EXAMINING AIR POLLUTANTS AS INFLUENCING FACTORS OF HONEY BEE COLONY COLLAPSE DISORDER

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Abstract. Colony collapse disorder refers to a set of symptoms manifested by the sudden disappearance of worker bees from the hive, the absence of dead bees in or in front of the hive, and the absence of predation, despite the presence of queen bee, covered brood and a large amount of food - honey and pollen. The causes of this syndrome have not yet been reliably determined, but it is considered that several factors are involved in its development. Today, bees are exposed to a large number of stress factors, due to which their immune system is so weakened that they become very sensitive to the effects of many harmful agents. Recently, environmental factors such as air pollution by ozone, PM particles, micro and nanoplastics have also attracted increasing attention. In order to prevent the occurrence of bee diseases, it is necessary to implement adequate measures, such as good agricultural practice, good beekeeping practice and good veterinary practice for the protection and remediation of the environment.

Keywords: *honey bee loss, honey bee diseases, microplastics, stressors, PM particles, ozone*

Abbreviations: CCD: colony collapse disorder; PM: particulate matter; O_3: ozone

Introduction

Colony collapse disorder refers to a set of symptoms manifested by the sudden disappearance of worker bees from the hive, despite the presence of the queen bee and covered brood, also the absence of dead bees in or in front of the hive, and the absence of predators - regardless of the large amount of food present in the hive, honey and pollen (Buczek, 2009; Johnson, 2010, Dainat et al., 2012; Bekić et al., 2014; Plavša and Pavlović, 2018; Stanimirović et al., 2019). When this syndrome occurs, the amount of bee brood is much higher compared to the number of worker bees. The predators and pests that usually attack weakened colonies are not present, but appear much later. This phenomenon most often occurs after the wintering of bee colonies (Johnson, 2010; Bekić et al., 2014; Stanimirović et al., 2019). The syndrome of the colony collapse disorder of bees first appeared in 2006 in the United States of America, and in the same year it also appeared in Europe (Ellis, 2007; vanEngelsdorp et al., 2007; Bekić et al., 2014., Hristov et al., 2020., Evans and Chen, 2021). The decrease in the number of bee colonies, which was recorded in Europe and the USA during the past decade, is now also happening in China and Japan. One of the countries with the biggest losses in the world is the United States of America. The percentage of lost bee colonies in apiaries ranges from 50 to 100% (Buczek, 2009; Dainat et al., 2012; Plavša and Pavlović, 2018; Bekić et al., 2014; Hristov et al., 2020; Evans and Chen, 2021). In the last three years, a higher percentage of bee colony deaths has been recorded in Montenegro, 15%, compared to the previous 10% (Anon., 2015). In neighboring countries, such as Serbia and Bosnia and Herzegovina, an increase in the number of dead bee colonies was also recorded (Anon., 2015). The disappearance of bees is not only a major threat to beekeeping but also to global agriculture and the economy. Bees are much more important in pollinating plants than in

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the production of honey and other bee products. Agricultural production depends on bees as natural pollinators of numerous types of vegetables, fruits and other plant species (Johnson, 2010; Sultana et al., 2024; Singh and Rana, 2025). The causes of this syndrome have not yet been reliably determined, but it is considered that several factors are involved in its development. Today, bees are exposed to a large number of stress factors, which weakens their immune system so much that, like farm animals, they become very sensitive to the effects of many harmful agents (Anon., 2015; Stanimirović et al., 2019; Singh and Rana, 2025). In the last ten years, increasing importance is given to increased air pollution with ozone, PM particles and microplastics (Vanderplanck et al., 2021; Negri et al., 2020; Masui et al., 2021; Buteler et al., 2022). The aim of the paper is to study the factors that influence the occurrence of the mass disappearance of bees, with an emphasis on air pollutants that are on the rise, in order to determine the importance of their inclusion in bee health protection programs by the state, and measures of good beekeeping practices by beekeepers.

Causes of the colony collapse disorder of honey bees

The cause of this disease is still unknown, but according to current knowledge, it is believed that a large number of factors play a role in its development. Exhaustion, i.e. the weakening of bee immunity due to the presence and action of pathogenic microorganisms (bacteria, viruses, fungi), parasites (*Varroa destructor*, *Acarapis woodi*) (vanEngelsdorp et al., 2008, 2009; Higes et al., 2009; Johnson, 2010; Neumann and Carreck, 2010; Barron, 2015; Manger, 2011; Ellis, 2016; Meana et al., 2017; Stanimirović et al.,2019; Chandra et al., 2019; García et al., 2019; Morawetz et al., 2019; Rucker et al., 2019; Hristov et al., 2020), the presence of pests, the weakness and low weight of the honey bee queen, the collection of pollen and nectar from large monoculture plantations, the presence of invasive plant species on pastures, the lack of diversity of plant honey crops, the introduction of invasive plant species are considered important factors for the occurrence of mass disappearance of bees (Johnson, 2010; Barron, 2015; Koprivica et al., 2019; Neov et al., 2019; Nikita et al., 2022).

Climate change, global warming characterized by increased emissions of carbon dioxide and methane, external temperature variations, droughts, habitat degradation and loss, habitat fragmentation, deforestation, urbanization, earlier spring flowering of plants, long, harsh, cold and wet winters, sudden weather changes, short wintering period, earthquakes, hurricanes, fires, also affect the phenomenon of mass disappearance of bees (Koprivica et al., 2019; Neov et al., 2019; Portus, 2020; Hendlin et al., 2021; Nikita et al., 2022).

Factors such as environmental pollution, electromagnetic radiation, inadequate exploitation of mines, air turbulence near roads, noise, uncontrolled and unprofessional use of pesticides and fertilizers, migration of bees over very long distances for pollination, improper treatment of bees with untested and unregistered chemical agents, resistance of parasites to treatment with certain chemical preparations, are also considered significant for the occurrence of bee loss (Johnson, 2010; Rucker et al., 2019; García et al., 2019; Neov et al., 2019; Stanimirović et al., 2019; Hristov et al., 2020; Hendlin et al., 2021; Nikita et al., 2022; Dharmalingam et al., 2025).

Nutritional stress due to the lack of quality food - quality nectar, honey, pollen, feeding bees with fructose sugar syrup, especially that which comes from corn that is genetically modified and treated with pesticides, feeding cakes with the addition of genetically modified soybeans, grazing on genetically modified plants, also influence the appearance

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of the mass disappearance of bees (Naug, 2009; Johnson, 2010; Ellis, 2016; Koprivica, 2019; Rucker et al., 2019; Neov et al., 2019; Stanimirović et al., 2019; Branchiccella et al., 2019; Bojanić Rašović, 2020a; Hristov et al., 2020; Jovanovic et al., 2021).

