Health Consultation

The Health Effects to Children of Low Frequency Electromagnetic Fields (EMF) Towers in Close Proximity to Schools

Utah

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SUMMARY

The Salt Lake Valley Local Health Department asked the Utah Department of Health (UDOH) Environmental Epidemiology Program (EEP) to investigate a Utah resident's concern about adverse health effects to children from exposure to low frequency electromagnetic fields on public school properties located along the Wasatch front. The concern centered around possible increased incidence of brain cancer and leukemia among children in close association with these EMF fields while attending school or residing within close proximity to one of these towers associated with a school. UDOH EEP located schools with these types of towers and examined incidences of the specific types of cancer associated with exposure to them.

A review of the literature showed that there is no causal association between the presence of cell towers located on school property and childhood leukemia. An analysis of Salt Lake County data on the incidence of childhood leukemia among children living in close proximity to cell towers showed that the incidence of childhood leukemia is not statistically significantly higher among children living near these towers compared to children not living near these towers. The results of our analysis support the findings of other scientific groups which have concluded that EMF from cell towers does not cause childhood leukemia. Although the incidence of childhood leukemia has increased in the last 30 years, there are many other environmental factors that may contribute to this increase.

Similarly, an analysis of the data was performed to evaluate the association between the incidence of brain cancer in children and exposure to EMF from cell towers. The results show no statistically significant association between exposure to EMF and brain cancer. Our data analysis showed that the risk of brain cancer for a child residing near a cell tower located on school grounds is not higher compared to a child not living near a school with a cell tower. This conclusion is supported by the majority of research done to assess the causal link between EMF exposure and childhood brain cancer.

PURPOSE AND HEALTH ISSUES

The Salt Lake Valley Health Department (SLVHD) requested that the Environmental Epidemiology Program (EEP) of the Utah Department of Health (UDOH) conduct this public health consultation to identify public health hazards to children associated with electromagnetic field (EMF) towers placed on public school campus' throughout the four counties comprising the majority of the Wasatch Front in Utah (Salt Lake, Davis, Utah and Weber).

The objective of a health consultation is to identify whether health hazards in an area exist and whether public health actions that should be taken at a potentially hazardous site to reduce or manage these exposures. The purpose of this health consultation is to determine if children in close proximity to these EMF towers (either by attending school with a tower or by residing within a 0.5 kilometer radius of a tower associated with a school) are at a higher risk for the development of cancers associated with exposure. The primary cancers in children that were analyzed for included brain cancer and leukemia.

BACKGROUND

The UDOH has a cooperative agreement with ATSDR to address environmental health issues related to exposure from hazardous waste sites and other potentially hazards sites in Utah. In an effort to respond to a Utah resident's concern over the health effects to children from the proximity of low EMF sources, the UDOH has created this health consultation to address the request.

A comprehensive literature search was conducted to determine the results of existing studies on the health effects of exposure to low frequency electromagnetic fields. Studies in the current literature have not been definitive on the health risks associated with exposure to EMF; while specific studies have linked health effects to exposure to EMF (COST 1999; RSC 1999), other researchers have found no correlation (Gurney and Wijngaarden 1999; Feychting 2005; Otto and Muhlendahl 2007).

Electromagnetic fields are not a new phenomenon; however, the environmental exposures to anthropogenic EMF has been steadily increasing, due primarily to the growing demand for electricity throughout the developing world. This demand has resulted in the creation of technology which utilizes a higher percentage of artificial sources of power and energy.

Electromagnetic fields result from both natural and man-made sources and are invisible to the human eye. Electric fields are produced by the local build-up of electric charges in the atmosphere following a thunderstorm. The earth's magnetic field causes a compass needle to orient in a north-south direction and provides the basis for the migratory paths used by both fish and birds. Anthropogenic sources of electromagnetic fields include those activities generated by man: x-rays, electricity from power outlets and those services that are required to transmit information- television antennas, radio stations and mobile phone stations.

Although the effects of EMF on human health are similar, these fields are composed of two separate types of energy that each have their own unique properties, shown in the following table (Table 1).

Table 1. Characteristic properties of both electric and magnetic fields.

