BEES AS ENVIRONMENTAL BIOINDICATORS: THE ASSESSMENT OF POLLUTION AND ECOLOGICAL RISK

Maja Došenović Marinković[1], Suzana Knežević[1], Milena Milojević[2], Aleksandra Milošević[3]

[1]Academy of Applied Studies Šabac, Unit for Agricultural and Business Studies and Tourism, Vojvode Putnika 56, Šabac, Republic of Serbia, s.knezevic@akademijasabac.edu.rs, m.d.marinkovic@akademijasabac.edu.rs
[2]Independent researcher, Belgrade, Republic of Serbia, milenaminorka23@gmail.com
[3]University of Belgrade, Faculty of Law, Bulevar Kralja Aleksandra 87, Belgrade, Republic of Serbia, alexandramilosevic77@gmail.com

REVIEW SCIENTIFIC PAPER

Received: 12 July 2026.
Accepted: 03 November 2026.
Published: 15 November 2026.
DOI: https://doi.org/10.63395/STEDConf15022026136D33

Corresponding Author: Suzana Knežević, Academy of Applied Studies Šabac, Unit for Agricultural and Business Studies and Tourism, Vojvode Putnika 56, Šabac, Republic of Serbia, s.knezevic@akademijasabac.edu.rs

Copyright © 2026 Maja Došenović Marinković et al., published by UNIVERSITY PIM. This work licensed under the Creative Commons Attribution-NonCommercial-NoDerivs 4.

Citation: Došenović Marinković, M., et al. (2026). Bees as Environmental Bioindicators: The Assessment of Pollution and Ecological Risk. In Kojić, D. & Sredić. D. (eds.) *Conference proceedings, International Conference on Social and Technological Development: STED 2026* (pp. 33-42). Trebinje, B&H: University PIM.

ABSTRACT

Honey bees (*Apis mellifera*) are reliable bioindicators of environmental quality due to their role as pollinators, their wide foraging range, and their continuous interaction with various components of the ecosystem. The aim of this paper is to examine the importance of honey bees as bioindicators by analysing the mechanisms of pollutant accumulation and their application in ecological risk assessment. During the collection of nectar, pollen, water, and plant resins, honey bees come into contact with pollutants originating from air, water, and soil, including heavy metals, pesticides, and microplastic particles, which can subsequently be detected in their tissues and bee products. In addition to chemical analyses, changes in the behaviour, physiological condition, and mortality of bee colonies represent important indicators of environmental contamination. Particular attention is given to pesticides, especially neonicotinoids, owing to their pronounced toxic and sublethal effects. Although research on the presence of microplastics in bee products is still evolving, current findings indicate their potential value in biomonitoring. Overall, honey bees represent an effective and cost-efficient tool for environmental biomonitoring, with considerable importance for ecological risk assessment and biodiversity conservation.

Keywords: bees, bioindicators, biomonitoring, environment, ecological risk.

INTRODUCTION

Honey bees play a vital role in maintaining the environment, biodiversity, and ecosystem functioning. Their importance extends beyond the production of food products to include a wide range of substances used in the pharmaceutical, cosmetic, and industrial sectors. Pollination by honey bees is a key ecological process in natural ecosystems, contributing to both the quality and yield of agricultural crops. In many countries, pollination is provided as an organised, contract-based service between crop producers and beekeepers. It also plays a crucial role in maintaining ecological balance and biological diversity. A large proportion of crops intended for human consumption depend, to varying degrees, on insect pollination, with honey bees serving as the primary pollinators. It has been estimated that approximately four million flowers must be visited to produce one kilogram of honey, while a single honey bee visits around 7,000 flowers per day [1]. Consequently, honey bees come into daily contact with extensive areas of soil, water, and vegetation, making them reliable bioindicators of environmental pollution [1]. A single bee colony can effectively „monitor" an area extending several kilometres from the hive, enabling relatively accurate assessments of local environmental contamination. Furthermore, honey bees respond rapidly to changes in environmental conditions, and alterations in colony size, behaviour, or mortality may be associated with increased levels of pollution. This review presents the findings of studies investigating honey bees and bee products as tools for environmental biomonitoring.

METHODOLOGY

The paper employs a review-based approach encompassing an analysis of the biological and ecological characteristics of the honey bee (*Apis mellifera*), including its taxonomic classification, developmental biology, and the organization of the honey bee colony. Particular emphasis is placed on the role of honey bees in the ecosystem and their interactions with plants, water, soil and air, thereby enabling an integrated assessment of environmental quality.