Lack of genetic diversity in queens, improper application of apitechnical measures, cold brood, presence of chemical residues in the hive, improper application of good beekeeping and hygiene practices, lack of clean, drinking water near apiaries, also play a major role in the occurrence of mass bee disappearances. However, researchers do not rule out the possibility that the cause of bee colony collapse disorder is some new cause that is not yet known or discovered (Johnson, 2010; Ellis, 2016; Rucker et al., 2019; Stanimirović et al., 2019; Bojanić Rašović, 2020a; Hristov et al., 2020).

In the last decade, an increasingly significant impact on the disappearance of bees has been attributed to air pollution by ozone, PM particles, as well as micro- and nanoplastics (Vanderplanck et al., 2021; Negri et al., 2020; Masui et al., 2021; Buteler et al., 2022). Under the influence of various stress factors, the animal organism is much more susceptible to the development of infectious, parasitic and other diseases (Hillayová et al., 2022; Insolia et al., 2022; Nikita et al., 2022; El-Seedi et al., 2022; Lamas et al., 2024; Shamappa et al., 2024; Singh and Rana, 2025). During the development of the bee's stress response, the function of certain tissues and organs and organic systems decreases, which inevitably entails a decrease in their resistance (Bojanić Rašović, 2018b). The flight of bees in search of pasture is the period when bees are most exposed to the lethal or sublethal effects of a large number of biotic and abiotic factors (Tiritelli et al., 2024).

Bees are indicators of the state of the environment, and their mass disappearance indicates an imbalance within the ecosystem. The disappearance of bees threatens the survival of the human population and all living things on Earth (Nath et al., 2023). *Table 1* shows the factors that could potentially lead to the colony collapse disorder of honey bees.

The significance of the variety of pastures and the amount of pollen in the occurrence of honey bee colony collapse disorder

The polyfloral nutrition of bees is of great importance for the proper functioning of their immune system, as well as the enzyme systems responsible for the detoxification of the bee organism. Intensive agriculture has reduced the number and variety of plants that bees use in their diet (Branchiccella et al., 2019). With the development of agriculture, large areas of natural bee habitats were turned into arable land where plants are grown in monoculture. Global changes in the quantity and quality of pollen and nectar, as well as the practice of growing monocultures (for example corn), which are of low quality for bees, further increases the risk of starvation due to lack of proteins (Watson and Stallins, 2016; Stanimirović et al., 2019; Jovanovic et al., 2021). In the last few decades, the diversity of honey plant species has been decreasing globally. Some species have completely disappeared, and some have seen a drastic reduction in the amount of nectar and pollen, such as white clover (*Trifolium repens*), red clover (*Trifolium pretense*), lemon balm (*Melissa officinalis*), thyme *(Thymus serpyllum*), mint (*Mentha piperita*) (Stanimirović et al., 2019).

Intensive use of pesticides reduces the production of pollen, which is a high-quality and irreplaceable food for bees aged 3-18 days and older open bee brood. The reduction in the number of grazing animals, primarily sheep and goats, leads to reduction in manure production, soil impoverishment and significantly lower reproduction of honey plants (Dainat et al., 2012; Anon., 2015; Miletić, 2018; Rucker et al., 2018; Stanimirović et al., 2019; García et al., 2019; Koprivica, 2019; Branchiccela et al., 2019). With the loss of habitat due to urbanization, industrial and intensive agricultural production, and

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deforestation, bees are losing their basic living and nutritional conditions. The disappearance of bees is greatest when the bee does not have available food in the immediate vicinity. When bees cannot find food, they enter a state of nutritional stress, after which they die very quickly (Naug, 2009; Vaudo et al., 2015; Branchiccella et al., 2019; Stanimirović et al., 2019).

Table 1. *Representation of factors that can potentially lead to the occurrence of colony collapse disorder of honey bees*

Factor	Effect	Scientific source
Lack of pasture (lack of nectar, pollen, honey)	Malnutrition, weight loss, weakened immunity, death	Naug, 2009; Branchiccella et al., 2019; Stanimirović et al., 2019; García et al., 2019; Abdella et al., 2024
Inadequate method of feeding bees (feeding by sugar syrup, use of inappropriate substitutes for honey and pollen)	Malnutrition, weight loss, energetic and oxidative stress, weakened immunity, intensifies development and reproduction of pathogens, death	DeGrandi-Hoffman and Chen, 2015; Sultana et al., 2024; Harman, 2017; Stanimirović et al., 2019
Environmental pollution (ozone, ammonia, nitrogen and nitrogen oxides, carbon dioxide, PM2.5, particles microplastics, nanoplastics	Weakening of the immune system, oxidative stress, poisoning, memory impairment, change the interaction between the plant and the pollinators	Shaher and Shakir, 2020; Rollin et al., 2022; Duque, 2024; Coallier et al., 2025; Shavali Gilani et al., 2025
Pesticides	Poisoning, weakened immunity, impaired orientation, death	Johnson, 2010; vanEngelsdorp et al., 2010; Suryanarayanan, 2015; López-Uribe and Simone-Finstrom, 2019; Roy et al., 2018; Hristov et al., 2020
Climate change and weather conditions	Disturbance of nutrition and metabolism, behavioral disorder, loss of biodiversity of flowering plants	Le Conte and Navajas, 2008; Nemésio et al., 2016; Sirk, 2018; Hillayová et al., 2022; Brunet and Fragoso, 2024
Pathogenic bacteria (*Paenibacillus larvae, Melissococcus pluton*)	Infection, weakening of bee immunity, death	Chantawannakul et al., 2016; Bojanić Rašović, 2021; Peña-Chora et al., 2023
Viruses (deformed wing virus, acute bee paralysis virus, Israeli acute bee paralysis virus, Kashmir virus, black queen cell virus)	Infection, weakening of bee immunity, death	Chantawannakul et al., 2016; Skubnik et al., 2017; Roy et al., 2018; Oddie et al., 2020; Peña-Chora et al., 2023
Fungi (*Nosema ceranae, Ascosphaera apis)*	Infection, weakening of bee immunity, death	Higes et al., 2006; Chen and Huang, 2010; Meana et al., 2017; Roy et al., 2018; Marín-García et al., 2022; Peña-Chora et al., 2023)
Parasites (*Varroa destructor, Acarapis woodi*)	Infection, weakening of bee immunity, death	Dahle, 2010; Williams et al., 2010; Guzman-Novoa, 2011; Chantawannakul et al., 2016; Skubnik et al., 2017; Roy et al., 2018; Hillayová et al., 2022; Peña-Chora et al., 2023; Mazur et al., 2024
The presence of pests (*Aethina tumida, Braula coeca,* wasps, wax moths)	Weakening of bee immunity	Hristov, 2014; Chantawannakul et al., 2016; Peña-Chora et al., 2023
Electromagnetic radiation	They affect their orientation and motor skills, increasing their anxiety, leading to muscle fatigue and death	Molina-Montenegro et al., 2022; As et al., 2024; Jayaraju et al., 2022; Nikita et al., 2022; Savu et al., 2023
Habitat fragmentation, deforestation, urbanization	Loss of habitat, grazing, biodiversity	Johnson, 2008; Ramírez et al., 2012; Ferreira et al., 2015; Nemésio et al., 2016; Hristov et al., 2020; Nath et al., 2023
Transport and migration of bee colonies	Exposure of bees to dramatic temperature fluctuations, deaths	Watson and Stallins, 2016; Roy et al., 2018; Martínez-Lopez et al., 2022
Genetic factors	Poor quality queen and drones	vanEngelsdorp et al., 2010; Roy et al., 2018; Hadjur et al., 2022; Nikita et al., 2022
Low level of education of beekeepers	Inadequate implementation of good beekeeping practice measures, preventive measures against the onset of the disease, failure to recognize the symptoms of the disease, irregular replacement of bee queens	Stanimirović et al., 2019; Bojanić Rašović, 2020a; De Carolis et al., 2024; Kortsch et al., 2024; Peña-Chora et al., 2023; Mazur et al., 2024

