Bibliographic Study on the Interaction between Electromagnetic Fields and Bees: The Impact on Behaviour, Health and the Ecosystem

Vasilică Savu[1], Agripina Şapcaliu[1], Viorel Fătu[2]

[1]Research Station for Sericulture Baneasa, 013685, Bucharest, 69 Bucuresti-Ploiesti, Romania
[2]Research and Development Institute for Plant Protection, 013813, 6 Ion Ionescu de la Brad Blv., Bucharest, România

Abstract
The interaction between electromagnetic radiation generated by current technologies (mobile phones and 4G/5G wireless antennas) and bees is an ongoing research topic with wider ecological and environmental implications, as bees play a crucial role in pollination and maintaining ecosystems. Since the interaction between bees and electromagnetic radiation is a complex and multifactorial issue, studies are needed in Romania to better understand the connection between non-ionizing electromagnetic radiation and bees. The aim of this paper was to highlight the importance and relevance of the impact of non-ionizing electromagnetic radiation on bees, in order to understand the potential threats to their health and the ecosystem. In order to explore the impact of electromagnetic radiation on bees, we considered publications accessible in the published scientific databases (2007-2024). Data were collected from more than 100 publications and finally 83 studies were considered, from which 76 studies were finally selected. The authors emphasized the negative effect on bees exposed to non-ionizing electromagnetic radiation (changes in flight behavior, disorientation, inability to identify the food source), emphasizing the relationship between the practical consequences of exposure to electromagnetic radiation and the decline of bee populations (CCD).

Keywords: bees, behaviour, biodiversity, electromagnetic radiation, environment.

1. Introduction

Since the introduction of electrification in the late 1800s and wireless communications in the 1930s, ambient radiation levels from devices, broadcast facilities, terrestrial telecommunications infrastructure, satellites, and military applications have gradually increased over a range of frequencies in the non-ionizing bands of the electromagnetic spectrum. There has been extensive discussion in the media and elsewhere about the effects of non-ionizing electromagnetic fields (EMFs) on humans, especially since the International Agency for Research on Cancer (IARC) of the World Health Organization (WHO) has classified electromagnetic fields as extremely low-level (ELF) and radio-frequency radiation (RFR) as 2B possible human carcinogens — similar to lead, exhaust fumes, DDT and formaldehyde [1]. Ambient electromagnetic fields, such as ELFs from power lines, wiring and electrical appliances and RFRs used in all transmission devices, wireless communications and transmission apparatus, are biologically active and can cause adverse effects on various species of living organisms. There is abundant research on how low-level EMFs affect non-human species, including extensive analyses of non-ionizing radiation at all frequencies and mediums that many environmentalists and regulators are unaware of. In research on the biological effects of EMF, it has been known since the 1960s that many species are sensitive to low-energy

*Corresponding author: Sapcaliu Agripina, 0755115819, sapcaliuagripina@yahoo.com

exposures. Numerous laboratory and field studies have observed increased sensitivity and adverse effects in birds, mammals, bacteria/protozoa, amphibians, insects, fish and turtles, trees and plants. Living organisms have evolved in a matrix of environmental non-ionizing electromagnetic fields, particularly the Earth's geomagnetic field. For example, it has long been known that the geomagnetic field is necessary to coordinate embryonic development and provide information for the directional migration of insects and birds. These fields are relatively weak and also vary by location. For millions of years, living organisms have lived and thrived in these domains of geomagnetic fields. Therefore, it is logical to assume that man-made fields, which are unfamiliar to living organisms, could disrupt their normal physiological functions [2, 3].

Bees, being among the most important natural pollinators, play a crucial role in maintaining balance in natural ecosystems and ensuring agricultural production [4, 5, 6]. However, they are frequently affected by a number of diseases that can threaten their health and survival. The main factors that currently contribute to the outbreak of bee diseases are the stress caused by changes in their habitat, the intensive use of pesticides, malnutrition, electromagnetic radiation and other environmental factors that favour a decrease in immunity and the onset of various diseases (bacterial, fungal, viral, parasitic), including the collapse of bee colonies [7, 8, 9, 10]. An important role in the decline of bee colonies is played by atmospheric pollutants, which break down the odour molecules emitted by plants, and these altered odours can confuse bees, affect the number of bees able to detect food sources, increase foraging time, while pollination efficiency decreases, thus affecting interactions between plants and insects [11, 12, 13].

