Anthropogenic Radiofrequency Electromagnetic Fields as an Emerging Threat to Wildlife Orientation

Article *in* Science of The Total Environment · July 2015

DOI: 10.1016/j.scitotenv.2015.02.077

1 author:

Alfonso Balmori
Junta de Castilla y León

Science of the Total Environment 518–519 (2015) 58–60

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Short communication

Anthropogenic radiofrequency electromagnetic fields as an emerging threat to wildlife orientation

Alfonso Balmori

Consejería de Medio Ambiente, Junta de Castilla y León, C/ Rigoberto Cortejoso, 14, 47071 Valladolid, Spain

HIGHLIGHTS

- The growth of wireless telecommunication technologies causes increased electrosmog.
- Radio frequency fields in the MHz range disrupt insect and bird orientation.
- Radio frequency noise interferes with the primary process of magnetoreception.
- Existing guidelines do not adequately protect wildlife.
- Further research in this area is urgent.

ARTICLE INFO

Article history:
Received 5 January 2015
Received in revised form 20 February 2015
Accepted 22 February 2015
Available online xxxx

Editor: P. Kassomenos

Keywords:
Ecological effect
Electromagnetic field exposure
Environmental pollution
Magnetic compass
Nonthermal effects
Orientation

ABSTRACT

The rate of scientific activity regarding the effects of anthropogenic electromagnetic radiation in the radiofrequency (RF) range on animals and plants has been small despite the fact that this topic is relevant to the fields of experimental biology, ecology and conservation due to its remarkable expansion over the past 20 years. Current evidence indicates that exposure at levels that are found in the environment (in urban areas and near base stations) may particularly alter the receptor organs to orient in the magnetic field of the earth. These results could have important implications for migratory birds and insects, especially in urban areas, but could also apply to birds and insects in natural and protected areas where there are powerful base station emitters of radiofrequencies. Therefore, more research on the effects of electromagnetic radiation in nature is needed to investigate this emerging threat.

Different animal groups are sensitive to low frequency electromagnetic fields, and many species with receptor organs are provided with important orientation cues from natural electric fields (Kalmijn, 1988). Animals can use the direction of the magnetic field as a compass and the intensity of the magnetic field as a component of the navigational map, with light-dependent reactions in specialised photo-pigments and reactions involving small crystals of magnetite, using one of these systems, or both simultaneously, depending on the animal groups (Kirschvink et al., 2001; Johnsen and Lohmann, 2005; Wiltschko et al., 2007; Hsu et al., 2007; Ritz et al., 2009; Wajnberg et al., 2010).

Some insects, like bumblebees (*Bombus terrestris*), can interact with floral electric fields and electric field sensing constitutes a potentially important sensory modality. The perception of weak electric fields by bees in nature, which should be considered alongside vision and olfaction, may have an adaptive value (Clarke et al., 2013). An applied static magnetic field affects circadian rhythms, magnetosensitivity and orientation of insects through cryptochromes, and a prolonged weakening of the geomagnetic field affects the immune system of rats (Roman and Tombarkiewicz, 2009; Yoshii et al., 2009).

In the radiofrequency range, the rapid development and increased use of wireless telecommunication technologies led to a substantial change in the radio-frequency electromagnetic field (RF-EMF) exposure (Levitt and Lai, 2010). This increased exposure was most consistently observed in outdoor areas due to emissions from radio and mobile phone base stations (Urbinello et al., 2014). Current evidence indicates that exposure at levels found in the environment (in urban areas and near base stations), may particularly alter the receptor organs to orient in the magnetic field of the earth, although the species conservation implications are unknown. Radio frequency fields in the MHz range disrupt birds' orientation interfering directly with the primary processes of magnetoreception and therefore disable the avian compass as long as

E-mail addresses: balmaral@jcyl.es, abalmorimartinez@gmail.com.

http://dx.doi.org/10.1016/j.scitotenv.2015.02.077

they are present (Wiltschko et al., 2014). Ritz et al. (2004 & 2009) reported the sensitivity for orientation of European robins (*Erithacus rubecula*) to radiofrequency magnetic fields. The orientation of migratory birds is disrupted when very weak high-frequency fields (broadband field of 0.1–10 MHz of 85 nT or a 1.315 MHz field of 480 nT) are added to the static geomagnetic field of 46.000 nT (Thalau et al., 2006). It was convincingly demonstrated that robins are unable to use their magnetic compass in the presence of urban electromagnetic radiofrequency noise in the frequency range of 2 kHz–5 MHz (Engels et al., 2014). Therefore, electrosmog scrambles birds' magnetic sense and this finding could inform policies written to protect the habitats of endangered species.