Electric fields	Magnetic fields
1) Electric fields arise from voltage.	1) Magnetic fields arise from current.
2) Strength is measured in volts per meter (V/m).*	2) Strength in measured in amperes per meter (A/m).*
3) An electric field can be present even when a device is switched off.	3) Magnetic fields exist as son as a device is switched on and current flows.
4) Field distance decreases with distance from the source.	4) Field distance decreases with distance from the source.
5) Most building materials shield electric fields to some extent.	5) Magnetic fields are not attenuated by most materials.

* EMF investigators commonly use a related measure, flux density (measured in microtesla (μT) or millitesla (mT)).

To address any adverse health issues resulting from exposure to EMF, the nature of the field (i.e., electric or magnetic, static or alternating at low, intermediate or high frequency (HF)) and the modulation (i.e., constant wave or pulsed) has to be considered. The exposure conditions expressed in terms of electric/magnetic field strength, power density and duration also play a large role. Table 2 characterizes electric, magnetic, and electromagnetic fields (classified according to their frequencies) and lists use examples for each.

Table 2. Frequency ranges of electromagnetic fields and typical applications of use.

Band Name	Abbreviation	Frequency Range (typical values)	Common Uses (examples)	Medical Uses (examples)
Static electric field	-	0 Hz	Clouds and thunderclouds; charged surfaces (e.g., televisions sets); spark discharges; DC rail systems	-
Static magnetic field	-	0 Hz	Terrestrial magnetic field and permanent magnetism	Magnetic resonance imaging (MRI) ; magnetic remedies (paramedicine)
Extremely low frequency	ELF	1-300 Hz	Railway power supply (16 2/3 Hz); household power supply (50 Hz); household devices (i.e., electric blankets, water beds and night storage heaters)	-
Low frequency	LF	1 (300)-100 kHz	Visual display units	Stimulation currents; gradient fields (MRI)
High frequency	HF	100 kHz-300 GHz	Radio; television; mobile phones; cordless phones; microwave oven; WLAN; Bluetooth; anti-theft devices; radar	Diathermy

Low-Frequency Electromagnetic Fields

Extremely low-frequency electric fields (ELFs) are those fields that occur between 1-3000 Hz and are generally anthropogenic in nature. They include electric power systems, electric and

electronic appliances and industrial devices. Although these structures are ubiquitous in the environment, environmental levels of ELF fields have been found to be minimal and not related to adverse health effects. Exposure levels for the general population are approximately 5-50 V/m for electric fields and 0.01-0.2 μT for magnetic fields (WHO 2002).

The interaction between low-frequency fields and living matter has been well documented in the literature (WHO 2005). The electric component of the field does not penetrate deeply into the organism, but is largely absorbed by the skin and muscle due to the high conductivity of these tissues. The magnetic field component for fields up to about 30 kHz is able to penetrate deeply into the body and may have the capacity to induce electric currents.

High Frequency Electromagnetic Fields

High frequency electromagnetic fields have fields that are greater than 3000 Hz; they include mobile telephones, television and radio transmitters and radar produced RF fields. These fields are strong enough to transmit information over long distances and form the basis of telecommunications as well as radio and television broadcasting all over the world. Microwaves are also considered high frequency fields, as they are used at high frequencies in the GHz range to quickly heat food.

The effect of high frequency radiation on the human body is the conversion of the radiation into heat. The body has the ability to compensate for this additional heat via thermoregulatory responses-; if the entire body is cold, the heat will be dissipated via the blood flow to areas in need of warmth. If the body is already warm, then the blood supply to the skin is higher and the heat is dissipated through evaporation and sweating. Adverse health effects are not anticipated until certain temperature thresholds are violated; animal studies have shown that a body temperature increased by 1° C for an extended period of time can cause impairment of metabolic process, behavioral changes and embryonic development (BfS 2008).

When examining the results of previously conducted studies, the equipment used to measure the EMF field is important in determining the amount of human exposure. The capabilities of these instruments to measure such fields have rapidly advanced in recent years, especially with regards to magnetic fields. In addition to simple, easy-to-use hand-held survey instruments, there are now portable personal exposure meters that have the capability of recording and describing the statistical, threshold, frequency and waveform characteristics of field exposure. The limiting factor in exposure assessment is not the capability of the instrumentation, but the lack of agreement as to the characteristics of exposure that are biologically relevant and thus potentially harmful (WHO 2002).