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The significance of bee feeding procedures in the occurrence of honey bee colony collapse disorder

Nutrition plays a fundamental role in preserving the health of bee colonies (Abdella et al., 2024). Honey bees provide carbohydrates, fats, proteins, minerals, vitamins by collecting nectar, pollen and producing honey (Woodring et al., 1993; Brodschneider and Crailsheim, 2010; DeGrandi-Hoffman and Chen, 2015; Vaudo et al., 2015; Sultana et al., 2024; Ansaloni et al., 2025). In the pursuit of material gain, beekeepers often neglect the needs of bees: they take away honey from the hive, which is an ideal and energy- and protein-balanced food for bees and is the most important factor for successful overwintering and rapid spring development of the bee brood and the development of the bee colony as a whole (Woodring et al., 1993; Brodschneider and Crailsheim, 2010; Ansaloni et al., 2025). Honey is an irreplaceable food for bees. A very important component of natural honey is coumarin acid. Coumarin acid enables the activation of genes responsible for detoxification, as well as genes that encode the synthesis of certain antimicrobial peptides. The lack of this acid in food additives can be one of the causes of CCD, because the bee colony becomes more sensitive to the action of pesticides and various pathogenic microorganisms (Mao et al., 2013; Kim et al., 2022; Niño et al., 2022).

Beekeepers try to compensate the bees with honey by adding sugar syrup. However, sugar syrup has a negative effect on the development and survival of the bee colony, leads to disruption of the structure of the winter colony, to energy and oxidative stress, a decline in the immune system and increased reproduction of pathogens (Brodschneider and Crailsheim, 2010; Kim et al., 2022; Harman, 2017; Stanimirović et al., 2019; Sultana et al., 2024). This problem, combined with the overloading of agricultural crops with various pesticides, has an extremely stressful effect on bees, resulting in bees' immune weakness and their reduced ability to care for the brood. The problem of malnutrition was found in as many as 50% of bee colonies that had signs of colony collapse disorder of bees, which is why nutrition is considered one of the most important factors in the development of CCD (vanEngelsdorp et al., 2009; DeGrandi-Hoffman and Chen, 2015; Rašić, 2018; Bojanić Rašović, 2020a; Branchiccella et al., 2019; Harman, 2017; Stanimirović et al., 2019; Kim et al., 2022; Sultana et al., 2024). Deficiency of proteins and lipids accelerates the aging process of bees and leads to a decrease in the population of the bee colony (Brodschneider and Crailsheim, 2010; DeGrandi-Hoffman and Chen, 2015; Branchiccella et al., 2019; Kim et al., 2022; Sultana et al., 2024).

Another very important factor in the development of CCD is the use of inappropriate substitutes for honey and pollen in the diet of bees. The addition of soy flour to bee food leads to a weakening of the bee's organism, because bees are not capable of digesting carbohydrates from soy. Also, soy proteins are not equivalent to pollen (Brodschneider and Crailsheim, 2010; DeGrandi-Hoffman and Chen, 2015; Bryś and Strachecka, 2024). Fructose-rich syrups used in bee nutrition lead to an increase in the concentration of hydroxymethylfurfural, which in higher concentrations can be toxic to bees (Brodschneider and Crailsheim, 2010; Koprivica, 2019). Different sugars and nutritional additives affect the composition and functionality of microbial communities in the bee gut (Brodschneider and Crailsheim, 2010; Abdella et al., 2024). Liquid glucose obtained from corn and wheat increases the death rate of bees. Sucrose hydrolyzed by organic acids is also toxic to bees (Brodschneider and Crailsheim, 2010; Vali and Mazaherseidi, 2016; Harman, 2017). The amount of hydroxymethylfurfural in homemade sugar syrups increases with increasing temperature and acidity, which leads to significant bee fatigue. Therefore, the syrup should not be heated or lemon or any other acidifying substance

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should be added in order to invert the sucrose (Woodring et al., 1993; Brodschneider and Crailsheim, 2010; LeBlanc et al., 2009; Frizzera et al., 2020). Acid syrup also interferes with the function of the epithelium of the intestinal tract and the intestinal microbiota of bees (Woodring et al., 1993). The distance to the pasture and the stresses on the way to the pasture can have a great influence on the occurrence of bee deaths. Collector bees are unable to mobilize trehalose from fat tissue during the flight, so the only food reserve available to them is in the honey stomach. This amount of food in the honey stomach can be enough for a maximum of 60 min of flight. Because of this, distant grazing and stressful events during the flight further deplete the bee's energy and lead to death (Woodring et al., 1993) Probiotics are thought to improve digestion and support bee gut health, but their effect on honey bee health is poorly studied (Woodring et al., 1993).

