Introduction

We live in an environment that has geomagnetic field and magnetic pollution from countless sources (Kim, 1976). Although main natural source of electromagnetic radiation is sun (as natural electromagnetic energy is necessary for photosynthesis in plants), yet its intensity being low it doesn’t affect biota.

During the last decade or so, there has been an exponential increase in use of modern electronic equipment and wireless communication devices. It has tremendously enhanced the levels of high frequency non-ionizing electromagnetic field radiations (EMFr) in the environment (Elwood, 2003). In fact, it has resulted in EMF smog, a novel type of pollution of varying amplitude due to a wide range of EMFr signals released by GSM (Global Systems for Mobile Communication) (Levitt and Morrow, 2007). This accelerated and widespread use of different wireless technologies has enhanced the exposure of living organisms to electromagnetic fields (EMF). These technologies are continuously emitting a wide range of radiations and include extremely low frequency sources such as power lines, appliances as well as high frequency sources like radio, television, and more recently cellular phones and their antennas (Elwood, 2003). Among these, mobile phones or cellular phones are used indiscriminately. These have become an integral part of modern telecommunications as they provide a continuous communication without any hindrance to movement of people.

In the present scenario, users of cell-phones are increasing rapidly and so the antenna/towers, which are haphazardly erected in the living areas. In India, cell-phones came into existence in mid 1990s with average growth rate of about 85 percent per annum. In the last decade, mobile phone users increased from 8,82,316 in March 1998 to 19,26,96,402 in March 2008 (COAI, 2010). As of today, mobile phones connections outnumber fixed-line telephones. The number of telephone subscribers in India increased to 600.6 million at the end of January 2010 from 562.21
Million in December 2009, out of which 56,37,94,992 millions are wireless subscriptions and the landline users has declined to 36.76 Millions (Telecom Regulatory Authority of India, 2010).

Cell-phone communication pulsed signals modulated on higher frequency carrier wave cf extremely low frequencies of 8.34 Hz and 2 Hz correspond to those found in the human brain and neurological system. These signals are bioactive since these contain pulsed signals of low frequencies (Fröhlich, 1988). They, therefore, can cause resonance phenomena and may disturb the biological system. Cell-phone towers emit EMFr round the clock whether we are using cell-phone or not, and work in the frequency band of 800, 900, 1800, 1900 and 2100 MHz. High frequency carrier waves of 900/1800 MHz used for communications by cell-phones and towers, are non-ionizing in nature, and do not have sufficient energy to pull-out electron from molecules. Instead, the EMF energy is absorbed by water molecule present in matter, where these excited water molecules collides with each other and generate heat, cause thermal effects (Cleveland and Ulcek, 1999). Such thermal properties of non-ionizing radiations are used to cook food in microwave oven and same microwave band of electromagnetic spectrum is used for wireless communications of slightly different frequency.

Despite so many benefits, electromagnetic field can affect living organisms (Blank and Goodman, 2002; Hood, 2004). There is a growing concern over EMF radiations due to its ill-health effects. An enhanced level of radiations in the environment has further increased the exposure risks and its hazardous effects on living organisms (Goodman et al., 1995). Various epidemiological and experimental studies have been carried out and the results have shown a close relation between biological effects and electromagnetic radiation (Sage and Carpenter, 2009).

EMFr are continuously irradiating all species that could suffer long-term effects, like reduction of their natural defenses, deterioration of their health, problems in reproduction and reduction of their useful territory through habitat deterioration (Balmori, 2009; Johansson, 2009a; Kundi and Hutter, 2009). Risk of cell-phone EMFr is not only restricted to man but extends to the diversity of life. Studies have shown behavioral, biological and biochemical changes in birds, mice and wildlife (Lai
and Singh 1995, 1996; Everaert and Bauwens, 2007; Balmori, 2009). EMFr can exert an aversive behavioral response in rats, bats and birds such as sparrows. Some work has been carried out on honey bees for understanding the influence of such radiations (Harst et al., 2006; Stefan et al., 2007). Reports of sudden disappearance of honey bees has been reported from various parts of world and termed as colony collapse disorder, CCD (Hamzelou, 2007). Therefore microwave and radiofrequency pollution constitutes a potential cause for the decline of animal populations and deterioration of health of plants living near phone masts (Balmori, 2009).

