

Environmental Impacts of Electromagnetic Radiation Inducted by High Voltage-Power Lines

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ABSTRACT:Electricity generated from power plants is usually sent over long distances through overhead power transmission lines with high-voltage wires that generate electromagnetic field (EMF) around them. Since living organisms generate and conduct electrochemical impulses through their different tissues and organs it may be affected by the EMF. The mechanism of this interference between EMF and plant as well as human tissues is not clearly understood.

Studying plant behavior under low EMF by some researchers revealed that these circumstances can affect plant growth. In addition, other researchers have found that weak EMF suppressed this growth, reduced cell division, intensified protein synthesis and/or cause disintegration in plant roots. On the other hand, other studies found an increase in plant growth such as enhancing seed growth for some species. The inconsistency and contradictory outcomes from the studies appear to indicate that the effects of EMF on plants may be dependent on species and/or EMF characteristics such as intensity and duration. While it is difficult to avoid all EMF radiation, certain precautions can be taken to avoid EMF radiation. Determining and avoiding the highest emitting items is crucial for general health. Additional steps that can be taken to avoid radiation include purchasing and running an aquarium in the home to absorb microwave energy, limiting mobile phone use and using a wired internet connection that is safer than the wireless one.

KEYWORDS: *Keywords:* Electro magnetic field; High voltage tower lines; plant growth

I. INTRODUCTION

The Kingdom of Saudi Arabia comprises an area of 2.25 million km², encompassing vast deserts, rugged mountains, coastal cities, villages, and settlements. The country is the fastest growing electricity consumer in the Middle East. Electricity consumption in the Kingdom was increased sharply during the 1990–2010 period due to rapid economic development. The total amount of energy produced by the Saudi Electricity Company in 2013 is about 198,900 GWH (Anonymous^{b&c}, 2013 and 2014, respectively). Production capacity is planned to be increased up to 120 GW by 2020.

Electromagnetic field (EMF)

There are different natural sources of electric, magnetic and electromagnetic fields on Earth which act on organisms. Besides, man has created other sources of electromagnetic fields in his environment which differ in their frequency and intensity.

The EMF consists of an electrical part and a magnetic part. The electrical part is produced by a voltage gradient and is measured in volts/meter. The magnetic part is generated by any flow of current and is measured in tesla. Shawanroy (2012) presented that EMF can be viewed as the combination of an electric field and a magnetic field. Electric field is produced by stationary charges, and the magnetic field by moving charges (current). Electro-Magnetic Field strength is measured in Ampere per meter (A/m). EMF researchers and investigators use a related measure, flux density, in microtesla (μ T) or millitesla (mT) instead. Both types of fields give biological effects, but the magnetic field is more damaging since it penetrates living tissues more easily. Magnetic fields as low as around one microtesla can produce

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biological effects. The electric current along a coiled-wire or conductor formed into an inductor produces an EMF. It exists when there is a current flowing along a conductor and its strength increases as soon a device like an inductor or a coiled-wire is switched on and current moves through it (RamezaniVishki, 2012^{a&b}). The magnetic field becomes stronger when there is greater electricity flow. According to Somasekaran (2007) one of the sources of producing EMF is the high power transmission lines. The High voltage means electrical energy at high voltages which is sufficient to cause harm or death upon living things. High voltage is used in several applications like electric power distribution, cathode ray tube to generate X-rays, particle beams, vacuum tubes, manufacturing and scientific applications.

Transmission lines system in Saudi Arabia

The high voltage direct current transmission lines (HVDC) is a high power electronics technology used in electric power systems mainly due to its capability of transmitting large amount of power over long distances (Sood, 2004). The HVDC technology was used in the Kingdom for the first time in 1954. The rapidly growing economy of the Kingdom is critically dependent on the performance of its transmission system and facilities. So far, the Kingdom has a power transmission network that spans around 38,000 circuit km of high voltage lines and cables and range from 110kV to 380kV. This network is operated by Saudi Electricity Company and managed by Transmission Business Unit (TBU) with the help of 570 substations and 1653 power transformers which have capacity of well over 148,088 MVA. In addition, The voltage level of high power transmission lines are 400 KV, 230 KV, 110 KV, 66 KV, etc. The voltage existing between each wire transmission tower is 380kV, all towers height is between 65-75 meters and there are 24 conductors in each face in the tower. Most of the areas in agricultural and forest lands in the Kingdom of Saudi Arabia are situated in the area where high power transmission lines pass (Anonymous^b, 2013).