Recently, concern has emerged over the possibility of adverse health effects resulting from prolonged exposure to EMFs. One of the primary concerns in the State of Utah is that often, these EMF and cell phone towers are constructed on public school property. The advantage to allowing one of these towers to be constructed on school property is the monetary contribution made to the school by the owner/operator of the tower. During difficult economic times when educational funding is continuously being cut, the monetary incentive for a school allowing a tower to be constructed on their property can be financially beneficial.
The debate over adverse health effects resulting from continued and prolonged exposure to EMF

and ELF towers is not new. Experiments have been conducted for approximately 30 years examining this topic. Therefore, a search of the literature produced the results of other countries and states' studies into the adverse health effects of EMF exposure in children.

Literature Review

EMF History

Mobile wireless communication refers to cellular phones, their base stations, some cordless and baby phones, and wireless local area network (WLAN) and Bluetooth technology. Mobile and wireless communication devices both use frequencies in the microwave range for the transmission of speech and data packets using to technologies, known as the global system for mobile communications (GSM) and the universal mobile communication systems (UMTS), respectively. GSM produces a "pulsed field" whereas the EMF produced by UMTS is not pulsed.

Antennas of mobile phone base stations usually emit a field, which is slightly down-tilted in order to reach potential customers in the surrounding areas. The law of decreasing field strength with increasing distance from the antenna holds strictly only along the axis of the main beam. When measured on the ground, the field strength in the immediate vicinity of the mast on a building is initially very low. With increasing distance the field strength increases slightly and reaches a relative maximum at the point where the focal point of the main beam intersects the ground. After this point the strength of the field decreases with increasing distance. Therefore, ascertaining circular safety zones around mobile phone base stations is not possible because the EMF have the above described shape. Fortunately, the field strength measured on the ground rarely exceeds a few percent of the limit value proposed by the International Commission on Non-Ionizing Radiation (ICNIRP). Quite often, a nearby digitally enhanced cordless telecommunications (DECT, or cordless phone) base emits a larger field than a mobile phone base station, which is farther away.

In mobile phone technology, the technically usable field strength covers at least 6-7 orders of magnitude. Exposure of individuals to HF fields in the vicinity of mobile phone base stations is 100-10,000 times below the currently valid exposure limit values- depending on the direction of the main beam, distance, shielding by buildings and other factors. Exposure limits for the electromagnetic frequency range up to 300 GHz can be found on the websites of the ICNIRP and the Institute of Electrical and Electronics Engineers (IEEE). The structures most generally included in the current mobile phone technology includes cellular towers, PCS towers, and antennas.

Utah implemented a statewide cellular radio service for public safety and emergency response services during 2001-2002. Cellular radio services transmit using frequencies between 800 and 900 MHz. Incorporated with the statewide public safety cellular radio service was an expanded personal communications service (pagers, and cell phones, PCS). Transmitters in the PCS use frequencies in the range of 1850-1990 MHz. Antennas used for cellular phones and PCS transmissions are typically located on towers, water tanks or other elevated structures including rooftops and the sides of buildings. The combination of antennas and associated electronic equipment is referred to as a cellular or PCS "base station" or "cell site". Typical heights for

free-standing base station towers or structures are 50-200 feet. In urban and suburban areas, cellular and PCS service providers now more commonly use “sector” antennas for their base stations. These antennas are rectangular panels, e.g., about 1 by 4 feet in dimension, typically mounted on a rooftop or other structure, but they are also mounted on towers or poles. At a given cell or PCS site, the total RF power that could be transmitted from each transmitting antenna at a cell site depends on the number of radio channels (transmitters) that have been authorized and the power of each transmitter. The signals from a cellular phones or PCS base station antenna are essentially directed toward the horizon in a relatively narrow pattern in the vertical plane. The radiation pattern for an omni-directional antenna might be compared to a thin doughnut or pancake centered around the antenna while the pattern for a sector antenna is fan-shaped, like a wedge cut from a pie. As with all forms of electromagnetic energy, the power density from a cellular or PCS transmitter decreases rapidly as one moves away from the antenna. Consequently, normal ground-level exposure is much less than exposures that might be encountered if one were very close to the antenna and in its main transmitted beam. Measurements made near typical cellular and PCS installations, especially those with tower-mounted antennas, have shown that ground-level power densities are thousands of times less than the FCC’s limits for safe exposure. In fact, in order to be exposed to levels at or near the FCC limits for cellular or PCS frequencies an individual would essentially have to remain in the main transmitting beam (at the height of the antenna) and within a few feet from the antenna. This makes it extremely unlikely that a member of the general public could be exposed to RF levels in excess of these guidelines due to cellular or PCS base station transmitters. Therefore, there is no reason to believe that such towers could constitute a potential health hazard to nearby residents or students (FCC).