As with birds, radio frequency magnetic fields disrupt magnetoreception in insects. The geomagnetic field reception in American cockroach is sensitive to weak radio frequency field causing a disruptive effect (Vacha et al., 2009), so these authors suggest that electromagnetic smog will have to be taken more seriously in animal magnetoreception experiments. In an experimentally-generated electromagnetic field of about 1 V/m with a realistic (and even lower) power intensity similar to those surrounding communication masts, the results and observations suggest that GSM (Global System for Mobile communications) 900 MHz radiation might have a severe impact on the nerve cells of exposed ants, especially affecting the visual and olfactory memory, causing the loss of their ability to use visual cues and suggesting that electromagnetic radiation may have an impact on the orientation behaviour and navigation of animals that use magnetic fields to find their way (Cammaerts et al., 2012, 2014). Honeybees are sensitive to pulsed electromagnetic fields generated by mobile phones and observable changes in the bee behaviour could be one explanation for the loss of colonies (Favre, 2011). Magnetoreception system in Monarch butterfly orientation (Guerra et al., 2014) may be also suffering interference with anthropogenic radio frequency magnetic fields and this, together with other factors (Brower et al., 2012), may be a cause of their population decline.

Electromagnetic fields act via activation of voltage-gated calcium channels (Pall, 2013). Changes in the size of the magnetic granules upon applying additional magnetic field to the cells of *Apis mellifera* were observed, and this size fluctuation triggered the increase of calcium intracellular (Hsu et al., 2007). Therefore, we may hypothesise that some of the disruptive effects of radio frequency fields on the orientation of animals may be related to the interference with calcium channels.

An aversive effect on bats has been found in habitats exposed to radiofrequency radiation (1–4 GHz) when compared with matched sites where no such radiation can be detected (Nicholls and Racey, 2009). Cattle exposed to radiofrequency emissions (900 MHz) from nearby base stations may suffer changes in the redox proteins and enzyme activities. It was also found that some are sensitive to radiation, while others are not (Hässig et al., 2014).

Exposure to low intensity radiation can have a profound effect on biological processes (Bolen, 1994). Although there is a good degree of evidence on the injurious effects of radiofrequency electromagnetic fields on the immune system, pineal gland, circadian rhythm, oxidative stress and teratogenicity, these topics remain controversial (Lerchl et al., 2008; Takahashi et al., 2009; Jin et al., 2012; Qin et al., 2012; Bilgici et al., 2013; Tsybulin et al., 2013; Yakymenko et al., 2014; Cao et al., 2015). Conversely, there is a scientific agreement regarding harmful effects of radio frequency radiation on human reproduction (Adams et al., 2014). Low-voltage electricity current-generated electromagnetic field can produce a significantly negative effect on the breeding success of birds (*Ciconia ciconia*) nesting directly on electricity lines (Vaitkuvienė and Dagys, 2014) and these same results have been found in nests exposed to radiofrequency radiation near phone masts (Balmori, 2005).

The health risk of electromagnetic fields to aquatic organisms needs to be addressed (Lee and Yang, 2014). The potential interactions between diadromous fishes of conservation importance and the electromagnetic fields and subsea noise from marine renewable energy developments are being studied (Gill et al., 2012).

In a systematic review of published scientific studies on the potential ecological effects of radiofrequency electromagnetic fields (RF-EMF) in the range of 10 MHz–3.6 GHz, about two thirds of the reviewed studies show ecological effects of RF-EMF at high, as well as at low, dosages (Cucurachi et al., 2013). The low dosages are compatible with real field situations, and could be found under environmental conditions (Cucurachi et al., 2013; Balmori, 2014). However, studies conducted in real field situations must be made with a sufficient experimental exposure time, since results with a short period of exposure are likely to be ambiguous (e.g. 48 h in Vijver et al., 2013).