Taxonomy and Species Diversity

Bees (Apiformes) comprise approximately 20,000 species worldwide [2]. They inhabit all continents except Antarctica. The western honey bee, *Apis mellifera Linnaeus* (1758) belongs to the subfamily *Apinae* within the family *Apidae* [3].

The biological classification of the European honey bee (*Apis mellifera, L*), as described by Linnaeus, is presented in Table 1.

Table1 Taxonomic classification of the species *Apis mellifera L.* (translated and adapted from [4]).

CLASS	
Regnum (Kingdom)	*Animalia*
Phylum (Type)	*Arthropoda*
Subphylum (Subtype)	*Mandibulata (Hexapoda)*
Classis (Class)	*Insecta*
Subclassis (Subclass)	*Pterygota*
Ordo (Order)	*Hymenoptera*
Subordo (Suborder)	*Apocrita*
Infraordo (Group)	*Aculeata*
Superfamilia (Superfamily)	*Apoidea*
Familia (Family)	*Apidae (bumblebees and honey bees)*
Subfamilia (Subfamily)	*Apinae (honey bees)*
Tribus (Tribe)	*Apini*
Genus	*Apis*
Species	*Apis mellifera Linnaeus (1758)*

Apis mellifera carnica (Pollmann, 1879) –The Carniolan honey bee is a subspecies of *Apis mellifera*. Due to its efficiency in nectar foraging and honey production, it is currently one of the most widespread subspecies of the honey bee in Europe and beyond. Its body is covered with fine hairs and is well adapted to a variety of climatic conditions. In particular, it is adapted to survive long and cold winters [5].

The Biology of the Species

Honey bee belongs to the group of holometabolous insects. This means that all members of a bee colony must pass through specific developmental stages during their life cycle (egg, larva, pupa, and adult), as shown in Figure 1.

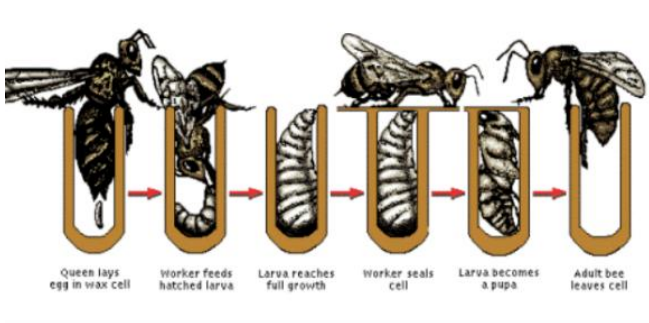


Figure 1 Holometabolous Development of the Honey Bee [6]

The complete development of the honey bee includes embryonic and post-embryonic periods. During embryonic development, which lasts three days, changes occur within the egg membranes. These processes result in the transformation of a single egg cell into a multicellular larva. After these transformations, the larva hatches by breaking through the egg membrane and enters the brood cell, marking the beginning of post-embryonic development. Post-embryonic development includes all subsequent developmental stages that take place outside the egg membranes.

The Structure and Organisation of the Honey Bee Colony

The honey bee is adapted to a social way of life. This colony consists of a single queen, two to three thousand drones (during the foraging season), and several tens of thousands of worker bees (Figure 2).

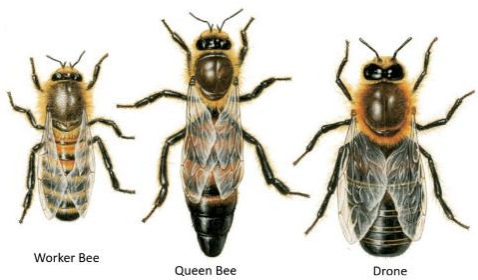


Figure 2 Worker Bee, Queen Bee and Drone (translated and adapted from [7])

The bee colony consists of both male and female members. The female members include the queen and worker bees, while the male members are drones. The queen is the only reproductively active female in the hive. She has the ability to secrete specific chemical substances (pheromones) that influence the development and behaviour of worker bees. In this way, the queen ensures the coordinated and integrated development of the bee colony.

Drones are the male members of the bee colony whose primary role is to fertilise the queen. The presence of drones in the hive stimulates worker activity and increases honey production. They also contribute to the thermoregulation of the hive, while drone brood serves as a reserve source of water and proteins. After mating with the queen, drones die.