Living things have been adapted to the Earth's magnetic field to which they have been exposed as a result of millions of years of natural selection. Many organisms use the earth's magnetic field for orientation in space and time [14]. Bees use the position of the sun [15], polarized light [16, 17], and other cues [10] to determine their direction. The ability of bees to sense the Earth's electromagnetic field is one of the most important factors that bees use to find direction. Although the most important factor that bees use to find direction is thought to be the sun, they can also use cues such as smell, polarized light, sky compass, signs around the hive, chemicals, acoustic instruments and the field magnetic. The state of the sky (cloudy or clear blue sky) and the time of day determine which of these elements will be used by the bees. The results of several studies found that not only humans are influenced by electromagnetic fields [18, 19], but also rabbits, rats [20], bats [21, 22], birds [23], frogs [24, 25], nematodes, *Drosophila*, plants (*Ghamlyavya*), paper wasp [26] and honey bees [27, 28]. In recent years, electromagnetic field emissions have caused great concern about the decline of pollinators, as the deployment of new technologies such as 4G and 5G networks has led to increased exposure to electromagnetic radiation in many areas of the globe, especially as the most of the world's population owns mobile phones. Bees, being millimetre in size, selectively absorb and amplify the frequencies of electromagnetic emissions with shorter wavelengths, such as 5G technology, radiation that has been implicated in the phenomenon of bee colony collapse disorder (CCD) [29, 30, 31, 32].

2. Materials and methods

To explore the impact of electromagnetic radiation on bees, we considered publications accessible in the published scientific databases (2007-2024) Elsevier, MDPI, PubMed, Web of Science, Research Gate, Springer and Wiley Online Library. To search for articles on this topic, we used the following keywords: impact on bees, behaviour, environment, electromagnetic radiation, electromagnetic frequencies, biodiversity. The criteria for selecting the publications consisted of the topic of the papers, years of study, articles in English that met the eligibility criteria. Data were collected from more than 100 publications, considering 83 major studies, from which 76 studies were finally selected. For the study of the impact of non-ionizing electromagnetic radiation emitted by 4G/5G telecommunications equipment as well as high voltage lines on the health and behaviour of bees, we selected 9 private apiaries from the south and east of Romania, one apiary each in PH, TR, AG, IF, CL, VL, IS and DB counties. From these hives, beehives with healthy bees and/or with different ailments will be located at different distances from the source of electromagnetic

radiation emission (GSM antennas and high voltage lines), observing the impact of this radiation on behaviour, flight and communication, as well as their influence in the phenomenon of bee colony collapse disorder (CCD).

3. Results and discussion

There is no information on the current situation regarding the impact of electromagnetic radiation on bees in Romania at the national level, research is needed to monitor the impact of different sources of electrical and electromagnetic radiation, including 4G and 5G networks, on bees and other pollinators, because they play a role important in maintaining biodiversity in the ecosystem, but also in food production and maintaining food security. Knowing that exposure to electromagnetic radiation can have negative effects on bees, further research is needed to fully understand the extent of these impacts and to develop appropriate strategies to mitigate them or to protect bee colonies through various screening devices.

At an international level, the situation regarding the impact of electromagnetic radiation on bees is still a subject of ongoing research and debate, both in Europe and in the world. A US Fish and Wildlife Service wildlife biologist and former telecom impact leader, Dr. Albert Manville, says the electromagnetic radiation standards used by communications companies continue to be based on thermal heating and the incorrect assumption that non-thermal non-ionizing radiation from low level cannot cause DNA breaks because it is so low in potency that the evidence to the contrary is clear in lab and wild animals. The conclusions of a 2012 report by the US Department of Environment and Forests [33], later published in the journal Biology and Medicine, state that "based on the currently available literature, it is warranted to conclude that exposure to RF-EMF radiation may alter the functions of neurotransmitters, the blood-brain barrier, morphology, electrophysiology, cellular metabolism, calcium efflux, and gene and protein expression in specific cell types even at lower intensities." The paper "Exposure of Insects to Radio-Frequency Electromagnetic Fields from 2 to 120 GHz", published in Scientific Reports by Thielens A. et al., 2018, is the first study to investigate how insects (such as the western honeybee) [34] absorb frequencies higher (2 GHz to 120 GHz) which are used in the rollout of 4G/5G technology. Scientific simulations showed increases in absorbed power between 3% and 370% when insects were exposed to ≥ 6 GHz, which researchers concluded could lead to changes over time in insect behaviour [16], physiology and morphology [35]. A 2021 three-part landmark review of wildlife effects published in Reviews on Environmental Health by US experts Blake Levitt, Dr Henry Lai and former US Fish and Wildlife Senior Biologist Albert Manville states that current science should trigger urgent regulatory action, citing more than 1,200 scientific references that have found adverse biological effects on wildlife from even very low intensities of non-ionizing radiation, with findings of impacts on orientation and migration, reproduction, mating, nesting, den building and survival [36].

