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Systematic review of biological effects of exposure to static electric fields. Part II: Invertebrates and plants

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ABSTRACT

Background: The construction of high-voltage direct current (HVDC) lines for the long-distance transport of energy is becoming increasingly popular. This has raised public concern about potential environmental impacts of the static electric fields (EF) produced under and near HVDC power lines. As the second part of a comprehensive literature analysis, the aim of this systematic review was to assess the effects of static EF exposure on biological functions in invertebrates and plants and to provide the basis for an environmental impact assessment of such exposures.
Methods: The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) was used to guide the methodological conduct and reporting.
Results: Thirty-three studies – 14 invertebrate and 19 plant studies – met the eligibility criteria and were included in this review. The reported behavioral responses of insects and planarians upon exposure strongly suggest that invertebrates are able to perceive the presence of a static EF. Many other studies reported effects on physiological functions that were expressed as, for example, altered metabolic activity or delayed reproductive and developmental stages in invertebrates. In plants, leaf damage, alterations in germination rates, growth and yield, or variations in the concentration of essential elements, for example, have been reported. However, these physiological responses and changes in plant morphology appear to be secondary to surface stimulation by the static EF or caused by concomitant parameters of the electrostatic environment. Furthermore, all of the included studies suffered from methodological flaws, which lowered credibility in the results.
Conclusion: At field levels encountered from natural sources or HVDC lines (< 35 kV/m), the available data provide reliable evidence that static EF can trigger behavioral responses in invertebrates, but they do not provide evidence for adverse effects of static EF on other biological functions in invertebrates and plants. At far higher field levels (> 35 kV/m), adverse effects on physiology and morphology, presumably caused by corona-action, appear to be more likely. Higher quality studies are needed to unravel the role of air ions, ozone, nitric oxide and corona current on alterations in physiological functions and morphology.

1. Introduction

All living organisms, including humans, animals and plants are exposed to atmospheric static electric fields (EF).[1] Other sources of static EF include subways, trams and overhead high-voltage direct current (HVDC) power lines. Researchers have studied the potential effects of such fields on biological functions over many decades.

Because HVDC lines can transport electricity over long distances with low line losses, HVDC lines have been constructed on land and submarine configurations. More recently, new HVDC lines are planned to transfer power generated by remote renewable wind, solar, and hydro sources to more urban areas where the demand is greatest. The characteristics of an HVDC line environment are illustrated in Fig. 1.

The potential biological effects of static EF have been evaluated in

Abbreviations: AC, alternating current; DC, direct current; EF, electric field; EMF, electro-magnetic field; HVDC, high-voltage direct current; IEEE, Institute of Electrical and Electronics Engineers; kV/m, kilovolt/meter; MF, magnetic field; NTP, National Toxicology Program; OHAT, Office of Health Assessment and Translation; PECO, Population, Exposure, Comparison, Outcome; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; SCENIHR, Scientific Committee on Emerging and Newly Identified Health Risks; SSK, German Commission on Radiological Protection; WHO, World Health Organization

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[1] Static electric fields vary little over time, and thus have a frequency of ~ 0 Hz.

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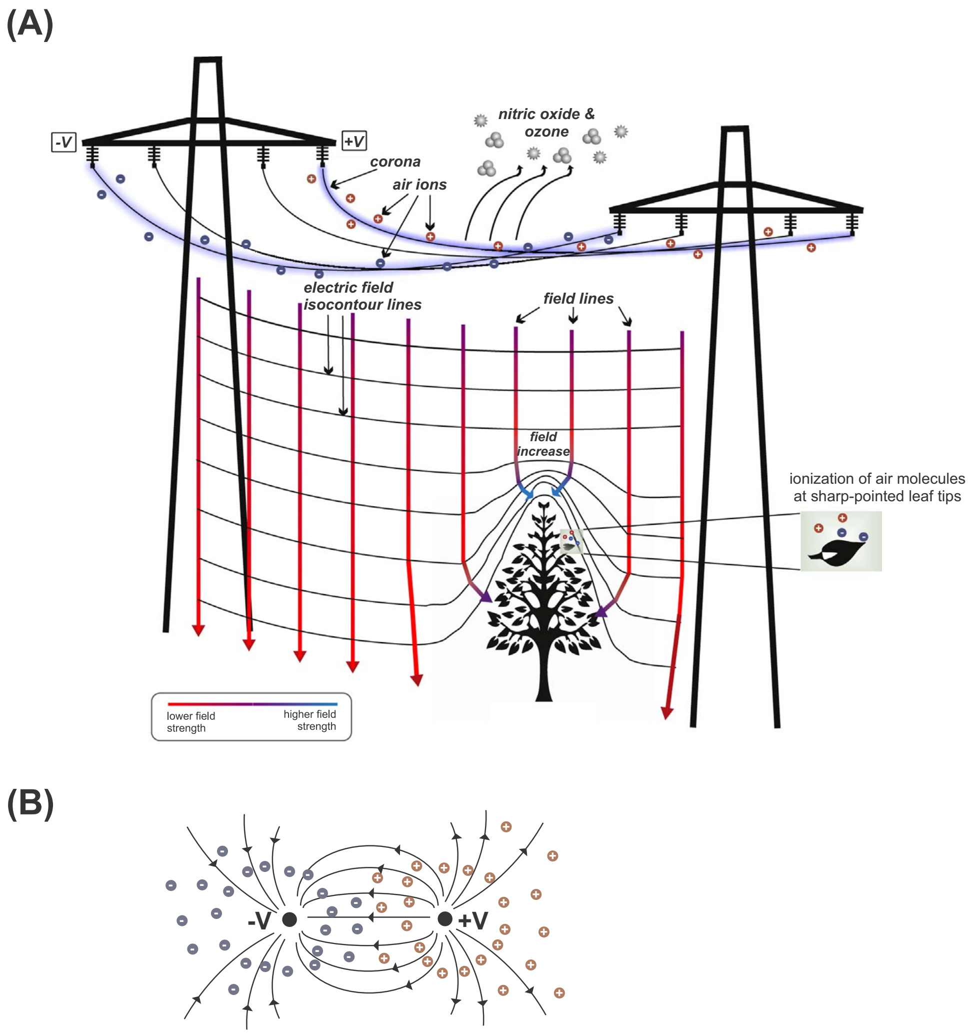