Effects of EMF on plant health

Limited information on the effect of EMF on plants is available. Most researchers focus on strategic crop plants leaving a knowledge gap on other species such as wild plants. Considering possible consequences, including economic and ecological impacts, more work is needed to clarify the basics of biological effects by electromagnetic fields.

Modern civilization depends heavily on the widespread use of high voltage transmission lines for industrial, agricultural, and domestic purposes. This has enhanced the exposure to the EMF that has adverse biological effects on living organisms. Plants play an important role in the living world as main producers of food and oxygen; therefore, it would be beneficial to examine their relations with today's increased exposure to electromagnetic fields.

All living organisms generate and conduct electrochemical impulses all the way through their different tissues and organs. Properties of temperature sensing in plants has been demonstrated experimentally (Plieth, 1999). The EMF from high power transmission lines affects the growth of plants. Extensive biological, geological, and oceanographic researches has been carried out to investigate the effects of high voltage fields on the environment (Cherry, 2001; and Demir, 2010). In electrical power transmission engineering high voltage is usually considered as any voltage above 35 KV. The voltage of these magnitudes can affect the plant in one way or the other as the most vital physical signal in any organism is electrical signal. In comparison to chemical signals (e.g. hormones) the electrical signal is able to transmit signals more rapidly over long distances.

Recently, biologists have revealed that electrical signals are significant in many physiological activities of plants. The electrical signaling in fruit trees in response to water and darkness conditions was studied by Trebaczet *et al.*, (2006), Gurovich, and Hermosilla (2009) and Paul *et al.*, (2006). In addition, Desrosiers and Bandurski, (1988) investigated the effect of longitudinally applied voltage on the growth of *Zea Mays* seedlings. Electrical signals are involved in many processes in plants life including respiration, water uptake, and leaves movements (Fromm and Lautner, 2007). Various changes regarding to plant growth parameters such as meristematic activities, cell differentiation, shoot length, root length, leaf area, specific leaf weight, total biomass content, total water content, chlorophyll, carotenoids, soluble sugar, soluble starch, soluble protein content, biochemical, and antioxidant system has been shown to be affected by environmental electric and magnetic fields (Walter *et al.*, 1997; Hanafy *et al.*, 2006; and Fromm and Lautner, 2007).

The electric field treatment has also been used to control invasive plants by affecting their tissues. It can be also used for allowing and avoiding many undesirable changes in products, pigments, vitamins, and flavoring agents, which are typical for other pre-treatment techniques, including thermal, chemical, and enzymatic ones. Electric field treatment is also capable of microbial inactivation (Vorobiev and Lebovka, 2008). As the resistance of the plant tissue varies considerably from plant to plant, hence, a clear idea of plant tissue electrical properties is essential for the assessment

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of its health status. The effect of high voltage at high frequencies may be more significant as compared to low frequency fields.

Effect of EMF on leaf area

Noguse *et al.*, (1998) and Yao *et al.*, (2006) have reported that EMF significantly decreased leaf area in the exposed plants. Reduction of leaf area under EMF radiation is a photomorphogenic response that can limit the damage to leaf tissue caused by radiation (Jansen, 1998). Reduction of leaf area is a response to reduce extent of cell division and elongation. EMF radiation decreased the proportion of mitotically active cells and increased the time taken for cell division (Hopkins, 2002). Rate of fresh and dry weight and leaf area in irradiation samples significantly decreased in comparison with control. The possible reason for reduction of fresh and dry biomass weight might be due to reduction of the leaf area (Noguse *et al.*, 1998).