Of late, the increasing EMFr levels in the environment have enhanced the concerns of many scientists to study their biochemical and physiological effects on biological systems including microorganisms, animals and humans (Goodman et al., 1995; Polk, 1996; Barteri et al., 2005). It has been documented that in animals EMF affect cell proteins (Kwee et al., 2001), change the cell membrane characteristics (Goltsov, 1999), affect reproductive capacity (Dimitris et al., 2004), alter enzyme activity (Barteri et al., 2005) and gene expression (Lee et al., 2005). Additionally, radiofrequency EMF induce lipid peroxidation and heat shock proteins, and elicit antioxidant response in human cells (Kwee et al., 2001; Moustafa et al., 2001; Leszczynski et al., 2002).

Most of the studies pertaining to ill-effects or risk-analysis of cell-phone radiations have been conducted on animals, including humans or microorganisms (Busljeta et al., 2004; Meral et al., 2007) and not much has been done in plants. Further, most of the available reports pertain largely to the effect of electromagnetic fields generated from electrical installations or radio frequency that is lower than mobile phone frequency and there have been conflicting reports. For example, Balodis et al. (1996) reported that radio frequency radiations affect the growth of pines. However, Tambiev and Kirikova (2000) noticed better growth and photosynthesis in blue-green alga *Spirulina platensis* with treatment of radiofrequency EMF. Likewise, the growth of rice plants was enhanced with electric field of 28.5 kV m\(^{-2}\) compared to those without electric field (Rotcharoen et al., 2003). Sandu et al. (2005) observed a decrease in chlorophyll content in leaves of *Robinia pseudoacacia* in response to treatment of 400 MHz EMFr.
Furthermore, not much is known about the exact mechanism of action of EMFr in inhibiting plant growth. Rather, the majority of the EMF studies in plants have been conducted on mitotic activity or cytological aspects and related changes. It has been demonstrated that EMFr affects mitotic division, and induces cytological and ultrastructural changes in pines (Selga and Selga, 1996). Belyavskaya (2004) reported changes in condensed chromatin and nucleolus compactization in plant roots nuclei in response to magnetic fields and attributed these to intensification of protein synthesis and degradation.

Nevertheless, there have been some studies with simulated systems emitting same frequency / wavelength of radiations as that of mobile phones. For example, Tkalec et al. (2005) reported that electromagnetic radiations of 900 MHz from signal generator inhibited growth of *Lemna minor* after 2 h of exposure. Later, it was reported that these 900 MHz EMFr enhanced lipid peroxidation and hydrogen peroxide content in duckweed (*Lemna minor*) indicating EMFr-induced oxidative stress (Tkalec et al., 2007). Recently, Tkalec et al. (2009) reported that exposure to 900 MHz radio frequency waves from an emitter increased the mitotic index, caused impairment in the mitotic spindle, and hence mitotic abnormalities in root meristematic cells of *Allium cepa*. However, studies using actual cell-phone in a talk+ listen mode are lacking. Further, the exact biochemical mechanism of action of mobile phones EMFr in plants remains to be investigated.

Keeping in mind these observations and aspects and to fill the information gaps, a systematic study was undertaken with following objectives:

**Objective**

- To measure EMFr power density in urban and rural areas of Chandigarh, and prepare an electro-smog map of UT, Chandigarh.

- To study the effect of cell-phone EMFr on plant growth, development, and differentiation in terms of seed germination, early seedling growth and development, including mitotic activity, and associated biochemical changes in plants
➢ To explore whether cell-phone radiations inhibit plant root growth by inducing oxidative stress
➢ To study the effect of electromagnetic field on development of chick embryo in terms of alterations in the early developmental stages.
➢ To study the effect of electromagnetic field on biology and behavior of honey bee.