Worker bees are the permanent and most numerous members of the bee colony, performing all functions within the colony except reproduction. In the first days after emergence, workers clean the cells and maintain hive hygiene, acting as hygienists. After this period, they take on the role of nurse bees, feeding the larvae and the queen. As they age, they begin to secrete wax and participate in comb construction, as well as in the processing of nectar into honey. In later life stages, they become hive guards. The oldest workers assume the role of foragers. They leave the hive and collect nectar, pollen, water, and propolis. During these activities, they can travel long distances and thereby contribute to plant pollination, which is of crucial importance for ecosystems and agriculture [8].

Honey bees possess a specific anatomical structure that becomes particularly important during the collection of nectar and pollen in nature. Bees have a specially adapted tibia and the first tarsal segment of the hind legs. The outer side of the tibia is concave, surrounded by a fringe of hairs. This structure is used by the bee to store pollen and is therefore referred to as the pollen basket (corbicula). On the upper part of the first tarsal segment, there is a spur-like projection used by the bee to press and pack the collected pollen into the tibia [9]. Without such specialised anatomical adaptations, bees would collect significantly less food, which would directly result in weaker brood development and a reduced population size of the bee colony.

The Role of Bees in the Ecosystem

The honey bee is the most economically important insect and, among other roles, serves as a pollinator of agricultural crops. As such, honey bees are crucial for maintaining biological diversity [10]. As pollinators, bees increase the yield of agricultural crops and also contribute to their quality. Through pollination of crops, bees improve their characteristics, including fruit shape and size, as well as acidity and sugar concentration.

In some parts of the world, such as the United States, the provision of commercial pollination services for agricultural crops is widely practiced. This service is considered economically profitable and is based on contractual agreements between crop owners and beekeepers. These contracts include information on the flowering stage of cultivated crops as well as any potentially wild vegetation within or surrounding the plantation; the average number of frames with bees and brood per colony at the beginning of the pollination service; the grower's commitment not to use pesticides that may be harmful to bees during their presence in the crop area; and an obligation to promptly inform beekeepers if pesticide application becomes necessary, along with other relevant provisions that ensure the protection of the rights and responsibilities of both contracting parties [8]. In Serbia, contract-based crop pollination is also practiced and is typically based on cooperation between larger companies and beekeeping associations.

Pollen of entomophilous plants (insect-pollinated plants) is heavier and stickier compared to pollen of anemophilous plants (wind-pollinated plants). According to Spürgin [11], approximately four honey bee colonies per hectare are required for efficient pollination. The attractiveness of cultivated plant flowers to honey bees depends on flower shape, size, colour, and scent; the flowering duration of the plant species; the distance of bee colonies from nectar sources; the availability of water sources; climatic conditions; colony strength; and the presence of wild and nectar-producing weed species [8]. In addition, bees contribute to the collection and production of honey, wax, propolis, pollen, royal jelly, and bee venom. All of these bee products are valuable natural resources in human nutrition and related applications [9]. As pollinating insects, bees play a significant role in the survival of rare plant species, and a healthy bee colony benefits many other organisms within the ecosystem [11].

Approximately one quarter of a honey bee colony, or about 10,000 worker bees, is involved in crop pollination. Each foraging bee performs an average of 12–15 flights per day. During a

single foraging trip, in order to collect nectar, a bee must visit around 100 apple blossoms (*Malus domestica*) or approximately 80 pear blossoms (*Pyrus communis*) to fill its honey stomach and secure sufficient reserves for its return to the hive [12]. On a daily basis, a single honey bee colony visits an average of 13,500,000 flowers. This finding highlights the crucial and irreplaceable role of honey bees in maintaining biological diversity, as well as their importance as biological indicators of environmental conditions. The specific anatomical structure of *Apis mellifera* not only enables efficient pollen collection but is also directly linked to their function as bioindicators of environmental quality. Due to the presence of pollen baskets (corbiculae) and dense body hairs, bees come into contact with a large number of plants and environmental particles during each flight. In doing so, they collect not only pollen and nectar but also various pollutants (e.g. pesticides, heavy metals, dust particles) that may be present on plants or in the air. Honey bees can therefore be considered "free" self-sampling organisms. They provide beekeepers with samples that can be used to determine numerous indicators of environmental conditions [13].

