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|  |  | ***Electricity: Benevolent or Malignant?***  Imagine your life without electricity! The world would be in the dark without simple appliances, like toasters and light bulbs, nor modern devices, like computers and cellular phones. Since human beings today depend on these magnificent contraptions, life would be unbearable. The truth is human beings need electricity! For the past 100 years, mankind’s livelihood has depended on the use of countless electrical machines. Whether at school, work, or play, humans are subjected to an electrical environment. However, electricity has its drawbacks, such as electrocution and has been classified as a possible human carcinogen by the National Institute of Environmental Health Sciences (NIEHS).  The electrical power system, is a giant network of power lines criss-crossing the country in a seemingly endless array of wires. In fact, the Department of Energy reported in 1992 that in the United States alone, there existed 350,000 miles of transmission line and some 2 million miles of distribution line. When electricity is moved over long distances, a dilemma is encountered: the corona effect, or the leakage of electricity from power lines, occurs. Taking into account that at least 40% of any power created in the United States is lost at any given moment, this is a serious problem indeed. To counter the problem, large step-up transformers are used to boost the energy to higher voltages in the range of 70 to 765 kilovolts (kV). The higher the voltage, the lower the loss of energy through the power lines. By increasing voltage, the EMFs produced are more intense.  ***What are EMFs?***  Electromagnetic fields (EMFs) consist of two parts: electric fields, or EFs, and magnetic fields, or MFs. Because of the presence and motion of electric charges (i.e. electric current), an EMF is produced in any electrical device, appliance, or wire. This means that electric and magnetic waves fluctuating at 60 cycles per second are emitted and radiated. In America today, with literally millions of miles of electrical wiring, trillions of electrical devices and countless power generators, it is simply impossible to escape from electromagnetic fields. As Ellen Sugarman notes, "EMFs are everywhere" [1]. Even in bed, people are exposed to EMFs and even more with electric blankets. Despite the fact that EMFs surround us on all sides, they go almost completely unnoticed as they are silent and invisible.  In many aspects, magnetic fields and electric fields are quite similar. For example, both fields are created by the flow of electricity, both radiate into surrounding space in the form of waves, and the intensities of both waves diminish significantly with distance. For instance, the intensity of the magnetic fields produced by a can opener drops from 1300-milligauss (mG) at a distance of 10 cm to less than 1 mG at a distance of 90 cm.  Although both electric fields and magnetic fields are produced simultaneously wherever electricity is in use, the two have significant differences. First, these two fields have differences in their origins. For instance, electric fields originate from electrical charges in all objects that have voltage in them. The motion of those charges, though, produces magnetic fields. Thus, the existence of electric fields in a given area may not necessarily mean that magnetic fields also exist. Electric fields exist whether or not an electrical device is on or off. Magnetic fields, on the other hand, are present only when electrical devices are on and when current runs through them. Another significant difference lies in shielding. Electric fields are susceptible to shielding effects by almost anything that stands in their way—walls, brick, trees, and countless other items tend to reduce the effect of electric fields. Contrarily, magnetic fields have a tendency to pass through almost all objects except those with a high concentration of iron. Yet another difference between electric and magnetic fields is how they vary. Usually, electric fields remain constant in a given environment such as an appliance or electrical wire. Conversely, magnetic fields are subjected to great fluctuations. The stronger the current, the stronger the magnetic field. Thus, during times of peak power usage (when the population draws the most current during the day for consumption), magnetic fields are highest.  A whole range of electromagnetic energy or radiation, known as the electromagnetic spectrum, exists in the universe. This electromagnetic spectrum is arranged according to frequency and wavelength. Highest frequency electromagnetic waves are known as ionizing waves and include gamma rays, x-rays, and ultraviolet radiation. The next level in the electromagnetic spectrum, which includes visible light, heat, and radio waves, is known as microwaves. Ionizing waves break chemical bonds and microwaves create thermal effects that can induce biological changes. Extremely low-frequency radiation, also know as ELF EMFs, is at the very beginning of the electromagnetic spectrum. It is here that waves emitted by power lines, at approximately 60-Hz, are classified. Unlike its counterparts, ELF EMFs lack the necessary energy to break chemical bonds or heat tissue. Because of this nature, they were not thought to be dangerous until recently. Countless studies have concluded that, just as short-term exposure to ionizing waves can lead to cancer, long-term exposure to extremely low frequency waves can also have the same effect. Yet, according to the NIEHS, "there remains considerable debate over what, if any, health effects result from exposure to EMFs" [2].  ***Table 1: Appliances and their Magnetic Fields:***  ***Magnetic Fields in Milligauss***   |  |  |  | | --- | --- | --- | | Appliances | At 4 Inches | At 36 Inches | | Clothes Dryers | 110 | 1 | | Clothes Washers | 3 | .48 | | Coffee Makers | 29 | .1 | | Toasters | 60 | .11 | | Crock Pots | 23 | .1 | | Irons | 45 | .2 | | Can openers | 4000 | 7 | | Mixers | 1400 | 2 | | Blenders | 220 | 1.1 | | Vacuum Cleaners | 1300 | 18 | | Portable Heaters | 281 | 2.5 | | Faust Blowers | 120 | 3.1 | | Hair dryers | 1400 | 2.8 | | Electric Shavers | 1600 | 3.3 | | Televisions | 100 | 1.5 | | Fluorescent Fixtures | 123 | 2.8 | | Fluorescent Desk Lamps | 200 | 2.1 | | Saver and Circular Saws | 2100 | 10 | | Drills | 500 | 2.0 |   ***What are the Drawbacks of EMFs?