Freeman *et al.*, (1999) have found that leaves of soybeans grown under high-voltage transmission lines had greater fluctuating asymmetry than those grown 100 m away. Plant leaves move both diurnally and as they grow leaf orientation toward the EMFs likely changes both diurnally and throughout leaf development. Thus, it is quite likely that the two sides of a leaf may not have experienced the same electromagnetic field strengths. This may partially explain the asymmetry that was observed in soybean leaves. Nevertheless, the mechanism by which EMFs impact symmetry is unknown, but it is possible that the EMFs may have affected internal cell oscillators and/or some aspect of cell signaling. These factors are epigenetic, and this is precisely the type of disruption that Graham *et al.*, (1993) and Emlen *et al.*, (1993) predicted would cause asymmetry.

Effect of EMF on chlorophyll content

Chlorophyll a is the most important assimilatory pigment involved directly in the conversion of solar energy into chemical energy at the molecular level, thus chlorophyll content is an indicator of plant health and productivity. Previous studies showed that photosynthetic pigments may increase or decrease under MF conditions. Chloroplasts have paramagnetic properties which means that magnetic field of magnetic moments of atoms in them are affected by MF and oriented downwards the field direction (Campbell, 1977). Moreover, EMF has an effect over photochemical activity, for example, the rate of CO₂ uptake in radish (*Raphanussativus L.*) was reduced following exposure to MF (Yano *et al.*, 2004).

Racuciu *et al.*, (2008) reported that long MF exposure has the ability to increase assimilatory pigments. This fact was confirmed by several studies for different plants; where MF treatment increased the chlorophyll content in sugar beet (*Beta vulgaris L.*) leaves (Rochalska, 2005) and content of chlorophyll a, b and carotenoids in potato (*Solanum tuberosum L.*) (Rakosy, 2005). Additionally, studies by Atak *et al.*, (2003) and Atak *et al.*, (2007) involving MF impact on soybean (*Glycine max L.*) confirmed that MF significantly increased chlorophyll a, chlorophyll b and total chlorophyll contents.

Study conducted by Atak *et al.*, (2003), reported that MF short exposure is accompanied with increases in chlorophyll a, chlorophyll b and total chlorophyll contents. In contrast, longer exposure decreased the level of photosynthetic pigments in *Zea mays L.* (Racuciu *et al.*, 2007) and *Robiniapseudoacacia L.* seedlings (Racuciu *et al.*, 2008). Taia *et al.*, (2007) reported that; Photosynthetic pigments decreases could be due to the effect of MF on the reduction in plastids inside the cells. The reduction of pigments explained by Commoner *et al.*, (1956), that chemical with unpaired electrons possess a magnetic moment which plays an important role in electron transfer and kinetics of chemical reactions. The electrons with magnetic moments can be oriented in the external MF. As a result of the interaction between the external MF and the magnetic moment of unpaired electrons, the energy is absorbed. Chloroplasts have magnetic moments and could be affected by the absorbed energy at a high dose of MF which can disturb the pigments synthesis. Dhawi and Al-Khayri (2008) reported that short exposure to alternating magnetic field had a positive impact, whereas long exposure had a negative effect on pigments content similar to MF effect on proline.

Mechanism of EMF effects on plants

EMF has magnetic and electrical properties that surround objects with an electrical charge which will interact with other objects within that field. Electrical fields result from the strength (voltage) of the charge and magnetic fields result from the motion (amperage) of the charge. The fields exist with varying strength and degrees, and wavelength and frequency will determine how it behaves.

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The impacts of EMFs on plants is a question being explored since plants are just as readily exposed to low-level magnetic fields as humans as a consequence of power lines and other industrial technology (Martinez *et al.*, 2004). It appears that a magnetic field does have an effect on the growth of plants. Belyavskaya (2004) found that weak electromagnetic fields suppressed the growth of plants, reduced cell division, intensified protein synthesis and cause disintegration in plant roots. Conversely, other studies such as those of RamezaniVishki *et al.*, (2012^{a&b}) found an increase in plant growth while other studies like those of Davies (1996) found some seeds increased in growth and others showed no change.