While some studies have suggested that exposure to electromagnetic radiation may have negative effects on bees, including changes in their behaviour, flight and communication, the results of these studies have been unclear and are not yet definitive. Some studies have suggested that exposure to electromagnetic radiation from sources such as cell phone towers [37] and Wi-Fi networks may have negative effects on bees, while others have found no significant impact. In 2011, the World Health Organization (WHO) recognized electromagnetic fields (EMF) as a possible environmental risk factor for bees, and some studies suggest that exposure to certain levels of electromagnetic radiation can have negative effects on bees, including changes in their behaviour and ability to navigate [38]. Different studies from different regions of the world have reported the negative effect of EMFs emitted by mobile phone towers, high voltage wires and various electronic devices on bees in terms of strength, navigation, behaviour, honey deposit, pollen deposit and brood zone. However. there is also research suggesting that these effects are negligible or within normal limits for bees [39]. Some researchers have argued that EMFs do not have a negative effect on bees [40]. According to a study by Mall and Kumar, bee colonies were not affected by EMF, but they reported that it could harm bees in the long term [41]. Currently, the scientific consensus is that more research is

needed to fully understand the potential impact of electromagnetic radiation on pollinators.

3.1. Electromagnetic fields increase stress levels

In 2018, Russian researcher Eskov [42] demonstrated that bees generate electromagnetic signals at frequencies between 180-250 hertz when performing their visual communication dances. GSM antennas transmit signal pulses at frequency of 217 hertz (carrier bursts of 0.577 ms duration), which means that these frequencies are found in the frequency band emitted by bees. Hungry bees immediately react to these 217 Hz frequencies by waving their antennae, a sign of stress and panic. Studies have shown that ELF and EMF cause some physiological and behavioural changes in insects and increase the level of stress proteins [43]. In another study by Treder, he found that there was a significant increase in insect motor activity because EMFs increased octopamine levels in the insects. Octopamine, a biogenic monoamine structurally related to noradrenaline, acts as a neurohormone, neuromodulator and neurotransmitter in invertebrates.

3.2. Electromagnetic fields disrupt cryptochrome-based magnetic navigation

Studies of the effects of electromagnetic fields on bees have determined that they appear to be affected by mobile radiation because insects (bees) use a pigment called cryptochrome to navigate and bees use it to sense the direction of the magnetic field of the earth, but are hindered by radiation from mobile phone operators' land bases. Because of this, the bees are confused and can no longer find their way to the hive [44]. Reproduction, foraging, navigation and survival of many animals depend on the earth's magnetic field, and more recent scientific studies demonstrate that artificial radio frequency electromagnetic radiation from mobile telecommunications interferes with these biological processes. Often their navigation systems fail and bees do not return to the hive after collecting pollen and nectar, which contributes to CCD (colony collapse disorder). Currently, the most important cause of CCD is claimed to be electromagnetic pollution [45, 46, 47, 48]. Due to increased electromagnetic pollution, it is suggested that bees that leave the hive to collect honey, pollen, propolis or water do not return to the hive. German researchers placed cordless phone stations (which emit modulated microwave radiation 24/7, just like cell phone masts) near some of their hives, while leaving others unexposed to the radiation. They then marked the bees as they left the hives and counted the proportion of the marked bees that returned. The researchers found a higher proportion of bees that did not return to the irradiated hives. The mechanism of this strange behaviour of bees proposed by the researchers would be the damage to cryptochromes, some pigments used by almost all animals and plants with the role of "body clock", which tell the body whether it is night or day, thus regulating metabolism and synchronizing the natural circadian rhythms of sleep-wake. Cryptochromes in the eye can detect the direction of the earth's magnetic field, and animals that navigate using the earth's magnetic field, including bees, superimpose the direction of the magnetic field on their visual field and navigate precisely.

