significantly higher in the roots than in the soil.

Table 2 The concentrations of 16 priority PAHs (µg/kg, dw) in the soil and root samples of *Hedera helix* together with the calculated BCFs

PAHs/Sample	Soil	Root	BCF
Nap ^a	72.43 ± 1.31	30.77 ± 0.36	0.4
Acy	9.78 ± 0.55	nd	nc
Ace	4.27 ± 0.62	75.60 ± 9.21	17.7
Flr	19.54 ± 1.39	491.06 ± 45.56	25.1
Ant ^a	nd	16.39 ± 1.91	nc
Phe ^a	98.88 ± 5.88	91.31 ± 5.70	0.9
Flt ^a	36.96 ± 2.15	190.26 ± 19.24	5.1
Pyr	10.15 ± 0.90	83.97 ± 3.58	8.3
BaA ^{a,b}	32.17 ± 1.09	nd	nc
CHR ^{a,b}	nd	nd	nc
BaP ^{a,b}	10.09 ± 0.13	nd	nc
Bkf+Bbf ^{a,b}	nd	1.74 ± 0.45	nc
IcP ^{a,b}	nd	nd	nc
BgP ^a	nd	nd	nc
DhA ^b	nd	94.31 ± 3.79	nc
Σ 16 PAHs	294.28	1075.4	
Σ 10 PAHs	250.54	330.46	
Σ 7 PAHs	42.26	0.0	

nd – not detectable; nc – not calculable

^a – Σ10 PAHs (Nap, Ant, Phe, Flt, BaA, CHR, BaP, BkF, IcP and BgP)

^b – Σ7 carcinogenic PAHs (USEPA) (BaA, CHR, BaP, BbF, BkF, IcP and DhA)

PAHs such as CHR, IcP and BgP were not registered in the samples of soil and roots of *Hedera helix*. The most abundant PAH in the soil sample was Phe (98.88 µg/kg), while in the root sample the most abundant was Flr (491.06 µg/kg). The dominant compounds among all 16 PAHs in soil were Phe, Nap, Flt, and BaA, but in roots were as follows: Flr, Flt, DhA and Phe.

As mentioned, the total concentration of 16 PAHs in the soil sample was 294.28 µg/kg; based on the level of soil pollution (Table 1) this soil can be classified as weakly contaminated.

The concentrations for $\Sigma 10$ PAHs (Nap, Ant, Phe, Flt, BaA, CHR, BaP, BkF, IcP and BgP) and $\Sigma 7$ cancerogenic PAHs (BaA, CHR, BaP, BbF, BkF, IcP and DhA) were not exceeding the defined maximum allowed concentrations (MAC) of 1000 $\mu\text{g}/\text{kg}$ [8–12] and 300 $\mu\text{g}/\text{kg}$ [9,10,13], respectively.

The values of BCFs for 16 PAHs are also given in Table 2. The highest accumulation rates for all investigated PAHs were found in the cases of Flr (25.1), Ace (17.7), Pyr (8.3) and Flt (5.1). The very high values of BCFs for these compounds were a safe sign that the investigated plant may be very useful for the application in the root phytoextraction/phytoaccumulation; the compounds such as Ant, BkF+BbF and DhA were totally extracted from the soil and accumulated in the roots, so, it can be concluded that *Hedera helix* can be successfully used in their phytostabilization too; obviously, it can keep large quantities of many PAHs in its roots.

The concentrations for Nap and Phe were higher in the soil sample than in the roots; therefore BCF values were less than 1. In the cases of Acy, BaA and BaP the concentrations were higher in the soil sample - in fact, they were not registered in the roots and BCF values were not calculable.

CONCLUSION

Observing all the tested compounds (16 PAHs), the results in this study showed that the concentrations of CHR, IcP and BgP were not detected in both investigated samples. The highest concentrations were detected in the roots for Flr (491.06 $\mu\text{g}/\text{kg}$), Flt (190.26 $\mu\text{g}/\text{kg}$) and DhA (94.31 $\mu\text{g}/\text{kg}$), while in the soil, the highest concentration was for Phe (98.88 $\mu\text{g}/\text{kg}$). Based on the calculated BCFs, it was clear that the highest values were for Ace, Flr, Flt and Pyr (17.7, 25.1, 5.1 and 8.3, respectively) which means that the investigated plant may be useful in the root accumulation for these compounds, practically in the soil phytostabilization. For the compounds such as Ant, BkF+BbF, and DhA, BCF values were not calculable, because their soil concentrations were practically totally extracted, which signalize that *Hedera helix* is able to keep large quantities of these compounds in the roots and can be also successfully used in their phytostabilization. However, more research is needed for the formulation of more safe conclusions about PAH accumulation capacities of *Hedera helix*.

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