Fig. 1. HVDC line environment. (A) The EF strength decreases from the positive (+ V) and negative (-V) polarity conductors of the power line with distance to the ground. The EF around the conductors can produce electrical discharges (corona) which is accompanied by ionization of the surrounding air molecules (see B for distribution) and the release of trace amounts of ozone and nitric oxide. An object underneath a power line (here a tree) is shown to perturb the uniformity of the field and field lines concentrate on parts closest to the conductor, which leads to an increase of the local EF strength at the surface of the tree (purple and blue parts of the field lines). When the field increase is high enough, corona also is initiated and air molecules ionized at the tip of the objects. (B) Detail of the distribution of the static EF and corona-produced air ions around the + V and -V conductors.

various governmental environmental impact assessments (Bailey et al., 1982, 1997; Kowalczuk et al., 1991; Lee et al., 1979; McKinlay et al., 2004). However, static EF have received less attention than static magnetic fields (MF) because static EF do not penetrate living systems and should thus only be able to act on the surface of an organism (World Health Organization, 2006). Also, static EF levels around HVDC lines which are up to 35 kV/m (± 600-kV HVDC transmission line) (Maruvada, 2012), overlap with those naturally occurring due to thunderstorms and other weather-related events (World Health Organization, 2006) and static charges on clothing (Johnson, 1985). Thus, standard-setting organizations have not proposed limit values for exposure to static EF (Institute of Electrical and Electronics Engineers, 2002; International Commission on Non-Ionizing Radiation Protection ICNIRP, 2009).

Since HVDC lines are being considered in Germany for the transfer of power from renewable sources in the north to southern industrial areas and no recent assessments of static EF effects have been published, it is appropriate to assess the biological effects of static EF as part of national environmental planning. Also, The German Commission on Radiological Protection SSK (2013) and the Scientific Committee on Emerging and Newly Identified Health Risks SCENIHR (2015) have encouraged further research projects in this field, in particular, with respect to the conditions that affect perception thresholds.

In a previous systematic review (Petri et al., 2017), we evaluated and critically appraised the internal validity of 48 studies on the biological effects of static EF on humans and vertebrates. Those studies provide convincing evidence that humans and other vertebrates are able to perceive the presence of static EF. Many of the animal studies also reported alterations in physiological functions upon exposure to static EF (e.g., metabolic activity, immunological, hematological or reproductive parameters – to name but a few) and some authors have hypothesized that the fields may penetrate tissue and directly affect cell functions (Altmann, 1969; Arzruny et al., 1999; Atalay and Güler, 1995; Güler et al., 1996; Möse et al., 1971; Sahakyan et al., 2015). However, as living systems are well shielded from the direct influence of static EF, the evidence strongly supports superficial sensory stimulation of hair and skin as the indirect source of physiological responses. A large number of animal studies included methodological flaws that raised concerns about the internal validity of these studies. Further, if not properly designed, the exposure apparatus and experimental setting could have been a source of potential confounders such as ozone, air ions, microshocks, or noise.

The present systematic review constitutes the second part of our comprehensive literature analysis of static EF influences on living organisms. Here, we evaluate and critically appraise the internal validity of experimental studies conducted on invertebrates and plants with exposures to static EF. The vast diversity of invertebrate species and their considerable biomass are essential to the ecological balance. They contribute to the pollination of plants and seed dispersal, aeration and formation of the soil, nutrient recycling through degradation of plant materials, and they form an important part of the food chain. Plants – just like invertebrates – play a vital and central role in ecosystems. They are an essential source of food and renewable resources for humans and animals. Plants also provide shelter and breeding grounds for many