These characteristics indicate that honey bees represent a unique biological system for monitoring environmental quality. Unlike conventional sampling of individual ecosystem components, bees simultaneously come into contact with air, water, soil, and plants during their daily activities, thereby enabling an integrated assessment of the presence of various pollutants within a given area. Due to this lifestyle, bee-based biomonitoring represents an efficient, cost-effective, and scientifically reliable approach for assessing environmental quality.

RESULTS

Pollution Indicators

Honey bees are considered among the most suitable insects for detecting environmental pollution and assessing its adverse effects. They are sensitive to various biocides, such as pesticides. They are referred to as a "first-order indicator species" since their disappearance signals a serious disturbance of ecological conditions. Any change in the natural environment may be reflected in bees through altered or increased mortality rates. Traces of environmental pollution may be present in bees, their brood, and bee products [12], [14]. Foraging bees are in direct contact with pollutants from water and air, and indirectly through plants and contaminants originating from soil (Figure 3). Pollutants that enter the hive via nectar, pollen, propolis, and water accumulate in bee products (collectors), as well as in larvae and adult bees (accumulators) [15].

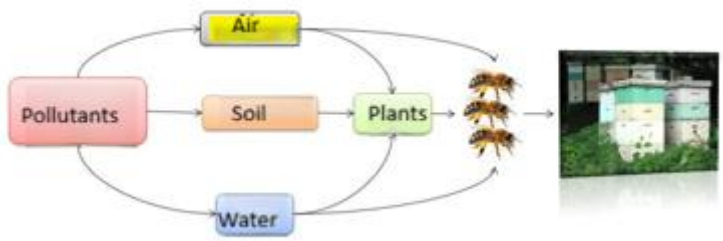


Figure 3 The Impact of the Environment on the Bee Colony (translated and adapted from [16])

Advantages of Honey Bees as Bioindicators

The advantages of honey bees as bioindicators are reflected in their large foraging range, daily contact with air, soil, water, and plants, as well as their ability to accumulate various pollutants in their bodies and bee products. In addition, sampling of bees and their products is relatively simple and cost-effective, enabling continuous biomonitoring of different types of ecosystems.

Heavy Metals

Heavy metals are classified among the most significant potentially harmful pollutants. Honey bees are exposed to heavy metals through contaminated air, water, soil, and food sources. The presence of heavy metals can affect physiological and metabolic processes in living organisms. Heavy metals are non-degradable and are therefore permanently present in the environment, entering biological cycles. For honey bees, the most important heavy metals are those that are most commonly found in the environment and exhibit strong toxic effects even at low concentrations. Due to their high toxicity to living organisms and wide environmental distribution, the most significant include cadmium (Cd), lead (Pb), mercury (Hg), arsenic (As), chromium (Cr), and nickel (Ni), as well as bioelements such as copper (Cu), iron (Fe), zinc (Zn), manganese (Mn), cobalt (Co), and selenium (Se). These bioelements in small concentrations are essential for various biochemical and physiological processes, but may become harmful at higher concentrations [16].

The results of previous studies indicate that the concentrations of heavy metals in bee bodies and their products reliably reflect the level of local environmental contamination. Due to their bioaccumulation capacity and constant contact with various components of the ecosystem, honey bees enable the assessment of the spatial distribution of pollution and the identification of potential sources of heavy metal emissions.

Pesticides

Honey bees come into contact with pesticides during the collection of nectar, pollen, and water from treated plants, which can lead to acute or chronic poisoning. In addition to direct toxic effects, pesticides may also cause sublethal effects. These sublethal effects may manifest as reduced immunity and increased susceptibility to diseases and parasites. Bees that come into direct contact with certain insecticides may die at the site of exposure or upon returning to the hive. The number of dead bees in front of the hive is considered one of the most reliable indicators for suspecting pesticide poisoning.

One of the early studies on the effects of pesticides on honey bees was conducted in northern Italy between 1983 and 1986 as part of a monitoring project. The study included apiaries located in areas with varying levels of agricultural intensity and chemical pressure. During the research, dead bees from sites with increased mortality were analysed. In 76% of the cases, the presence of a chemical agent responsible for bee mortality was identified [12].

In Brazil, during 2003 and 2004, honey samples from apiaries located near the ecological reserve in Bauru were found to contain 48 different pesticides. The detected pesticides belonged to various chemical groups, including organochlorine, organophosphate, organonitrogen, and pyrethroid compounds [17]. These results indicated the widespread presence of pesticides in the environment and their incorporation into bee products.

