



Review Article

An overview of anthropogenic electromagnetic radiations as risk to pollinators and pollination

Sanjay Kumar*

Department of Zoology, Kamla Nehru Institute of Physical and Social Sciences, Sultanpur (U.P.), India

Vinay Kumar Singh

Zoological Survey of India, Kolkata (West Bengal), India

Pashupati Nath

Department of Civil Engineering, Roorkee College of Engineering, Roorkee, Haridwar (Uttarakhand), India

PC Joshi

Department of Zoology and Environment Science, Gurukula Kangri Vishwavidyalaya, Haridwar (Uttarakhand), India

*Corresponding author. Email: kumarsanjaynitin2011@gmail.com

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Abstract

Pollinators play a key functional role in most terrestrial ecosystems and provide important ecosystem service to maintain wild plant communities and agricultural productivity. The decline in pollinators has been related to anthropogenic disturbances such as habitat loss, alterations in land use, and climate change. The surge in mobile telephony has led to a marked increase in electromagnetic fields in the atmosphere, which may affect pollinator and pollination. Several laboratory studies have reported negative effects of electromagnetic radiation on reproduction, development, and navigation in insects. The abundance of insects such as the beetle, wasp, and hoverfly, decreased with electromagnetic radiation (EMR), whereas the abundance of underground-nesting wild bees and bee fly unexpectedly increased with EMR. Potential risks for pollinators and biodiversity are anthropogenic radiofrequency electromagnetic radiation (AREMR) (light, radiofrequency). Artificial light at night (ALAN) can alter the function and abundance of pollinator. Evidence of impacts of AREMR is not adequate due to a lack of high quality, field-realistic studies. Whether pollinators experiencing a threat of ALAN or AREMR, while major knowledge gap exists. In this review, the effects of EMR on wild pollinator groups such as wild bees, hoverflies, bee flies, beetles, butterflies, and wasps etc. have been highlighted. Researchers are also recommended for further study on the effects of EMR on insects. This study will be significant to conserve pollinators and other important insects.

Keywords: Anthropogenic, Electromagnetic, Pollinator, Radiations, Risk

INTRODUCTION

Insects are a major group of animals on the earth and occur everywhere. They were the first organisms to successfully colonize land and were most beneficiaries to humankind in many ways from ancient time. The insects play an important role in maintaining the cycle of nutrients, protection, soil regeneration and pollination of phanerogamic plants (Singh, 1988; Bhatia, et al., 1995; Singh, 1997; Dag and Gazit, 2000, Larson, et al., 2001, Evenhuis et al., 2008; Halder, et al., 2019; Hunicken, et al., 2020; Sawe, et al., 2020). About 85% of the flowering plant species depend upon animals, mostly insects for pollination and worldwide total annual economic value of crop pollination is estimated

about \$153 billion (Gallai, et al., 2009). Pollinators play a key functional role in most terrestrial ecosystems and provide important ecosystem service to maintain wild plant communities and agricultural productivity (Klein et al. 2007; Kremen et al. 2007; Potts et al. 2010).

Pollinators have many benefits in nature and for humankind, but they are facing multiple anthropogenic threats. Over the past time, many studies have cautioned about the decline of pollinators (Ashman, et al., 2004; Biesmeijer, et al., 2006; Pauw, 2007; Goulson, et al., 2008; Burkle, et al., 2013; Godfray, et al., 2015; Aguero, et al., 2020, De Santis and Chacoff, 2020; Marques, et al., 2020). The urbanization and use of wireless technologies, including mobile (5G, internet