Despite the variable results from different researches, one thing that is not well understood is how magnetic fields affect plants. One of the proposed mechanisms is related to the levels of calcium ions within plant cells. It is found that exposure to weak EMFs remove calcium ions from cell membranes influencing calcium availability and thereby affecting plant processes and ability to respond to stress (Pazuret *et al.*, 2006). Researchers like RamezaniVishki *et al.*, (2012^{a&b}) suggest that the intensification of growth is due to the increasing of metabolism in irradiated seeds. The leakage of calcium ions into the cytosol (the main part of the cell) acts as a metabolic stimulant, which accounts for the reported accelerations of plant growth (Goldsworthy, 2007), hypothesizes that the loss of calcium ions from cell membranes is the reason why weak fields are more effective than strong ones, why low frequencies such as 16 Hz are more potent and why pulsed fields do more damage. Another proposed mechanism is geotaxis, a phenomenon where magnetic fields will affect cellular organelles such as amyloplasts and influence the direction of plant growth (Peñuelas *et al.*, 2004).

Literature supports that weak EMFs interfere with plant physiology but the mechanisms are not clear. The inconsistency and contradictory outcomes from the studies appear to indicate that the effects of magnetic fields on plants may be species-specific and/or is dependent on the characteristics of field exposure such as intensity and duration. Researches of the effects EMFs on plants are relatively new and information is still limited. Most research focuses on agriculturally important plants leaving a knowledge gap on other species such as algae. Considering possible consequences, including economic and ecological impacts, more work is needed to clarify the basics of biological effects by electromagnetic fields.

The possible effect of electric current upon the growth of plants has been the object of various types of research for more than 150 years. In recent years many phases of this problem have been studied by English, French, Finnish, German and American observers and scientists. A number of them have reported apparent significant increases in crop yields resulting from treatment with electric current; others have found little or no difference. Among these later trials, which, in most instances, appear to have been conducted under carefully controlled conditions, the majority show significant yield increases for the electrical treatment. In the few experiments where the effect of electric current upon the physiologic functions of plants has been investigated, the results obtained have failed to provide a satisfactory explanation for yield differences, therefore, field study of high voltage on natural vegetation is highly required.

Most of the recent studies focus on the growth of plants and the germination of their seeds. According to some studies these fields exerts beneficial effects as it increases rate of growth and early germination of seeds (Florez *et al.*, 2004; Dardenizet *et al.*, 2006; Liang *et al.*, 2009). On the other hand, some studies suggested harmful effects like inhibition of growth and seed germination (Apasheva *et al.*, 2006; Ahmad *et al.*, 2007). In fact, EMF causes an oxidative stress that increases the activity, concentration and lifetime of free radicals (Tkalec *et al.*, 2005). EMF alters protein biosynthesis, enzyme activity, cell reproduction and cellular metabolism (Nirmala and Rao, 1996). Exposure to EMF leads to cell death as a result of increase in free oxygen radicals and DNA damage (Ivancsits *et al.*, 2003). Several studies have been conducted to find out the effect of EMF on the growth and physiology of the plants (Yao *et al.*, 2006; Shabrangi and Majd, 2009), such as studying effects of EMF on seeds germination and seedlings growth and seed vigor (Moon and Chung, 2000 and Phirke *et al.*, 1996).

Plants produce a high diversity of secondary metabolites and antioxidant defense with a prominent function in the protection against stresses on the basis of their defense reactions. Secondary metabolites are to be involved in plant chemical defense systems. High concentrations of secondary metabolites for example phenols and flavonoids might result in a more resistant plant (Wuyts *et al.*, 2006). Electromagnetic radiation stress induces proline accumulation in plants (Verbruggen and Hermans, 2008; Kostalet *et al.*, 2011). Proline accumulation is believed to be very important as part of the physiological adaptation of plants to stress (Siripornadulsilet *et al.*, 2002).

There is highly occurrence and diversity of many wild plant species occupying the arid land, among which *Calotropis procera* is that known as medicinal plant. *Calotropis procera* is a species of flowering plant in

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the dogbane family, apocynaceae, that is native to North Africa, Tropical Africa, Western Asia, South Asia, and Indochina. Common names for the plant include apple of Sodom (Upadhyay, 2014) or milkweed (Hindi, 2013 and 2014). The distribution of *Calotropis procera* is covering most of the desert and semi desert areas, including underneath of the power transmission lines. An attempt to find out the main consequence of high voltage transmission lines on natural vegetation with emphasis on *Calotropis procera* shrubs in Makkah region was made by Alaishet *al.* (2014) to fill the gap concerning to the consequence of high voltage of EMF in natural vegetation.