The importance of air pollution in the occurrence of honey bee colony collapse disorder

With increasing air pollution, the risk of bee mortality has also increased. Air pollution is thought to have a direct impact on bees and is a likely cause of colony collapse disorder. Bees and other insects that follow the scent of flowers are directly affected by air pollution. Pollinators exposed to pollutants cannot recognize, remember, or locate flowering plants. Poor air quality reduces navigation, impairs sense of smell and foraging, and also weakens the bee's immune system (Rollin et al., 2022).

Pollutants also affect the quality and abundance of food sources. They change the concentration of pollen, nectar, and amino acids in flowers and directly affects the survival of insect populations. Air pollution can accelerate or delay the onset of flowering or its duration. This leads to a mismatch between the timing of plant flowering and pollinator activity (Duque, 2024). Some of the key air pollutants are PM particles, ozone, ammonia, nitrogen and nitrogen oxides, carbon dioxide. Increased concentrations of carbon dioxide lead to an increase in plant mass, but at the same time to the dilution of nutrients in the pollen of those plants (Filipiak et al., 2024). Atmospheric concentrations of ammonia are increasing, but the effects of this pollutant on pollination by insects are not well known (Duque et al., 2024). Bees are exposed to various forms of pollution also around roads, such as noise, light, exhaust fumes, dust and metals. Turbulence caused by traffic at the roadside can disturb pollinators and make foraging difficult (Sordello et al., 2020; Phillips et al., 2021). All this indicates that air pollution should be taken into account in management plans to conserve biodiversity and implement more sustainable food production practices (Rollin et al., 2022).

The importance of PM2,5 particles in the emergence of honey bee colony collapse disorder

PM particles in the air are widely distributed pollutants, that can originate from natural sources, such as soil erosion, volcanic eruptions, forest fires, or from anthropogenic sources (motor vehicles, industry, agriculture) (Papa et al., 2021; Javorac, 2024). Extreme droughts caused by climate change lead to fires, and thus to the emission of harmful smoke that carries various harmful air pollutants, such as PM2.5 particles. These particles carry on their surface adsorbed toxic substances (heavy metals, polycyclic aromatic hydrocarbons, pesticides) that danger insects and human health (Haberkon et al., 2024; Matei et al., 2025; Alharbi et al., 2025). PM particles increase the acidity of lakes and rivers, change the nutritional value of coastal waters, degrade soil, damage forests and agricultural crops, and affect the biodiversity of ecosystems (Manisalidis et al., 2020;

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Negri et al., 2020; Bojanić Rašović, 2025). Atmospheric pollutants from the smoke created during the fire can have a negative effect on the bee's sense of smell and thus on reduced foraging. Elevated levels of PM2.5 particles in the atmosphere affect the polarization of light, which disrupts bee navigation during flight. The impact of PM2.5 particles adsorbed to the surface of insect cuticles on bee health has not been sufficiently studied (Negri et al., 2020; Margaoan et al., 2025). Poor air quality poses a new threat to bee foraging. The duration of the flight of bees in search of food increases with decreasing light polarization and with increasing concentration of fine PM particles. The effects of fine PM particle concentration are synergistic with cloudy skies. The average duration of honey bees' foraging time increases by 32 min at elevated PM particles concentrations, meaning they spend 71% more time foraging (Cho et al., 2021).

The importance of ozone in the emergence of honey bee colony collapse disorder

Elevated concentrations of ozone lead to the degradation of floral scent, disturb the diffusion of pheromones and thus lead to a decrease in foraging activity. They also change the emission of floral volatile aromatic substances of plants and thus change the interaction between the plant and the pollinators (Démares et al., 2022; Langford et al., 2023; Démares et al., 2024). Ozone pollution makes it harder for bees to recognize and find flowers by 90%. Exposure to high concentrations of O_3 can result in oxidative stress in plants and animals, which leads to significant ecological consequences. Ozone is one of the most important pollutants that should be given special attention. Ozone is a strong oxidant and as such has a harmful effect on humans, animals and plants. At an ozone concentration of 100 ppb, fatigue occurs in people, and lung damage occurs with prolonged exposure. In plants, there is a decrease in the leaf area, a decrease in the number and size of flowers, and an extension of the flowering and ripening time (Marković et al., 2003). The enzyme superoxide dismutase of bees, which has an antioxidant effect, has reduced activity in the presence of an ozone concentration of 80 ppb (Démares et al., 2022, 2024). Ozone affects the learning and memory processes of pollinators and disrupts communication between insects and plants (Vanderplanck et al., 2021; Masui et al., 2021; Otieno et al., 2023). In the Northern Hemisphere, O_3 concentrations range from 25-50 ppb and are increasing at a rate of 0.2 to 2% per year due to increasing emissions of its chemical precursors, with local pollution episodes reaching concentrations exceeding 200 ppb (Vingarzan, 2004; Langford et al., 2023). Ground-level ozone is formed during complex photochemical reactions involving nitrogen oxides and volatile organic compounds. Therefore, controlling ground-level ozone concentrations is very complex (Zhang et al., 2023). Ground-level ozone concentrations are significantly influenced by meteorological factors (temperature, air pressure, relative humidity) and the presence of other pollutants (particles, carbon dioxide, volatile organic compounds, formaldehyde, nitrogen oxide, nitrogen dioxide, and carbon monoxide). A strong and positive correlation has been found between temperature and ground-level ozone concentrations (Yildizhan et al., 2024). Ozone concentrations are usually higher in rural areas because the removal of ozone by reaction with nitrogen oxides is relatively small compared to urban areas (Ryalls et al., 2022). A higher wind speed reduces the stability of the ground air layer, accelerates the entry of ozone concentration from higher to lower layers of the atmosphere, and thus the ozone concentration increases (Arsić, 2012). The maximum values of ozone in the atmosphere are found at the end of winter and the beginning of spring (Basic-Palkovic, 2005). Ozone has milder effect on bees at a concentration of 0.25 ppm, and is disturbing to them at a concentration of 0.5 ppm. When bees were exposed

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to air that had passed through ozone filters, the bees showed no signs of distress (Harfash Abu-Ragheef and Hadi, 2024). From the aspect of human health, the daily dose of 120 μg/m^3 must not be exceeded (Anon., 2023). Ozone doubles the negative effect of pesticides and temperature on pollinators. Differences in beekeeping practices in the use of agrochemicals and pest control can explain why the effect of ozone concentration on bee mortality is different between beekeepers. Air quality is an important factor of honey bee mortality. The risk of honey bee mortality increases with poorer air quality (air quality health index and ozone), but is significantly reduced in regions with greater availability of vegetation. That is why increasing the area under greenery is a key solution for the protection of bees and other pollinators (Coallier et al., 2025).