of things) are responsible for the proliferation of anthropogenic electromagnetic radiations (EMR). Anthropogenic radiofrequency electromagnetic radiation, artificial light at night emitted from power lines and used in wireless technologies were reported as an additional growing threat to pollinators (Adam, *et al.*, 2019). Lack of high quality scientific studies led to unavailability of information on the anthropogenic EMR as a risk to pollinators. Only a few studies provided evidence on the effect of artificial light at night and anthropogenic radiofrequency electromagnetic radiation on alteration in pollinator communities, pollination and fruit set. Some researchers provided some evidence on the honey bee *Apis mellifera* and other invertebrates, which can detect EMR and use it for orientation or navigation. Studies also revealed that AREMR influences abundance or diversity of pollinators and reported positive and negative effects depending on the pollinator group and geographical locations. Therefore, anthropogenic EMR (ALAN or AREMR) is a significant threat to insect pollinators, ecosystems and humanity (Adam, *et al.*, 2019). The anthropogenic disturbances such as alterations in land use, loss of habitat and climate change are liable for pollinators to decline (Kearns, *et al.*, 1998; Aguilar, *et al.*, 2006; Hegland, *et al.*, 2009; Potts, *et al.*, 2006; Potts *et al.*, 2010; Chiawo *et al.*, 2017; Dimobe *et al.*, 2017; Stein *et al.*, 2018; Tangtorwongsakul, *et al.*, 2018). Due to exponential use of mobile telephony during recent years, pronounced increase of electromagnetic fields has been reported in the environment (Lazaro, *et al.*, 2016). Studies reported the harmful effects of electromagnetic exposure for different living organisms, from invertebrates to vertebrates, plants and bacteria (Cucurachi, *et al.* 2013; Balmori, 2015; Malkemper, *et al.*, 2018; Driessen, *et al.*, 2020).

The effects of electromagnetic radiation have been reported by a majority of studies on model species such as fruit fly (*Drosophila melanogaster*) and the honeybee (*Apis mellifera*). The electromagnetic radiation delays the development of fruit fly (Atli and U' nlu' 2006) and affect negatively on reproductive success (Panagopoulos, *et al.* 2004; Atli and U' nlu' 2006, 2007; Panagopoulos and Margaritis, 2010; Panagopoulos, *et al.* 2010; Chavdoula, *et al.* 2010), positive effect (Weisbrot, *et al.*, 2003) and no effects (Vijver, *et al.* 2013) due to DNA fragmentation and reproductive cell death (Chavdoula, *et al.* 2010; Panagopoulos, *et al.* 2007, 2010). Studies reported the effect of radiation on honey bee in decreasing colony strength and oviposition rate (Sharma and Kumar, 2010; Sahib, 2011), and induces swarming behaviour (Favre, 2011). Electromagnetic radiation also interferes with honeybee navigation in honey bee (Kirschvink *et al.* 2001; Wajnberg, *et al.* 2010; Valkova and Vacha 2012; Balmori 2015). Studies reported that exposure to electromagnetic smog, honeybees are often unable to return to their hives, which lead to colony collapse (Harst, *et al.*

2006; Warnke 2009; Favre, 2011; Sharma and Kumar, 2010; Sahib, 2011). The effects of radiofrequency magnetic fields has been reported on the interruption of magnetoreception in the American cockroach (Vacha, *et al.* 2009). In another study, the influence of electromagnetic radiation reported on olfactory memory, visual and ability to locate food (Cammaerts, *et al.*, 2012), orientation, locomotion in ants (Cammaerts, *et al.* 2014; Cammaerts and Johansson, 2014). Studies are carried out under laboratory conditions on model organisms (Cucurachi *et al.*, 2013). Insects are affected negatively by electromagnetic radiation (Balmori 2015). Studies investigated the electromagnetic radiation emitted by mobile telecommunication antennas affects the abundance and diversity of wild pollinators (Tscheulin, *et al.* 2010, Hill, and Bartomeus, 2016, Shepherd, 2018, Egdogan and Cengiz, 2019, Sanchez-Bayo and Wyckhuys, 2019).

Pollinators and pollination under threat: Many anthropogenic activities may result in global environmental change, which may act as a threat to global insect biodiversity and to nature (Hallmann *et al.*, 2017; IPBES, 2016; Potts *et al.*, 2016; Sánchez-Bayo and Wyckhuys, 2019). Based on their importance, status and trends, insect pollinators are facing threats and particularly high on the science and policy agenda worldwide (IPBES, 2016). Major pressures impacting pollinators and pollination services include use and misuse of pesticides, intensive agricultural management, land-use change, climate change, pests and pathogens, alien invasive species (Vanbergen, 2013; Brown *et al.*, 2016; IPBES, 2016).