Previous studies have evidence that low frequency electromagnetic radiation caused abiotic stress on the growth parameters and activity of defense mechanisms of some plants. Consequently, high voltage of electromagnetic field is expected to have some effects on plant growth. *Calotropis procera* shrubs that grow in electromagnetic field areas might be different than other shrubs that grow in their natural environment.

The effect of EMF on organisms has become very important among scientists. The results of numerous researches deal with the sensitivity of organisms to the EMF effect. The effects may be useful and harmful depending on the intensity and frequency of the field, the period of exposure and the organism itself. Both effects seem to be very important to human life and activity.

Since the 1960's, different studies were conducted to identify the effects of electromagnetic field on living world. There were mixed opinions and results from these studies, positive, negative and no changes were reported (Foster and Repacholi, 1999). The nature of the interaction of biological material with an electromagnetic source depends on the frequency of the source, so that different types of electromagnetic sources must be evaluated separately. Little research about the effect of high voltage transmission lines on physiological, morphological and metabolic parameters of plants exist in the literature, therefore, this chapter is outlining in brief the major and applicable previous research findings to represent the depth of scope of studies related to EMF effect on plant and soil properties.

Effect of high voltage exposure on human health

Humans are continuously exposed to electromagnetic fields (EMF) emitted from such sources as electric transmission lines, telecommunication and radio-television antennas. Thus resulting in EMFs of various frequencies is ubiquitous to our environment. The extensive network of high voltage (HV) transmission limits (TLs), electric engines in cars, trains and trams, welding devices, and the electrical appliances are the primary sources of extremely low frequency. All countries set their own national standards for exposure to EMFs.

However, the majority of these national standards draw on the guidelines set by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). The effects of chronic exposure to environmental EMF have been the subject of intensive researches (Djanab, 1960), unfortunately, leading to no definitive answers. However, possible risks for childhood and adult leukemia have been acknowledged (Portier and Wolfe, 1998; Wartenberg, 1998 and Yang *et al.*, 2008). Moreover, many other health outcomes are reported, among them are breast cancer (Stevens and Davis, 1996), neuropsychological disorders (Sobelet *al.*, 1996; Verkasaloet *al.*, 1997; and Liu *et al.*, 2008), decrease in blood sugar (Abbasi and Nakhjavani, 2002), and reproductive outcomes (Hatch, 1992; Roychoudhury *et al.*, 2009). Earlier, Reiter, (1993) reported that, the underlying mechanism that could explain all of these potential effects is alteration of melatonin secretion as a result of EMF exposure. Melatonin secretion is important in the regulation of circadian rhythms and sleep (Brzezinski, 1997), it could also be involved in the aging process (Poeggeleret *al.*, 1993), carcinogenesis (Fedrowitz and Loscher, 2008), and reproduction (Reiter, 1998). In conclusion, that extremely low frequency magnetic fields are possibly carcinogenic is valid. This was concluded based on studies indicating that children exposed to relatively strong magnetic fields from power lines were more likely to develop leukemia (Draper *et al.*, 2005). In European countries, the proportion of children exposed to such levels is less than 1% (Anonymous^a 2007).

II. CONCLUSION

- Electro magnetic field (EMF) generated around this network interferes with plant and human tissues but the mechanisms are not clear.
- The effects of magnetic fields on plants may be species-specific and/or is dependent on the characteristics of field exposure such as intensity and duration.

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- The nature of the interaction of biological material with an electromagnetic source depends on the frequency of the source, so that different types of electromagnetic sources must be evaluated separately.
- The finding that of EMF's effect on human health are possibly carcinogenic is valid. There are different results in the human health scope such as possible risks for childhood and adult leukemia, decrease in blood sugar, alteration of melatonin secretion, neuropsychological disorders, reproductive risk, ...etc.
- Certain precautions can be taken to avoid EMF radiation such as accurate determining and avoiding the highest emitting levels, running an aquarium in the home to absorb microwave energy, limiting mobile phone use and using a wired internet connection that is safer than the wireless one.

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