***  EMFs pose a more difficult challenge than electrocution and thermal injury. Not only are they invisible, but magnetic radiation can freely pass through most materials. Many studies have concluded that EMFs can change the production of enzymes, cause mutations that may result in cancer, alter chemical equilibrium, and effect electrical signals in living organisms. A few studies that have been completed on human beings include:   |  |  | | --- | --- | |  | Savitz reported a 300% increase in brain tumors in children whose mothers had used electric blankets during their pregnancies. | |  | Tomenius found that children living with homes with EMF measurements of 3 mG or above were twice as likely to die of cancer than children whose exposure was lower. | |  | Szmigielski studied cancer mortality in Polish military officers with ELF radiation exposures and found death rates that were 6 times as high as those without exposure. | |  | Gibson reported that when he exposed human subjects to 60 Hz and 45 Hz EMFs their short-term memory was impaired. |   Also, there have been several investigations on animals showing that EMFs:   |  |  | | --- | --- | |  | Change cell growth and key cellular functions; | |  | Increase tumor growth; | |  | Effect the central nervous system, including changes in the production of important hormones; | |  | Induce reproductive disorders, birth defects, and increase miscarriage rates; | |  | Change blood chemistry; and | |  | Cause behavioral changes. |   ***Can EMFs Cause Cancer?***  In 1979, a Colorado epidemiologist, Nancy Wertmeir, began a study of some 344 children who had died of leukemia in Denver. She soon observed that many of these leukemia victims had lived in close proximity to pole-mounted electrical transformers. Teaming up with physicist Ed Leeper, the two eventually concluded that magnetic fields from 60-Hz power systems could cause cancer. Since then, numerous other studies including epidemiological, in vivo, and cellular investigations have been conducted supporting the hypothesis that EMFs pose a serious health threat. In 1989, Granger Morgan and Indira Nair, from Carnegie Mellon University, published an article assessing the validity of previous EMF research and concluded that EMFs may cause cancer. In California, teachers at Alvarado Elementary School refused to work in classrooms near four pole-mounted transformers and distribution wires after an onset of twenty-two cases of cancer among staff who had worked in those classrooms.  EMF exposure has been linked to changes in the activity of many hormones and enzymes, which are related to cancer. Ornithine decarboxylase (ODC) is an enzyme involved in cell growth. Although it is present in normal cells, it is found in much greater quantities in cancerous cells. At University of California (UC), Riverside, Professor Byus reported that "EMF exposure greatly altered ODC activity in cells [which suggests] that 60Hz EMFs may function as tumor promoters" [1]. Melatonin, produced by the pineal gland, inhibits tumor growth; therefore it is used in chemotherapy, especially in cases of breast and prostate cancers. Since magnetic fields may suppress the production of melatonin, they may also stimulate tumor growth.  ***What About Plants?***  Since most of the biological experimentation relates to the effect of EMFs on human beings and animals, it is evident that plants have received little attention. People have considered the effect of EMFs on themselves, while overlooking the impact of EMFs on agriculture and the environment. Still, a few respectable scientists, such as Mark Davies and Stephen Smith, have explored the effects of EMFs on plants. In 1996, Davies tested the effects of EMF on the early growth of barley, radish, and mustard, and found a significant increase in growth in only barley and radish, while mustard showed little difference. Smith, in 1991, found that plants subjected to calcium tuned radiation had stimulated growth, whereas those exposed to potassium tuned radiation had inhibited growth. Previously, in 1984, Smith tested the effects of EMF on root cuttings and discovered that all species he used demonstrated decreased root elongation. (For a summary of these and other related experiments, please refer to the Literature Review on page 9.)  In our experiment, we will compare the effect of an induced electromagnetic field created by a coil surrounding 32 Wisconsin Fast Plants to a control sample without an induced electromagnetic field. If there is a significant difference, then we may be able to conclude that EMFs do affect the physiological aspects of *Brassica rapa*.  ***Why Brassica rapa?***  We chose Wisconsin Fast Plants, a genetically specialized breed of rapid-cycling Brassica (RCB), a relative of the mustard. They have not been genetically engineered, but rather genetically bred for relatively constant plants. One of the reasons for using *Brassica rapa* is that it has a short growing cycle of approximately 40 days and flowers within 20 days. Each plant can be grown and pollinated easily, as they are not too big and can be pollinated by a paintbrush. Furthermore, the plants can reproduce at high densities, which has allowed us to use a greater sample size. Since we wanted to replant the seeds from the experimental ones to test second generation plants, Wisconsin Fast Plants were most suitable as they produced an average of 78 seeds per plant.  ***Figure 1: Growth of rapid-cycling Brassica rapa showing growth stages at various time from seedling until 28 days***  **Test Runs**  Since the full cycle to seedpod requires 43 days to complete, time was an issue to repeat this experiment. The first test run was performed to observe the full-cycle of the plants and obtain seeds from the seedpods. The second test run is currently underway for display at the fair. |

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