Environmental pollution is another risk to pollinators and pollination, although its impact is much less studied (IPBES, 2016). The global spread of anthropogenic electromagnetic radiation such as radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma radiation is a form of pollution, which is a potential risk to wildlife (Balmori, 2015; Bandara and Carpenter, 2018; Grubisic *et al.*, 2018; Russell, 2018). WHO recognized the risk of human health, from non-ionizing anthropogenic Electromagnetic Radiations (up to 300 GHz). At present, neither the WHO nor the OECD (OECD, 2012), have reported the current or future indirect risks from anthropogenic EMR to the natural environment. The artificial light at night (ALAN) and anthropogenic radiofrequency electromagnetic radiation (AREMR) utilized in mobile and smart wireless technologies are increasing globally for increasing urbanization and the worldwide launch of next-generation wireless technologies and the Internet of Things (Macgregor *et al.*, 2015; Bandara and Carpenter, 2018; Bin Zikria *et al.*, 2018; Russell, 2018).

Effects of artificial light at night (ALAN): The artificial light at night has been reported as a potential risk to nocturnal pollinators and pollination (Macgregor *et al.*, 2015) and mentioned in the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem

Services (IPBES) assessment of pollinators and pollination as “a driver clearly affecting nocturnal species and growing in importance due to urbanization”. The IPBES also noted that compared to other drivers effects of artificial light at night is still scarcely studied and called for further studies to assess the degree of light pollution effects on nocturnal pollinators (IPBES, 2016). The artificial light altered the architecture of communities of nocturnal pollinator and reduced the visitation rates to plants by 62% leading to a 13% drop in the fruit set of a focal plant species (*Cirsium oleraceum*, Asteraceae) (Knop *et al.*, 2017). Some studies have reported the effects of artificial street lighting on the reduction of local species richness, abundance, rates of pollen transport and feeding in moths (Macgregor, *et al.*, 2017; van Langevelde, *et al.*, 2017; Grubisic, *et al.*, 2018).

Study on combined diurnal and nocturnal plant-pollinator interaction revealed that light pollution transmitted to the diurnal animals through a trophic association between nocturnal and diurnal species (Knop *et al.*, 2017). Other studies reported the influence of Artificial light at night (ALAN) in impairment of behaviour of diurnal pollinators (Vanbergen, 2013; Potts *et al.*, 2016).

Effects of anthropogenic radiofrequency electromagnetic radiation (AREMR): Apart from ALAN, the IPBES report (IPBES, 2016; Potts *et al.*, 2016) has not reported other sources and wavelengths of anthropogenic EMR. It was due to insufficient data for an evidence assessment, with only a few studies considered utilization of magnetic fields by bees for foraging behaviour (Clarke *et al.*, 2013; Gould *et al.*, 1978; Hsu and Li, 1994) and few workers recognized the potential effects of AREMR (Greenberg *et al.*, 1981; Favre, 2011). Another study related to biodiversity conservation, natural capital and ecosystem services, reported the potential, but unstudied threats of wildlife in form of non-ionizing radiation from wireless transmission setups and 5G mobile phones (Sutherland *et al.*, 2018).

In addition to ALAN, AREMR is reported as a growing risk to pollinators and pollination (Balmori, 2015). Other studies revealed that honey bees (*Apis mellifera*) can detect magnetic fields physiologically (Gould *et al.*, 1978; Kirschvink and Kirschvink, 1991; Hsu and Li, 1994; Liang *et al.*, 2016; Lambinet *et al.*, 2017) and can use this capability for navigation, orientation and foraging behaviours. Additionally, honey bees use electric fields of the same magnitude as commonly encountered AREMR for intraspecific and interspecific communication for foraging on floral resources (Clarke, *et al.*, 2013; Greggers, *et al.*, 2013). Therefore, it has been concluded that AREMR can disorder the physiological functions and affecting bee health and survival of honeybee.