A limited number of studies have addressed the effects of radiofrequency radiation on plants indicating that these effects depend on the plant family, growth stage, exposure duration, frequency, and power density, among other factors (Senavirathna and Takashi, 2013; Halgamuge et al., 2015). There are two papers warning on negative effects of radio frequencies from mobile phone masts on trees (Balmori, 2004; Waldmann-Selsam and Eger, 2013) and researchers have found very worrying effects in laboratory studies (Pesnya and Romanovsky, 2013). The results of these preliminary findings indicate that further research on this topic is extremely urgent.

These results could have important implications for wildlife, especially in urban and suburban areas, but also in rural, natural and protected areas where there are powerful base station emitters of radiofrequencies (Bürgi et al., 2014). Such effects have not yet been examined, but the consequences continue due to the fact that the existing guidelines of public health protection only consider the effects of short-term thermal exposure (Hyland, 2000) and do not adequately protect wildlife. EMF safety standard should be based on the more sensitive, natural biological response (Blank, 2014). Therefore, more research on the effects of electromagnetic radiation in nature is needed to investigate this emerging threat (Balmori, 2014).

Acknowledgements

The author is grateful to J.L. Telleria, D.O. Carpenter, R. Carbonell and S. Wright for their help and advice. The author reports no conflicts of interest.

References

Adams, J.A., Galloway, T.S., Mondal, D., Esteves, S.C., Mathews, F., 2014. Effect of mobile telephones on sperm quality: a systematic review and meta-analysis. Environ. Int. 70, 106–112.

Balmori, A., 2004. ¿Pueden afectar las microondas pulsadas emitidas por las antenas de telefonía a los árboles y otros vegetales? Ecosistemas 13, 79–87.

Balmori, A., 2005. Possible effects of electromagnetic fields from phone masts on a population of white stork (*Ciconia ciconia*). Electromagn. Biol. Med. 24, 109–119.

Balmori, A., 2014. Electrosmog and species conservation. Sci. Total Environ. 496, 314–316.

Bilgici, B., Akar, A., Avci, B., Tuncel, O.K., 2013. Effect of 900 MHz radiofrequency radiation on oxidative stress in rat brain and serum. Electromagn. Biol. Med. 32, 20–29.

Blank, M., 2014. Cell biology and EMF safety standards. Electromagn. Biol. Med. 25, 1–3 (Epub ahead of print).

Bolen, S., 1994. Radiofrequency/microwave radiation biological effects and safety standards. A Review (Report, Jun. 1988–May 1993). Rome Laboratory. Air Force Materiel Command. Griffiss Air Force Base, New York.

Brower, L.P., Taylor, O.R., Williams, E.H., Slayback, D.A., Zubieta, R.R., Ramirez, M.I., 2012. Decline of monarch butterflies overwintering in Mexico: is the migratory phenomenon at risk? Insect Conserv. Divers. 5, 95–100.

Bürgi, A., Scanferla, D., Lehmann, H., 2014. Time averaged transmitter power and exposure to electromagnetic fields from mobile phone base stations. Int. J. Environ. Res. Public Health 11, 8025–8037.

Cammaerts, M.C., De Doncker, P., Patris, X., Bellens, F., Rachidi, Z., Cammaerts, D., 2012. GSM 900 MHz radiation inhibits ants' association between food sites and encountered cues. Electromagn. Biol. Med. 31, 151–165.

Cammaerts, M.C., Vandenbosch, G.A., Volski, V., 2014. Effect of short-term GSM radiation at representative levels in society on a biological model: the ant *Myrmica sabuleti*. J. Insect Behav. 27, 514–526.

Cao, H., Qin, F., Liu, X., Wang, J., Cao, Y., Tong, J., Zhao, H., 2015. Circadian rhythmicity of antioxidant markers in rats exposed to 1.8 GHz radiofrequency fields. Int. J. Environ. Res. Public Health 12, 2071–2087.

Clarke, D., Whitney, H., Sutton, G., Robert, D., 2013. Detection and learning of floral electric fields by bumblebees. Science 340, 66–69. http://dx.doi.org/10.1126/science.1230883.

Cucurachi, S., Tamis, W.L.M., Vijver, M.G., Peijnenburg, W.J.G.M., Bolte, J.F.B., Snoo, G.R., 2013. A review of the ecological effects of radiofrequency electromagnetic fields (RF-EMF). Environ. Int. 51, 116–140.