Previous EMF Studies

The landmark study on EMF and health effects in children was completed by Wertheimer and Leeper (1979). This study examined cancers in Colorado children exposed to electrical wiring components. In the study, an excess of electrical wiring configurations, suggestive of high current-flow, was noted near a specific Colorado residential community from 1976-1977. The study compared children in these residential neighborhoods who developed cancer to those of control children. Results suggested that the closer children lived to the wiring, the higher rates of cancer that were observed; the correlation was strongest for those children who had remained at the same residence their entire lives. A strong dose-response dependency was observed in these cases. Although potential confounders were considered, the results did not seem to be an artifact of neighborhood, street congestion, social class or family structure.

For the Wertheimer and Leeper study of childhood cancer mortality, homes in the Denver area were compared according to wire code classification. Relative to children in low-current configuration homes, children living in a high-current configuration home had a risk of death from brain cancer that was 2.4-fold (95% CI 1.0–5.4) higher. In 1988, Savitz et al. published results of a similar wire code study in the Denver area which reported a 2.0-fold higher risk(95% CI 1.1–3.8) for children living in a high-current configuration versus low-current configuration homes.

In the 1990s, considerably larger case-control studies on wire codes and childhood brain cancer incidence were conducted in Los Angeles by Preston-Martin et al.(1996b) and in Seattle by Gurney et al. (1996); neither study found an association between wire code configuration and brain tumor

occurrence. Similarly, epidemiologic studies using measures of exposure based on calculated cumulative or average residential magnetic field exposure (Feychting and Ahlbom, 1993; Olsen et al., 1993; Tynes and Haldorsen, 1997; Verkasalo et al.,1993), in-home magnetic field measurements (Preston-Martin et al., 1996b; Savitz et al., 1988), electrical appliance use (Gurney et al., 1996), and electric blanket use (Preston-Martin et al., 1996a) found little if any evidence to support an EMF–brain cancer relation in children.

After the results of the Wertheimer and Leeper study, a large number of epidemiological studies on the correlation of residential magnetic fields (i.e., 50-60 Hz) and childhood leukemia have been published. The majority of these studies report a positive correlation between the cause and effect relationship, resulting in a small but significant increase in risk (Kheifets and Shimkhada 2005).

In 2001, an expert group from the International Agency for Research on Cancer (IARC, an institution of the World Health Organization, WHO) reviewed reports on the carcinogenicity of ELM/ELFs. They used evidence derived from cellular (biological), animal and human studies, especially from epidemiological studies available on childhood leukemia and classified EMFs/ELFs as "possibly carcinogenic to humans" (WHO 2001).

Epidemiological studies generally provide the basis for these claims; however, the use of studies and approaches of an epidemiological nature include a number of confounders, thus making a clear correlation between cause and effect difficult to assess for a number of reasons. These include:

- Electromagnetic fields are ubiquitous in nature and have a variety of sources;
- These fields vary considerably over both spatial and temporal scales;
- The number of possible confounding parameters that need to be controlled for, including socioeconomic status (SES), viral infections, ionizing radiation, exposure to tobacco smoke, etc.) (Lightfoot 2005);
- As leukemia occurs relatively rarely (approximately four cases in 100,000 children under the age of 15) in Western countries, only retrospective studies are feasible and there are inherent shortcomings and complications with conducting these types of studies.

The observed association appears to only be true for children; there is no evidence to corroborate an association in either adults or laboratory animals. In addition, leukemia is the only type of cancer shown to be minimally correlated to ELF/EMF exposure in children.

Cancer

Cancer is a disease in which healthy cells stop functioning and maturing properly. As the normal cell cycle of creation and death is interrupted, the newly mutated cells begin to multiply uncontrollably, no longer operating together for the good of the body. This rapid multiplication of cells eventually leads to the formation of a tumor, which left untreated, results in cancer and is almost always fatal.

Scientists believe that cancers are generated in two steps, referred to as initiation and promotion. Factors that trigger the initiation process are called initiators or triggers. They interact directly

with cellular DNA to begin the cell damaging process. Initiators often take the form of chemical carcinogens (i.e., tobacco smoke, environmental pollution, pesticides, heavy metals and industrial chemicals) as well as specific (oncogenic) viruses, radiation exposure, oxygen free radicals and hormones (especially estrogens).