With the increasing use of pesticides from the neonicotinoid group for seed treatment of agricultural crops, a significant rise in the occurrence of neonicotinoid residues has been observed in pollen, water, soil, and bees. Bees exposed to sublethal doses of neonicotinoids lose their orientation ability and sense of taste, which affects their feeding behaviour. Consequently, their overwintering capacity is reduced, leading to increased colony mortality [18]. Since neonicotinoids are used worldwide, their residues can be found in food products such as fruit, vegetables, cereals, honey, and baby food, and they also persist in the environment.

Available findings indicate that honey bees can be used not only for the detection of acute poisoning events but also for monitoring long-term exposure to pesticides. The analysis of dead bees, honey, pollen, and wax enables the assessment of the level of chemical load in agroecosystems. Based on the presented studies, it can be concluded that honey bees represent an extremely sensitive biological system for the early detection of pesticide presence in agroecosystems.

Microplastics

Microplastic particles (MPs) are defined as polymer particles containing plasticizers and having a diameter of less than 5 mm. Microplastics are present in various environmental compartments, including air, soil, and water [19].

Microplastics are classified into two subgroups, primary and secondary microplastics. Primary microplastics are manufactured directly as microscopic materials and are intended for use in consumer products such as cosmetics, detergents, cleaning agents, and abrasive blasting media. Secondary microplastics originate from the degradation of plastic materials in the atmosphere or aquatic environments under the influence of natural ageing processes and weathering conditions. Examples of secondary microplastics include particles generated by the wear of tyres and road surfaces, as well as sludge from municipal wastewater treatment [20], [21]. It is generally considered that the majority of environmental microplastics consist of secondary microplastics [22], [23]. Microplastic particles that enter the atmosphere have negative impacts on both aquatic and terrestrial organisms, including honey bees [24].

Studies have shown that polystyrene microplastics (PS-MPs) can reduce bacterial diversity in the gut of the western honey bee, induce changes in the gut microbiome, and alter the expression of genes associated with oxidative damage, detoxification, and immune responses [25]. Bee mortality induced by microplastic particles is significantly increased when the gut microbiome is disrupted due to tetracycline exposure [25].

Environmental factors such as weather conditions, solar radiation, pH, exposure duration, and the hydrophobicity of persistent organic pollutants (POPs) can influence the adsorption kinetics of pollutants onto microplastics [26]. For instance, polyethylene (PE) microplastics may serve as important carriers of pesticides in agricultural soils [27], thereby further enhancing pesticide exposure effects in honey bees.

Accumulation of pollutants in bees, either on their bodies or within them, as well as in bee products such as honey, pollen, and wax, enables their use as indicators of environmental quality [28], [29], [30]. The presence of microplastics in honey and pollen not only indicates environmental risk but may also have potential consequences for both bee and human health.

Although the application of honey bees in microplastic monitoring is still in the developmental stage, current findings highlight the significant potential of this approach. At the same time, differences in sampling methods and laboratory analyses indicate the need for standardized protocols to ensure comparability of results across studies.

Overall, the results of numerous studies confirm that honey bees can serve as reliable bioindicators of different types of pollution. Their capacity to accumulate contaminants, together with changes in the behaviour, physiology, and vitality of bee colonies, enables the assessment of ecological risk and the early detection of changes in environmental quality.

Legislative Framework in Serbia

The Food Safety Law regulates the conditions for the production and trade of food with the aim of protecting consumer health. Within this legal framework, honey as a bee product is subject to monitoring for the presence of contaminants, including pesticides and heavy metals. Although bees are not formally recognised as environmental bioindicators in a legal sense, the analysis of their products enables indirect monitoring of environmental pollution in ecosystems, thereby linking food safety systems with ecotoxicological research [31]. The Plant Protection Products Act, harmonised with EU regulations (in particular Regulation (EC) No 1107/2009), does not formally recognise bees as a specific legal category of organisms; however, they are explicitly included in risk assessment procedures as sensitive non-target organisms [32].

Additional elements of the regulatory framework include the Environmental Protection Law and the Chemicals Law, which govern the control of pollutants and hazardous substances in the environment, including air, water, and soil [33], [34]. These regulations provide a general basis for monitoring and managing the chemical load of ecosystems, in which bees play an important role as indicators of environmental contamination.

Although current legislation does not formally recognise honey bees as bioindicators, their application in scientific research and biomonitoring programmes may represent a significant complement to existing environmental monitoring systems.