The importance of microplastics and nanoplastics in the emergence of honey bee colony collapse disorder

The decline of honey bee populations has occurred worldwide, and recently microplastic pollution has been considered a possible cause (Buteler et al., 2022). Microplastics are plastic particles with a size of 1 μm to 5 mm, while nanoplastics have particles smaller than 1 μm. Microplastics in the air are created by the decomposition of plastic products such as construction or packaging materials or originate from point sources such as industrial emissions (Shavali Gilani et al., 2025; Lee and Bee, 2024., Kadac-Czapska et al., 2024).

Microplastic particles are highly resistant to degradation and are widely distributed in the environment, water, soil and air (Diaz-Basantes et al., 2020). Microplastics in a living organism can cause oxidative stress, necrosis, cell apoptosis and inflammatory reactions (Jiang, 2018). Microplastics are toxic because they release additives, unintentionally added substances and pollutants that they have bound from the environment (Gómez-Méndez et al., 2024). The sublethal effects of microplastics on the honey bee are: increased sensitivity to pathogenic microorganisms, damage to the midgut, reduction in body weight, changes in the way of feeding, as well as learning and memory disorders (Al Naggar et al., 2024; Tiritelli et al., 2024). Microplastic fibers are embedded in the cuticle, digestive tract and larvae of adult bees, as well as in honey and beeswax (Alma et al., 2023; Shavali Gilani et al., 2025). Microplastics accumulate in honey bee organs - the brain, midgut, Malpighian tubules, trachea, in the hemolymph, which can lead to negative effects on the health and behavior of honey bee colonies. They also affect the immune system, alter cuticle properties, reduce body weight and change feeding frequency, all of which affect the survival rate of bees. Microplastics can disrupt the balance of the gut microbiota, immune system function and neuronal signaling pathways that are crucial for learning and memory processes in honey bees. They reduce bacterial diversity in the gut of bees and weaken their immunity and detoxification capacity. Microplastics can also adsorb to the body surface of honey bees (Shavali Gilani et al., 2025). Plastic fibers and fragments can damage the digestive system of bees, as well as change their behavior and foraging ability (Gómez-Méndez et al., 2024). Microplastic particles can cause intestinal blockage in small animals, and are also immunotoxic and genotoxic (Gómez-Méndez et al., 2024). Honey bees are thought to be more susceptible to viral infections after consuming polystyrene microplastics. It was found that *N. ceranae* reproduces faster in bees that are simultaneously exposed to microplastics and the insecticide flupyradifuron (Tiritelli et al., 2024). Microplastics have also been found in honey, posing a potential threat to bees' survival, their immunity and behavior, as well as the function of their gut microbiota (Al Naggar et al., 2024).

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Polystyrene nanoplastics with a size of 100 nm have an even stronger negative effect on the health of honey bees than microplastics. Introduced nanoplastic leads to the accumulation of pollen in the rectum, i.e. prevents its digestion and utilization. Nanoplastics also increase the reproduction of *Hafnia alvei* bacteria in the host's intestines and their spread in the hemolymph, which results in increased mortality of honey bees (Naggar et al., 2023). Nanoplastics have a synergistic effect with pathogens, neonicotinoids, polycyclic aromatic hydrocarbons and toxic metals and can change the distribution of available flowering plants. Wind, rain, and runoff facilitate the transport of nanoplastics over long distances from pollution sources (Sheng et al., 2024).

The importance of electromagnetic waves on the appearance of CCD

It is believed that the emission of electro-magnetic waves via mobile phones and relay towers interfere with the bees' navigation system, thus confusing them and preventing them from finding their way back to the hive (Kumar, 2018; Wyszkowska et al., 2019; Patel and Mall, 2019; Li et al., 2022; Molina-Montenegro et al., 2022; As et al., 2024; Jayaraju et al., 2022; Savu et al., 2023). The research results showed that electromagnetic waves are a stressor for honey bees, influencing their orientation and motor skills, increasing their agitation, increasing their daily activity, which exhausts them, leads to muscle fatigue and death. This problem is receiving increasing attention as new 4G and 5G networks are being implemented, leading to increased exposure to electromagnetic radiation (Wyszkowska et al., 2019; Patel and Mall, 2019; Li et al., 2022; Molina-Montenegro et al., 2022; As et al., 2024; Jayaraju et al., 2022; Savu et al., 2023).

The importance of pesticides in the occurrence of honey bee colony collapse disorders

Pesticides, such as neonicotinoids used to treat the seeds of cultivated plants, have been found to lead to various negative effects on the bees. Excessive concentrations of these pesticides lead to the death of bees, and sublethal doses lead to chronic suppression of the bee's immune system, hinder the process of decomposition and resorption of pollen in the bee's digestive tract, change the bee's behavior, which is manifested by nervous symptoms, such as disorientation, memory loss, which all leads to the inability of bees to return to their hive (Chensheng et al., 2014; Kiljanek et al., 2016; Anon. 2018; Roy et al., 2018; López-Uribe and Simone-Finstrom, 2019; Stojić and Pucarević, 2019; Bojanić Rašović, 2021). Neonicotinoids act on the central nervous system of insects, leading to their paralysis and death. These pesticides bind permanently to nicotinic acetylcholine receptors, thereby blocking the passage of nerve impulses. Of the neonicotinoids, imidacloprid, clothianidin and thiamethoxam are known to occur death of bees that went to graze on plantations of sunflowers, almonds and other monocultures whose seeds were treated neonicotinoids (Anon., 2013; Rişcu and Bura, 2013; Kiljanek et al., 2016; Tihelka et al., 2018). Imidacloprid is particularly toxic to bees, damaging their memory and brain metabolism (Kiljanek et al., 2016., Bojanić Rašović, 2025). From the seeds of plants, neonicotinoids reach the flowers, which is fatal for the bee organism. In the countries of the European Union, due to the harm to bees, neonicotinoids are excluded from the use in growing plants outdoors (Anon. 2013). A very important fact for beekeepers is that the bee disappearance syndrome does not occur with organic beekeeping. This clearly indicates how much influence pesticides, mostly insecticides and fungicides, have on the development of this disease, then improper treatment of bees against the disease with chemical means, grazing of bees on genetically modified plants, etc. (Johnson, 2010). Neonicotinoids are most often mentioned as the main causes of