Following the initiation stage, the cancer will begin a latency period, which can last up to 30 years (AICR 2007). During the latency period, the cells have been damaged, but not yet propagated to a level than can result in a diagnosis of cancer. Factors which help to promote the disease during this latency period are called promoters. While promoters do not directly interact with the cellular DNA, they can further the damage, causing the malignant cells to spread abnormally. Promoters can also alter specific tissues of the body to make tumor growth more favorable.

The most common factors that have been correlated to the initiation and promotion of cancer include:

- Diet/Nutrition
    - Caffeine
    - Smoked, pickled or salt-cured foods
    - Food additives
- Smoking and Tobacco use
    - Secondary smoke

Leukemia

Leukemia is the most common form of childhood cancer (national rate = 1 of every 22,000 children) and is the most common type of cancer reported in children accounting for up to 35% of all childhood malignancies. The incidence rate for leukemia in Utah is much lower than the national rate (http://ucr.utah.edu/PDF/Childhood.pdf). The disease is characterized by uncontrolled proliferation of hematopoietic progenitor cells located in the bone marrow. Although childhood leukemia encompasses a variety of hematopoietic malignancies, the initiating events for most are believed to occur in utero, resulting in genetic alterations that include specific translocations or hyperploidy. In most cases, these alterations are necessary, but not sufficient, to trigger progression to leukemia. Post-natal events or exposures like infection, chemical exposures and errors in DNA repair are usually necessary for progression to leukemia. The incidence of childhood leukemia peaks between the ages of 2 and 5. The main morphologic subtypes are acute lymphoblastic leukemia (ALL) which accounts for 80% of cases, and acute myeloblastic leukemia (AML) (Kavet 2005; Lightfoot 2005).

Causation

Epidemiological studies of magnetic fields have consistently found an association between ELF and childhood leukemia, but lack of a known mechanism at such low energy levels and negative animal data detract from a conclusion that the ELF and childhood leukemia is causal (IARC 2002). In vitro research on the carcinogenicity of ELF has been plagued by a lack of consistency and reproducibility. Of the approaches to evaluating ELF as a potential health hazard, toxicological experiments provide the most consistently negative data (Portier and Wolfe 1998; (Kheifets and Shimkhada 2005). In particular, data on leukemia in experimental animals is

negative (IARC 2002).

Prenatal and early life exposures are thought to be important determinants of childhood leukemia. Exposure to possible carcinogenic or toxic substances early in a female's life may result in permanent damage. Since no new oocytes (female germ cell involved in reproduction) are formed after birth and their maturation begins during gestation, exposures occurring during this critical time may be of the greatest importance. Furthermore, exposures to which the maternal grandmother was subjected, while she was pregnant with the index child's mother, may be responsible for any germline mutations that arise in the offspring. Paternal exposures may play a role as well. As spermatogenesis continues from puberty to old age, there is a greater period of time during which the accumulation of mutations may occur. During pregnancy, exposures to agents such as ionizing radiation may act directly while others may act indirectly via placental transfer (Lightfoot 2005).

Mode of Action

It is difficult to provide a plausible explanation for the correlation of EMFs to either brain cancer or leukemia because no direct biologically plausible mode of action has been identified. EMF reside in the non-ionizing part of the electromagnetic spectrum, meaning they do not produce a high enough quantum energy to cause an effect at the molecular level by direct damage to DNA through the formation of free radicals. In the case of ELF related to the cellular level, the magnetic flux density is on the order of 0.3-0.4 μT which is orders of magnitude below the critical density where damage to cells and tissues becomes plausible (IET 2006).

Relying on scientific theory, it is improbable that ELF/ELM fields contribute to the initiation of cancer. Therefore, the mechanisms of cancer promotion must be investigated instead. A number of hypotheses have been generated to explain the possible link. One current theory is that magnetic fields have an inhibiting influence on the production of melatonin in the pineal gland (Henshaw and Reiter 2005). Melatonin acts as a radical scavenger and a protector of nuclear DNA and membrane lipids from oxidative damage. Henshaw and Reiter point to evidence of a decreased blood serum level of melatonin when subjected to power frequency magnetic fields.