Experimental studies on EMR exposure to pollinators: Several scientific laboratory experiments have considered that insects can detect and may orientate

using electromagnetic fields and affect behaviour, cell development and physiological function (Wan *et al.*, 2014; Bae *et al.*, 2016; Sutton *et al.*, 2016; Tomanova and Vacha, 2016). Based on a few experimental studies, little evidence of exposure to EMR has been reported, which may affect the development, reproduction in animals (Wan *et al.*, 2014; Bae *et al.*, 2016; Wyszowska *et al.*, 2016; Zhang *et al.*, 2016). Most of studies are related to the effects of EMR on cockroach (Vacha, 2009), birds (Engels *et al.*, 2014) and mammals (Malkemper, *et al.*, 2015). Acute exposure (20 to N100 μ T EMF) had a clear negative impact on learning and memory in the honeybee workers (Shepherd, *et al.*, 2018).

A study has been carried out on the effects of EMF (5 –15 μ T) on behaviour and cognition in bee (Burda *et al.*, 2009). Other effects of EMF(100 μ T) on the foraging and flight rate on a sugar source have been reported in worker bee, which can alter the foraging in the ground vegetation (Shepherd *et al.*, 2018).

Experiment on honey bees reported that very close proximity to AREMR (900 MHz) could affect acoustic and swarming behaviour (Favre, 2011). Another experimental study showed that exposure of AREMR increased mortality during pupation and reduced hatching rate of the new queens (Odemer and Odemer, 2019). In an entomological study of wild pollinator communities around 10 mobile phone antennas with high frequencies (800–2600 MHz), major effects have been reported on insect abundance (Lazaro *et al.*, 2016). This study revealed a correlation between insect abundance and anthropogenic electric field, measured at distance intervals (50, 100, 200 and 400 m) from the antenna, but varied with geographical locations. Greater exposure to EMR was related positively to underground nesting wild bees and bee flies, negatively to hoverflies; wasps, or uncorrelated to butterflies in terms of abundance (Lazaro *et al.*, 2016). Another field study on phylogenetically unrelated invertebrate taxa such as Collembola, Heteroptera, Hymenopteran parasitoid and *Drosophila melanogaster*, reported no effects on reproductive capacity in animals exposed to EMR from a mobile antenna (Vijver *et al.*, 2014).

Recommendations for future research: Further research is required to evaluate the potential threat to pollinators and other invertebrates from exposure to anthropogenic EMR. More research studies are required to assess the unstudied effects of emerging AREMR technologies on pollinators and another biodiversity (Bandara and Carpenter, 2018; Bin Zikria *et al.*, 2018; Russell, 2018). Good quality scientific investigations must improve to obtain an accurate level of the level of risk (Makinistian, *et al.*, 2018). As reported by other researchers (Gonzalez-Varo, *et al.*, 2013; Vanbergen, 2013; Godfray, *et al.*, 2014), assessments of chronic exposure and synergistic effects arising from exposure to sources of ALAN/AREMR and other

stressors such as pesticides, pathogens, nutritional deficits need testing to evaluate the overall level of risk from anthropogenic EMR. To understand exposure and effects requires consideration of traits of pollinator species, such as nesting habits, foraging or dispersal behaviour and sociality, which govern the level of impact of different sources of anthropogenic EMR (Vanbergen, 2013; Potts, *et al.*, 2016). Measurement of pollinator responses to EMR exposure at different biological levels such as species, population, community and resulting change crop yield over the longer-term exposure would be especially valuable. Interdisciplinary collaborators (engineers, physicists, ecotoxicologists and biologists) must come together, to test hypotheses about biological impacts of exposure of anthropogenic EMR (Makinistian *et al.*, 2018) on pollinators and other insects.

Conclusion

Some recent evidence revealed the effects of ALAN on pollinator communities, although there is a need for further high-quality studies to conclude its role as a major threat to pollinators. Due to the lack of high-quality scientific research, knowledge about the impact of AREMR on invertebrates and other pollinators is inadequate and is hindered. Most of experimental as well as field studies are failed due to unavailability of good scientific methods, improper reporting of technical and scientific details. The anthropogenic EMR (ALAN or AREMR) is considered as a significant threat to insect pollinators. The abundance and composition of wild pollinators in natural habitats are affected by electromagnetic radiation from telecommunication antennas. Studies reported that the effects of EMR on the abundance of different pollinator groups might be due to different susceptibilities of larval stages to radiation. Anthropogenic EMR emissions are proliferating, but more research study is required to study the adverse impacts on pollinators and pollination.

Conflict of interests

There is no conflict of interest regarding the publication of this article.

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