Research has shown that these electromagnetic fields disrupt magnetic and solar navigation based on cryptochromes and thus prevent animals from orienting themselves in space. Electromagnetic fields distort the bees' perception of the earth's magnetic field and they can fly in the wrong direction, disrupting their cryptochrome-based magnetic and solar navigation, as well as their orientation "dance" and foraging. Because of this, the bees are confused and no longer find the way to food or hives, having a negative impact on the activity and health of the colonies [49, 50, 51, 52]. According to, significant differences were found in the return of bees to the hives: 40% of the non-irradiated bees and 7.3% of the irradiated ones returned to their hives.

The cryptochrome-based body clock in insects is also affected by magnetic fields, as shown by Taishi Yoshii in 2009. Electromagnetic radiation from cell phone antennas and wireless devices can disrupt the bee's ability to navigate both through the sun and through the earth's magnetic field. Bees have crystal structures of magnetite in the fat cells of their bodies. These magnetite structures are the active components of the magneto-reception system [53]. Thanks to these structures, bees can sense even slight changes in the earth's magnetic field lines. These delicate structures are affected by the slightest magnetic pollution that occurs, and it causes the bees to lose their

direction. The bee dances that bees use to communicate with each other are distorted.

3.3. Electromagnetic fields cause the decline of bee colonies.

Studies have shown a dramatic reduction in bee populations due to the use of mobile phones, the signal emitted by them disorienting the insects, leading to confusion, chaotic flight and their failure to return to the hive, which ultimately leads to the decline of bee colonies. Moreover, mobile phone emissions affect the laying of eggs by the mother, affect the sperm of drones, with the appearance of genetic disorders in the offspring. India lowered its RF limits by 1/10 of ICNIRP after a 2010 government report documented that most research studies found adverse effects on wildlife, birds and bees [54].

3.4. Electromagnetic fields cause the immune system to collapse

The bees' immune systems are also under the control of their circadian rhythms to efficiently use the body's repair resources only at night. If these rhythms are interrupted or their amplitude is reduced by electromagnetic radiation, the immune system no longer functions at full capacity. Under the influence of electromagnetic frequencies, the immune system of bees collapses and they become unusually sensitive to pathogens, which will cause diseases and the decimation of bee colonies [55, 56, 57].

4. Conclusions

Electromagnetic fields from power lines, cell phones, cell and wireless towers impact birds, bees, wildlife and our environment. Electromagnetic radiation standards used by communications companies continue to be based on thermal heating, a criterion nearly 30 years out of date and inapplicable today, while exposure patterns change rapidly with each new technology development, long before our understanding of the biological consequences.

In Romania, as in other countries, it is important to assess the potential impacts of electromagnetic radiation on bee populations and to implement measures to protect them. This may include monitoring bee populations, monitoring exposure to electromagnetic radiation, and conducting research to better understand the effects of these radiation sources on bee health.

It is also important to ensure that these networks are used in a safe and responsible way and to assess the potential risks and impacts on human health and the environment. Further research and monitoring are needed to fully understand the impact of these networks on pollinators and to inform political decision-makers in Romania and other countries. It is also important for policy makers to consider the potential impacts of electromagnetic radiation when developing and implementing policies related to 4G and 5G networks and other sources of electromagnetic radiation.

In general, concern about the impact of electromagnetic radiation on bees is part of a larger issue related to the potential impact of human activities on the environment and wildlife. Overall, the situation regarding the impact of electromagnetic radiation on bees is complex and is an area that requires continuous research and monitoring. Maintaining healthy bee populations will require a multifaceted approach that takes all of these factors into account.

Many countries, including the European Union, have taken steps to monitor the development of 5G technology and its potential effects on the environment, including pollinators. In response to these concerns, some countries have implemented measures to protect bees and other pollinators, such as restrictions on the use of pesticides and the creation of protected habitats.

There has also been increased investment in research to better understand the effects of electromagnetic radiation on bees and other pollinators and to develop strategies to mitigate these impacts. Some states have also implemented guidelines and regulations to minimize potential risks to pollinators and other wildlife.

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