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the disappearance of bees in France, Germany, Italy and some other European countries (Anon., 2013; Bojanić Rašović, 2022a). In Serbia, in Vojvodina, bees are often poisoned by neonicotinoids due to going to the pasture of sunflowers whose seeds have been treated with neonicotinoids (Anon. 2015; Bojanić Rašović, 2022a). It should be borne in mind that toxic substances that bees ingest together with nectar and pollen during grazing are also deposited in the honeycomb in the hive. This can be a significant reason why bees no longer recognize their hive as a healthy place to live (Bojanić Rašović, 2020a, 2022a; Hristov et al., 2020). This is supported by the fact of one research, that a swarm of bees that swarmed from one hive did not want to return to that hive after it was prepared for acceptance (Magal et al., 2019; Koprivica, 2019; Bojanić Rašović, 2020a, 2022a; Tihelka et al., 2018; Hristov et al., 2020). Bees treated with synthetic pesticides are much more susceptible on diseases. Synthetic acaricides such as amitraz and fluvalinate negatively affect bee immunity by reducing the concentration of lysozyme and other antibacterial proteins in the hemolymph of honey bees. Bee resistance is also reduced by the use of coumaphos-based preparation (Getchev and Kantchev, 1998; Bojanić Rašović et al., 2018).

The significance of weather conditions in the occurrence of honey bee colony collapse disorder

Weather conditions significantly affect the amount of nectar available to bees. For example, high rainfall during the flowering of acacia negatively affects the attractiveness of this plant for bees, because rain dilutes the nectar (Le Conte and Navajas, 2008). Drought periods are very dangerous for bees, because bees cannot find a sufficient amount of good nutrients in nature, they are in a qualitative and quantitative nutritional deficit. In extreme drought, lavender flowers do not produce nectar at all (Le Conte and Navajas, 2008; Koprivica, 2019; Rucker et al., 2018).

The temperature of the hive during wintering has a major impact on the immunity of the bee colony (Minaud et al., 2024). Even short periods of rain and cold have a negative impact on foraging activity. Bee flight is directly hampered by low temperature (< 10°C) or high temperature (> 40°C), wind speed greater than 2–7 m/s, rain (> 3–5 mm/day) or fog (Vincze et al., 2025) Changes in temperature and weather patterns not only affect feeding and reproduction, but also susceptibility to disease and colony survival (vanEngelsdorp et al., 2008). Honeybee colonies can suffer if clean water supplies become less available due to climate change. Unexpected spring or autumn cold snaps usually precede mass bee losses (Vincze et al., 2025). Changes in air temperature, humidity, pressure, solar radiation intensity and wind speed, and precipitation significantly affect the flight and behavior of honeybees. Warm winter weather leads to wasted foraging and depletion of valuable reserves, while prolonged spring rains prevent pollen feeding. Land use changes and deforestation also contribute to climate change, which represent the greatest danger for pollinators (Sirk, 2018; Brunet and Fragoso, 2024). Honeybee respiration is very significantly affected by changes in atmospheric pressure. Decreases in atmospheric pressure can lead to reduced activity due to unstable weather and increased risk of mortality (Woodworth, 1932; Azevedo et al., 2023).

The importance of Nosema ceranae infection in the occurrence of honey bee colony collapse disorder

The 2005 mass bee die-off in the United States coincided with the discovery of a new parasite, *Nosema ceranae*, in the European honey bee in Europe and the United States.

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This pathogen was first discovered in 1994 in the eastern honey bee, *Apis ceranae*, near Beijing, China (Higes et al., 2006; Chen and Huang, 2010; Meana et al., 2017; Marín-García et al., 2022) In the European (western) honey bee *A. mellifera*, *N. ceranae* was discovered in the spring of 2005 in Taiwan, where is the natural habitat of *A. ceranae*. The first case of *N. ceranae* in *A. mellifera* within its native range was confirmed in Spain in the summer of 2005, where the eastern honey bee *A. ceranae* is not present. Its spread was due to intensive international trade. This pathogen is attributed to the loss of bee colonies in Spain in 2004-2005. *N. ceranae* is considered the leading cause of the mass disappearance of bees in Spain (Higes et al., 2006, 2010; Chen and Huang, 2010; Meana et al., 2017; Marín-García et al., 2022). Today, this causative agent is widespread in Canada, the USA, Central America, Australia, and North Africa. Many studies have confirmed that in most communities affected by CCD, nosemosis was almost always present (Higes et al., 2006; Chen and Huang, 2010; Meana et al., 2017; Marín-García et al., 2022).

Nosema apis and *Nosema ceranae* differ in the sequence of the genes encoding the synthesis of the small subunit of 16S rRNA (Huang et al., 2005; Higes et al., 2006; Gisder and Genersch, 2013). *N. ceranae* is more virulent than *Nosema apis*, it irreversibly damages the epithelial cells of the bee intestine, prevents food resorption and causes a lack of energy in the bee. Damaged cells of the midgut of bees lose their function, the secretion of enzymes for food digestion decreases, as well as the absorption of nutrients, which leads to malnutrition and eventually to the death of the bees. In this way, *N. ceranae* causes additional nutritional stress in bees and their high mortality. Sick bees, due to exhaustion, do not have the strength to return to the hive, but die in the pasture. Often, due to the lack of nectar and pollen near the hive, bees have to fly much further, which further exhausts them and robs them of energy (Chen et al., 2009; Naug, 2009; Paxton, 2010; Gajger Tlak et al., 2016; vanEngelsdorp et al., 2009; Ellis, 2016; Pandiscia et al., 2024).

A symptom indicating infection with *Nosema ceranae* is the sudden disappearance of worker bees. Bees from an apparently healthy hive remain on pasture and never return. It is considered that bee nutrition rich in B complex vitamins is very important in the fight against nosemosis. Prevention of the occurrence of nosemosis is achieved by choosing a dry and sunny place for the apiary in which there is plenty of pollen and nectar in the spring and summer (Higes et al., 2009, 2010). It is necessary to take care of the optimal number of bee colonies in a location in order to reduce the possibility of infection. It is very important to restore the comb and remove the old, dark comb from the hive. Weakened and diseased bee societies must not merge with healthy societies, because this is how disease spreads (Higes et al., 2009, 2010; Bojanic Rasovic, 2022b).