Engels, S., Schneider, N.L., Lefeldt, N., Hein, C.M., Zapka, M., Michalik, A., Elbers, D., Kittel, A., Hore, P.J., Mouritsen, H., 2014. Anthropogenic electromagnetic noise disrupts magnetic compass orientation in a migratory bird. Nature http://dx.doi.org/10.1038/nature13290.

Favre, D., 2011. Mobile phone-induced honeybee worker piping. Apidologie 42, 270–279.

Gill, A.B., Bartlett, M., Thomsen, F., 2012. Potential interactions between diadromous fishes of UK conservation importance and the electromagnetic fields and subsea noise from marine renewable energy developments. J. Fish Biol. 81, 664–695.

Guerra, P.A., Gegear, R.J., Reppert, S.M., 2014. A magnetic compass aids monarch butterfly migration. Nat. Commun. 5.

Halgamuge, M.N., Yak, S.K., Eberhardt, J.L., 2015. Reduced growth of soybean seedlings after exposure to weak microwave radiation from GSM 900 mobile phone and base station. Bioelectromagnetics 36, 87–95.

Hässig, M., Wullschleger, M., Naegeli, H.P., Kupper, J., Spiess, B., Kuster, N., Capstick, M., Murbach, M., 2014. Influence of nonionizing radiation of base stations on the activity of redox proteins in bovines. BMC Vet. Res. 10, 136. http://dx.doi.org/10.1186/1746-6148-10-136 (http://www.biomedcentral.com/content/pdf/1746-6148-10-136.pdf).

Hsu, C.Y., Ko, F.Y., Li, C.W., Fann, K., Lue, J.T., 2007. Magnetoreception system in honeybees (*Apis mellifera*). PLoS ONE 2, e395. http://dx.doi.org/10.1371/journal.pone.0000395.

Hyland, G.J., 2000. Physics and biology of mobile telephony. Lancet 356, 1833–1836.

Jin, Y.B., Pyun, B.J., Jin, H., Choi, H.D., Pack, J.K., Kim, N., Lee, Y.S., 2012. Effects of simultaneous combined exposure to CDMA and WCDMA electromagnetic field on immune functions in rats. Int. J. Radiat. Biol. 88, 814–821.

Johnsen, S., Lohmann, K.J., 2005. The physics and neurobiology of magnetoreception. Nat. Rev. Neurosci. 6, 703–712.

Kalmijn, A.J., 1988. Detection of weak electric fields. Sensory Biology of Aquatic Animals. Springer, New York, pp. 151–186.

Kirschvink, J.L., Walker, M.M., Diebel, C.E., 2001. Magnetite-based magnetoreception. Curr. Opin. Neurobiol. 11, 462–467.

Lee, W., Yang, K.L., 2014. Using medaka embryos as a model system to study biological effects of the electromagnetic fields on development and behavior. Ecotoxicol. Environ. Saf. 108, 187–194.

Lerchl, A., Krüger, H., Niehaus, M., Streckert, J.R., Bitz, A.K., Hansen, V., 2008. Effects of mobile phone electromagnetic fields at nonthermal SAR values on melatonin and body weight of Djungarian hamsters (*Phodopus sungorus*). J. Pineal Res. 44, 267–272.

Levitt, B., Lai, H., 2010. Biological effects from exposure to electromagnetic radiation emitted by cell tower base stations and other antenna arrays. Environ. Rev. 18, 369–395.

Nicholls, B., Racey, P.A., 2009. The aversive effect of electromagnetic radiation on foraging bats—a possible means of discouraging bats from approaching wind turbines. PLoS ONE 4, e6246.

Pall, M.L., 2013. Electromagnetic fields act via activation of voltage-gated calcium channels to produce beneficial or adverse effects. J. Cell. Mol. Med. 17, 958–965.

Pesnya, D.S., Romanovsky, A.V., 2013. Comparison of cytotoxic and genotoxic effects of plutonium-239 alpha particles and mobile phone GSM 900 radiation in the *Allium cepa* test. Mutat. Res. Genet. Toxicol. Environ. Mutagen. 750, 27–33.

Qin, F., Zhang, J., Cao, H., Yi, C., Li, J.X., Nie, J., Chen, L.L., Wang, J., Tong, J., 2012. Effects of 1800-MHz radiofrequency fields on circadian rhythm of plasma melatonin and testosterone in male rats. J. Toxic. Environ. Health A 75, 1120–1128.