CONCLUSION

The results of the analysed studies confirm that honey bees represent a reliable and highly versatile bioindicator of various forms of environmental pollution. Their use enables the simultaneous assessment of the chemical load of ecosystems and the monitoring of biological responses of organisms to the presence of contaminants, making them a valuable tool in modern biomonitoring programmes. Although the potential applications of honey bees in biomonitoring are well documented, further improvement of standardised sampling methods and laboratory analyses is necessary to ensure comparability of results across different studies. The integration of bee-based biomonitoring into environmental monitoring programmes may enhance early detection of pollution and enable more effective planning of ecosystem protection measures. Given their multiple ecological and economic roles, the inclusion of honey bees in routine environmental monitoring programmes could significantly contribute to biodiversity conservation, improved food safety, and more efficient protection of natural resources.

DECLARATIONS OF INTEREST STATEMENT

The authors affirm that there are no conflicts of interest to declare in relation to the research presented in this paper.

LITERATURE

1. Matović, K. B. (2024). *Pčelarstvo i veterinarsko-medicinska praksa*. Veterinarski specijalistički institut „Kraljevo" & Partenon.
2. Ascher, J. S., & Pickering, J. (2014). *Discover Life bee species guide and world checklist (Hymenoptera: Apoidea: Anthophila).* Discover Life.
3. Michener, C. D. (2007). *The bees of the world* (2nd ed.). Johns Hopkins University Press.
4. Engel, M. S. (1999). The taxonomy of recent and fossil honey bees (Hymenoptera: Apidae; Apis). *Journal of Hymenoptera Research, 8*(2), 165–196.
5. Laktić, Z., & Šekulja, D. (2008). *Suvremeno pčelarstvo*. Nakladni zavod Globus.
6. Jesse Project. (n.d.). *Apis mellifera*. Retrieved April 17, 2026, from https://jesseproject.weebly.com/apis-mellifera.html
7. The Animalist. (n.d.). *Pčele*. Retrieved April 17, 2026, from https://theanimalistba.com/pcele/
8. Plavša, N., & Nedić, N. (2015). *Praktikum iz pčelarstva*. Poljoprivredni fakultet, Univerzitet u Novom Sadu.
9. Grbeša, I. (2018). *Uloga pčela u ekosustavu* (Diplomski rad). Veleučilište u Šibeniku.
10. Le Conte, Y., & Navajas, M. (2008). Climate change: Impact on honey bee populations and diseases. *Revue Scientifique et Technique (Office International des Épizooties), 27*(2), 499–510.
11. Spürgin, A. (2018). *Pčele – od košnice do pčelarstva*. Večernji list d.o.o.
12. Celli, G., & Maccagnani, B. (2003). Honeybees as bioindicators of environmental pollution. *Bulletin of Insectology, 56*(1), 137–139.
13. Zavrtnik, S. (2020). Identifikacija pčela *Apis mellifera* kao bioindikatora onečišćenja okoliša ispitivanjem prisutnosti specifičnih onečišćivala u tlu, vodi i medu. In *Zbornik radova: Treći simpozij poslijediplomskih doktorskih studija Dijalozi III*. Fakultet filozofije i religijskih znanosti.
14. Madras-Majewska, B., Ochnio, L., Ochnio, M. (2014). Impact of the bioaccumulation of selected toxic elements on the condition of bees and other organisms. *Medycyna Weterynaryjna, 70*(12), 715–718.
15. Cvitković, D. (2007). *Gospodarstvena obilježja pčelarstva u Hrvatskoj* (Disertacija). Veterinarski fakultet Sveučilišta u Zagrebu.