The importance of Varroa destructor in the occurrence of honey bee colony collapse disorder

Varroa destructor, a parasite of *A. mellifera*, also represents one of the greatest dangers for beekeeping (Schüler et al., 2023). Due to the lack of an effective control program, attacked bee colonies collapse within two to three years of infestation. Varroa infestation first results in a decline in bee immunity, and then in their death. It was recently established that the Varroa feeds primarily on the bee's fatty tissue, which is very important for maintaining the bee's life (Gajić, 2016; Reyes-Quintanaa et al., 2019; Ramseya et al., 2019; Traynor et al., 2020). Fat tissue of bees is very important for proper immune function and hormone regulation of bees, detoxification from pesticides,

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survival, hibernation, etc. Because of this, due to the loss of fat tissue, bees become more sensitive and die faster. It contains the substance vitellogenin, which by its chemical structure is a phosphoglycolipoprotein and which is very important for maintaining bee immunity (Gajić, 2016; Reyes-Quintanaa et al., 2019; Ramseya et al., 2019; Traynor et al., 2020). Vitellogenin is created and stored in the fatty tissue of the bee's abdomen and reduces oxidative stress, significantly extending the life span of bees during the winter. This substance is a precursor of the proteins that make up the queen's eggs and is a source of food for the queen during the early stage of egg laying. The loss of fat tissue of bee larvae and pupae in covered brood hinders the process of metamorphosis (transformation of larvae and pupae into an adult form) and affects the size and health of the future adult bee (Gajić, 2016; Reyes-Quintanaa et al., 2019; Ramseya et al., 2019; Traynor et al., 2020).

The importance of Varroa destructor in the transmission of bee viruses and the consequent development of colony collapse disorder

In addition to exhausting the bee by feeding on the fatty tissue and hemolymph of the bee, Varroa is also significant as a biological and mechanical transmitter of various bee viruses, which has a very negative effect on the bee. Some of these viruses are deformed wing virus, acute bee paralysis virus, Israeli acute bee paralysis virus, Kashmir virus, black queen cell virus and many others (Skubnik et al., 2017; Roy et al., 2018). It has been established that in bee colonies with weakened immunity due to the effects of various stress factors, viruses multiply much faster and usually lead to the death of such colonies (Liggon, 2019; Bojanić Rašović, 2019; Posada-Florez et al., 2019; Traynor et al., 2020). Stress factors acting together intensify their negative effect and lead to the decline of the bee colony. Acting together with the virus of deformed wings, Varroa causes a very harmful effect on bees and reduces their lifespan (Dahle et al., 2010). Many bee viruses attack the brain of bees, which leads to their disorientation, impaired learning, accelerated aging, reduced sensory properties, interference with food collection; body tremors, inability to fly, gathering of bees in groups, shortening of life span, dying of bees. Viruses are most often transmitted between hives, by the entry of bees from another hive (Santrač, 2013; Cirkovic et al., 2018; Brborić, 2019). Colonies in which treatments against Varroa were not adequately carried out, which were deprived of honey and which were fed sugar syrup or sugar cakes, and which were grazed on sunflower (sunflower is grown last in the season and is contaminated with agropesticides) are more susceptible to viral infections (Santrač, 2013; Cirkovic et al., 2018; Brborić, 2019). The results of testing the presence of viruses in bee colonies in Serbia indicate the need to test the presence of bee viruses and their impact on the health of bees in Montenegro.

Measures to prevent varroosis consist in choosing an adequate place for the apiary, early detection of the disease, inspection of bee colonies before merging, control of newly acquired colonies, control of treatment efficiency, selection of bee queens, etc. The work to prevent and suppress varroosis must be continuous, because societies collapse very quickly (Bojanić Rašović et al., 2018). It is very important to select a bee queen from colonies that are more resistant to *V. destructor*. Better knowledge and understanding of the relationship between Varroa and the bee is very important in the fight against this parasite, and researchers are still working hard on this. In the fight against Varroa, biotechnical, physical and chemical methods are used. Due to the negative effects of synthetic preparations, natural preparations based on essential oils and organic acids are increasingly used to treat Varroa (Bojanić Rašović et al., 2018). Due to the low probability

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of acquiring Varroa resistance, as well as not leaving residues in bee products, natural preparations represent a solution for integrated Varroa control. In many European countries, essential oils of garlic (*Allium sativum*), walnut (*Juglans regia*) and pine (*Pinus sylvestris*) are used in the fight against Varroa. Essential oils of marjoram (*Origanum majorana*), thyme (*Thymus vulgaris*), mint (*Mentha piperita*), camphor - obtained from the camphor tree, camphor tree (*Cinnamomum camphorae*) and others are also used (Bojanić Rašović et al., 2018). Applying a treatment with a temperature between 40 and 42°C for 1.5-3 h to reduce Varroa infestation and viral infections may have potential (Xu et al., 2025).

The importance of American and European brood rot in the emergence of honey bee colony collapse disorder

In order to successfully fight against the emergence of American and European foulbrood of honey bees is necessary to pay close attention to hygiene in the apiary, hygiene during work with the bee colony, hygiene during feeding of bees, hygiene of water for feeding bees (Bojanić Rašović, 2018a; Bojanić Rašović et al., 2022; Peña-Chora et al., 2023). The causative agent of the American foulbrood, spores of *Paenibacillus larvae*, can be transferred from an infected hive via beekeeping tools, equipment, drinking water, using beeswax, honey and other bee products to other bee colonies on the same or other apiaries in a diameter of at least 3 km (Alonso-Salces et al., 2017; Bojanić Rašović, 2018a; Bojanić Rašović et al., 2022; Peña-Chora et al., 2023). The primary source of *Paenibacillus larvae* spores are diseased and dead larvae. Secondary sources of spores are honey, pollen, combs, frames and inner surfaces of hive walls. Honey containing the spores of this causative agent is particularly important in the spread of the disease. Feeding bees with contaminated honey and pollen or during the predation of honey or bee cakes, the introduction of infected bee queens from infected colonies leads to the spread of the disease. If wax contaminated with *P. larvae* spores is used for the production of honeycomb, the infection can also spread (Genersch, 2010; Bojanić Rašović, 2018a; Bojanić Rašović et al., 2022; Peña-Chora et al., 2023; Matović et al., 2023). The infection can often be spread by beekeepers when joining the frames of weaker colonies with stronger colonies without prior health control. Infection is also easily introduced into the apiary through infected beekeeping equipment. Drones can transmit infectious spores because they freely enter all hives. Various pests (wax moth, bee lice, small hive beetle, mites, ants, etc.) can also transfer spores from infected hives to another hive (Bojanić Rašović, 2018a; Bojanić Rašović et al., 2022; Peña-Chora et al., 2023).