Ritz, T., Thalau, P., Phillips, J.B., Wiltschko, R., Wiltschko, W., 2004. Resonance effects indicate a radical-pair mechanism for avian magnetic compass. Nature 429, 177–180.

Ritz, T., Wiltschko, R., Hore, P.J., Rodgers, C.T., Stapput, K., Thalau, P., Wiltschko, W., 2009. Magnetic compass of birds is based on a molecule with optimal directional sensitivity. Biophys. J. 96, 3451–3457.

Roman, A., Tombarkiewicz, B., 2009. Prolonged weakening of the geomagnetic field (GMF) affects the immune system of rats. Bioelectromagnetics 30, 21–28.

Senavirathna, M.D.H.J., Takashi, A., 2013. The significance of microwaves in the environment and its effect on plants. Environ. Rev. 22, 1–9.

Takahashi, S., Imai, N., Nabae, K., Wake, K., Kawai, H., Wang, J., Shirai, T., 2009. Lack of adverse effects of whole-body exposure to a mobile telecommunication electromagnetic field on the rat fetus. Radiat. Res. 173, 362–372.

Thalau, P., Ritz, T., Burda, H., Wegner, R.E., Wiltschko, R., 2006. The magnetic compass mechanisms of birds and rodents are based on different physical principles. J. R. Soc. Interface 3, 583–587.

Tsybulin, O., Sidorik, E., Brieieva, O., Buchynska, L., Kyrylenko, S., Henshel, D., Yakymenko, I., 2013. GSM 900 MHz cellular phone radiation can either stimulate or depress early embryogenesis in Japanese quails depending on the duration of exposure. Int. J. Radiat. Biol. 89, 756–763.

Urbinello, D., Joseph, W., Verloock, L., Martens, L., Röösli, M., 2014. Temporal trends of radio-frequency electromagnetic field (RF-EMF) exposure in everyday environments across European cities. Environ. Res. 134, 134–142.

Vacha, M., Půžová, T., Kvíčalová, M., 2009. Radio frequency magnetic fields disrupt magnetoreception in American cockroach. J. Exp. Biol. 212, 3473–3477.

Vaitkuvienė, D., Dagys, M., 2014. Possible effects of electromagnetic field on White Storks (*Ciconia ciconia*) breeding on low-voltage electricity line poles. Zool. Ecol. 24, 289–296.

Vijver, M.G., Bolte, J.F., Evans, T.R., Tamis, W.L., Peijnenburg, W.J., Musters, C.J.M., de Snoo, G.R., 2013. Investigating short-term exposure to electromagnetic fields on reproductive capacity of invertebrates in the field situation. Electromagn. Biol. Med. 33, 21–28.

Wajnberg, E., Acosta-Avalos, D., Alves, O.C., de Oliveira, J.F., Srygley, R.B., Esquivel, D.M., 2010. Magnetoreception in eusocial insects: an update. J. R. Soc. Interface 7, S207–S225. http://dx.doi.org/10.1098/rsif.2009.0526.focus.

Waldmann-Selsam, C., Eger, H., 2013. Baumschäden im Umkreis von Mobilfunksendeanlagen. 26-3. umwelt medizin·gesellschaft, pp. 198–208.

Wiltschko, R., Stapput, K., Ritz, T., Thalau, P., Wiltschko, W., 2007. Magnetoreception in birds: different physical processes for two types of directional responses. HFSP J. 1, 41–48.

Wiltschko, R., Thalau, P., Gehring, D., Nießner, C., Ritz, T., Wiltschko, W., 2014. Magnetoreception in birds: the effect of radio-frequency fields. J. R. Soc. Interface 12, 20141103. http://dx.doi.org/10.1098/rsif.2014.1103.

Yakymenko, I., Sidorik, E., Henshel, D., Kyrylenko, S., 2014. Low intensity radiofrequency radiation: a new oxidant for living cells. Oxid. Antioxid. Med. Sci. 3, 1–3.

Yoshii, T., Ahmad, M., Helfrich-Förster, C., 2009. Cryptochrome mediates light-dependent magnetosensitivity of *Drosophila*'s circadian clock. PLoS Biol. 7, e1000086.