16. Nikolić, T. (2017). *Molekularne osnove odgovora medonosne pčele (Apis mellifera L.) na stres izazvan jonima teških metala* (Doktorska disertacija). Univerzitet u Novom Sadu, Prirodno-matematički fakultet.
17. Rissato, S. R., Galhiane, M. S., de Almeida, M. V., Gerenutti, M., & Apon, B. M. (2007). Multiresidue determination of pesticides in honey samples by gas chromatography–mass spectrometry and application in environmental contamination. *Food Chemistry, 101*, 1719–1726. https://doi.org/10.1016/j.foodchem.2006.03.055
18. Vojvodić, M., Virić Gašparić, H., Čačija, M., Lemić, D., & Bažok, R. (2021). Zabrana neonikotinoida u ratarskim kulturama: Uzroci i posljedice. *Glasilo biljne zaštite, 21*(4).
19. Mammo, F. K., Amoah, I. D., Gani, K. M., Pillay, L., Ratha, S. K., Bux, F., & Kumari, S. (2020). Microplastics in the environment: Interactions with microbes and chemical contaminants. *Science of the Total Environment, 743*, 140518.
20. Järlskog, I., Strömvall, A.-M., Magnusson, K., Gustafsson, M., Polukarova, M., Galfi, H., Aronsson, M., & Andersson-Sköld, Y. (2020). Occurrence of tire and bitumen wear microplastics on urban streets and in sweepsand and washwater. *Science of the Total Environment, 729*, 138950.
21. Rolsky, C., Kelkar, V., Driver, E., & Halden, R. U. (2020). Municipal sewage sludge as a source of microplastics in the environment. *Current Opinion in Environmental Science & Health, 14*, 16–22.
22. Hidalgo-Ruz, V., Gutow, L., Thompson, R. C., & Thiel, M. (2012). Microplastics in the marine environment: A review of the methods used for identification and quantification. *Environmental Science & Technology, 46*, 3060–3075.
23. Duis, K., & Coors, A. (2016). Microplastics in the aquatic and terrestrial environment: Sources (with a specific focus on personal care products), fate and effects. *Environmental Sciences Europe, 28*.
24. De Souza Machado, A. A., Kloas, W., Zarfl, C., Hempel, S., & Rillig, M. C. (2018). Microplastics as an emerging threat to terrestrial ecosystems. *Global Change Biology, 24*, 1405–1416.
25. Wang, K., Li, J., Zhao, L., Mu, X., Wang, C., Wang, M., Xue, X., Qi, S., & Wu, L. (2021). Gut microbiota protects honey bees (*Apis mellifera* L.) against polystyrene microplastics exposure risks. *Journal of Hazardous Materials, 402*, 123828.
26. Antunes, J. C., Frias, J. G. L., Micaelo, A. C., & Sobral, P. (2013). Resin pellets from beaches of the Portuguese coast and adsorbed persistent organic pollutants. *Estuarine, Coastal and Shelf Science, 130*, 62–69.
27. Wang, T., Yu, C., Chu, Q., Wang, F., Lan, T., & Wang, J. (2020). Adsorption behavior and mechanism of five pesticides on microplastics from agricultural polyethylene films. *Chemosphere, 244*, 125491.
28. Sadeghi, A., Mozafari, A.-A., Bahmani, R., & Shokri, K. (2012). Use of honeybees as bio-indicators of environmental pollution in the Kurdistan province of Iran. *Journal of Apicultural Science, 56*(2), 83–88. https://doi.org/10.2478/v10289-012-0026-6
29. Silici, S., Uluozlu, O. D., Tuzen, M., & Soylak, M. (2016). Honeybees and honey as monitors for heavy metal contamination near thermal power plants in Mugla, Turkey. *Toxicology and Industrial Health, 32*(3), 507–516. https://doi.org/10.1177/0748233713503393
30. Zarić, N. M., Ilijević, K., Stanisavljević, L., & Gržetić, I. (2016). Metal concentrations around thermal power plants, rural and urban areas using honeybees (*Apis mellifera* L.) as bioindicators. *International Journal of Environmental Science and Technology, 13*(2), 413–422. https://doi.org/10.1007/s13762-015-0895-x
31. Republika Srbija. (2009). *Zakon o bezbednosti hrane* (Sl. glasnik RS, br. 41/2009, 17/2019). https://www.paragraf.rs/propisi/zakon_o_bezbednosti_hrane.html
32. Republika Srbija. (2009). *Zakon o sredstvima za zaštitu bilja* (Sl. glasnik RS, br. 41/2009, 17/2019). https://www.paragraf.rs/propisi/zakon-o-sredstvima-za-zastitu-bilja-republike-srbije.html

33. Republika Srbija. (2004). *Zakon o zaštiti životne sredine* (Sl. glasnik RS, br. 135/2004… 94/2024 – dr. zakon). Paragraf Lex. https://www.paragraf.rs/propisi/zakon_o_zastiti_zivotne_sredine.html
34. Republika Srbija. (2009). *Zakon o hemikalijama* (Sl. glasnik RS, br. 36/2009… 25/2015). Paragraf Lex. https://www.paragraf.rs/propisi/zakon_o_hemikalijama.html