When it comes to the European foulbrood, it is also very important that all measures of good beekeeping practice and good veterinary practice are applied, so that the resistance of the bee colony does not decrease, which is a prerequisite for the appearance of both this and other bee diseases. The appearance of the European foulbrood is decisively influenced by unfavorable environmental conditions and errors in beekeeping technology (Bojanić Rašović et al., 2022). Climate change, rainy springs and summers, long winters, long stay of bees in the hive, poor quality grazing, lack of pollen, lack of nectar, sudden increase in nectar quantity, small number of feeder bees in relation to the size of the brood, nosemosis and other bee diseases, loss bee queens, microclimatic conditions in the hive (increased humidity), overheating or cooling of the brood, errors in technology, bee poisoning, stress, etc. are factors that influence the occurrence of the disease. Colds and poisoning very often precede the appearance of European foulbrood (Bojanić Rašović et al., 2022; Peña-Chora et al., 2023). Due to the weakening and deterioration in infected bee colonies, the disease leads to large losses. The disease most

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often occurs in the spring - when colonies reach their largest population, but it can also occur in the fall (Bojanić Rašović et al., 2022; Peña-Chora et al., 2023). European foulbrood spreads along the same routes as American foulbrood. Healthy colonies are usually infected through bees which take food by predation from diseased colonies; the disease can also be transmitted by beekeepers through infected equipment. Within the hive itself, the disease is transmitted by bees that feed on the larvae. The causative agent of this disease, the bacterium *Melissococcus plutonius* (Fowler et al., 2023; Flower et al., 2025), is also transmitted through the bite of the *Varroa destructor* mite (Bojanić Rašović et al., 2022; Peña-Chora et al., 2023).

The importance of transport and migration of bee colonies in the occurrence of CCD

Industrial migratory beekeeping that exists in developed countries is a significant factor in causing CCD (Watson and Stallins, 2016; Martínez-Lopez et al., 2022). Transporting bee colonies over long distances exposes bees to dramatic temperature fluctuations and reduces natural foraging, which is stressful for them. Very often, even 10% of bee colonies die after transport, with possible losses of up to 30% (Watson and Stallins, 2016; Martínez-Lopez et al., 2022).

The importance of the level of education of beekeepers in the occurrence of CCD

A strong connection between losses of bee colonies and the level of knowledge and education of beekeepers was established (Bojanić Rašović, 2020a; De Carolis et al., 2024). Professional beekeepers manage to save bee colonies from decay, unlike those who do beekeeping as a hobby. Professional beekeepers know immediately to recognize the symptoms of diseases such as American plague of bee brood or varroosis and to apply adequate measures in a timely manner. Organized control of *V. destructor* in the bee colony should be carried out due to its parasitic and vector role, and hygienic and sanitary measures and principles of good beekeeping practice should be observed (Bojanić Rašović, 2020a; De Carolis et al., 2024). All these preventive measures should be accompanied by a spring and autumn health check of the bees by a veterinarian, who, if necessary, will suggest appropriate treatments. In order to prevent this phenomenon, as well as all other bee diseases, continuous education and mutual cooperation, exchange of experience and connection of all beekeepers is important, which is what they work on every day (De Carolis et al., 2024; Kortsch et al., 2024).

Preventive measures to combat the colony collapse disorder of honey bees

In order to prevent the occurrence of diseases, it is very important to systematically implement measures that increase the body's resistance. Under the influence of stress factors, bees are much more susceptible to the development of infectious, parasitic and other diseases (Bojanić Rašović, 2018). Taking into account the possible causes of the colony collapse disorder of honey bees, preventive measures should be implemented to prevent diseases, which are: choosing a suitable location for setting up apiaries, ensuring sufficient amounts of quality food and clean drinking water, avoiding the use of sugar syrup, which in excessive quantities can cause energy and oxidative stress, adequate protection of bee health (Anon., 2007; Grubić, 2018; Rašić, 2018; Anon., 2019; Bojanić Rašović, 2020a, b, c, 2022b; Sunil et al., 2022). The proximity of pastures and the number of bee colonies per square kilometer significantly affect the health of bees and the

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production and reproductive capabilities of bee colonies. The distance between apiaries should be at least 1.5 km, in order to avoid competition in collecting food, therefore, overcrowding of hives should be avoided (Al-Ghamdi et al., 2016; Rašić, 2018; Anon., 2019; Bojanić Rašović, 2022b; Sunil et al., 2022). The apiary should be located away from overhead power lines and relay towers. The presence of a young, healthy queen in the hive enables the development of a healthy bee colony and successful beekeeping (Anon., 2007; Grubić, 2018; Rašić, 2018; Anon., 2019; Bojanić Rašović, 2020a, b, c, 2022b; Sunil et al., 2022). Changing environmental conditions pose a challenge for predicting pollinator behavior in the future. Society should be aware of the importance of air pollution and implement measures to prevent and eliminate this pollution (Sirk, 2018).

Air pollution should be taken into account in plans for biodiversity protection and the implementation of sustainable food production practices (Rollin et al., 2022). Increasing the area under greenery is crucial for the protection of bees and other pollinators (Coallier et al., 2025). Intensive work is needed to investigate the impact of increasing concentrations of environmental pollutants, such as ozone and microplastics (Bashir et al., 2024; Rodriguez et al., 2025). The synergistic effects of microplastics and other stressors, such as pesticides and pathogens, on bee health should also be studied. These studies are essential for developing effective strategies to prevent and mitigate the impact of these factors on the life of honeybee populations. It can be concluded that urgent and effective measures are needed to reduce air pollution (Bashir et al., 2024).

Conclusion

The colony collapse disorder of honey bees is caused by a number of factors and occurs in the following steps: first, various non-specific factors act - climate change, agrochemicals, air pollution, inadequate food, inadequate treatment of bee colonies against diseases, wintering of bee colonies contaminated with pesticides and pollutants, poor weather conditions for wintering of bee colonies, etc., which have a stressful effect on bees and lead to their exhaustion. Such colonies easily become susceptible to bacterial, fungal and parasitic infections and eventually die. In the last ten years, increased concentrations of ozone, PM particles and microplastics have had an increasing impact on the phenomenon of colony collapse disorder of honey bees. It is necessary to work more intensively on studying the impact of increasing air pollution and microplastics on the health and survival of bees, in order to adopt high-quality and effective programs to protect their health and survival. Continuous monitoring of colony collapse disorder of honey bees by each beekeeper, as well as at the state level, is necessary in order to obtain accurate information on the frequency of this phenomenon, its causes, and to take adequate measures to prevent it. Accordingly, in order to prevent the decline of bee colonies, the social community should systematically and continuously work on eliminating harmful factors, consistently implement comprehensive environmental and biodiversity protection measures, as well as measures of good agricultural, good production and good veterinary practice.

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