A second hypothesis examines "contact currents" from the system of electrical wiring installed in US homes. These wires may lead to a small voltage being created between the residential water supply and the contact current. For example, a child placed in a grounded bathtub or shower may experience a contact current upon touching the faucet or water stream in the bathroom. Kavet (2005) determined that a contact current of this nature could produce an electrical field sufficiently high enough to produce an adverse effect in the bone marrow of the arms and legs. This hypothesis is intriguing due to the fact that the European and Asian countries have different wiring systems than the US; therefore, similar investigations into the electrical configurations of these systems provide the possibility of either proving or disproving this hypothesis.

Trends in Incidence of Childhood Leukemia

In most countries where data are available (industrialized countries), registry rates for most but not all types of childhood cancer appear to have risen during the 20th century (Draper 1994, Cole 2004). In the UK, childhood-cancer registration rates have risen by 35% from 1962 to 1998, an

average of 0.8%/year. Specifically, acute lymphocytic leukemia (ALL) rose by 0.7%/year from 1974 to 2000. In the US from the mid-1970s to the late 1990s, the estimated increase was 0.5%/year for all leukemias and 1.1%/year for ALL (Linet 1999; Ries 2001). Steliarova-Foucher (2004), using data from the European Automated Childhood Cancer Information System (ACCIS) from 19 countries, found a 1.0%/year increase from 1970 to 2001 in age-standardized incidence rates across all cancer types. For leukemia, the increase was 0.7%/year (Kheifets et al. 2006).

Trends in Childhood Acute Lymphocytic Leukemia (ALL)

ALL incidence has a characteristic age pattern: at first rates increase dramatically and reach a peak at age 2-3 years of 7.5-8.5 cases per 100,000. A slow decline follows until about age 10, when the rate stabilizes at about 1.5-2.0 cases per 100,000. Incidence of acute myeloid leukemia has a different pattern with rates fairly stable throughout childhood (Ries 2001).

Health Effects

The WHO have addressed concerns about the effect of EMFs on public health in their Fact Sheet No. 263 October 2001 (McKinney 2005). This document states "there is no consistent evidence that exposure to ELF fields experienced in our living environment causes direct damage to biological molecules, including DNA. Since it seems unlikely that ELF could initiate cancer, a large number of investigations have been conducted to determine in ELF exposure can influence cancer promotion or co-promotion. Results from animal studies conducted so far suggest that ELF fields do not initiate or promote cancer".

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) has worked with the WHO to develop evidence-based guidelines for EMF exposure limits (WHO 2001)**.** The ICNIRP considers the scientific information on potential carcinogenicity of ELF fields insufficient for establishing quantitative limits on long-term exposure. The limits they developed are designed for protection from the effects related to short-term exposure only.

Susceptibility of Children

Researchers have also speculated that a subpopulation of children with an increased genetic susceptibility to the effects of EMFs may exist, but there is no concrete data to date supporting this hypothesis. Similarly, concerns about effects of EMF in the developing fetus exist but this issue has yet to be critically evaluated (Otto and Muhlendahl 2007).

In addition to the well-known thermal effects, numerous reports on so-called athermal effects have been published. Athermal effects are biological effects, which occur at very low levels of the field and cannot directly be attributed to heating. Quite often the "pulse character" of GSM fields has been held responsible for athermal effects. However, this hypothesis has never been proved (Gollnick, 2006). National expert panels such as the ICNIRP and the WHO have come to the conclusion that "there is no convincing scientific evidence that the weak radio frequency signals from base stations and wireless networks cause adverse health effects" (WHO fact sheet No. 304, 2006).

A review article discussing the epidemiology and risk factors of central nervous system (CNS) tumors in children related to EMF states that exposure to ELF/EMF, at any level, has not been

associated with childhood CNS tumors, but the current evidence base is inadequate for complete evaluation (McKinney 2005).

Much of the evidence linking EMF exposure and childhood leukemia has been obtained from ecological studies. Both the incidence rates of childhood leukemia and the levels of EMF exposure in the environment have increased in the past 25 years. Ecological correlation cannot be used as evidence of a causal link, however (Kheifets et al. 2006). Two pooled analysis (Ahlbom 2000; Greenland 2000) estimated about 1.7 – 2 times increased leukemia risk among children in homes with 24-h average magnetic fields above 0.3 – 0.4 uT, which is an uncommonly high level, but detected no clear increase at more common levels (Kheifets et al. 2006). Correlations between increases in electricity consumption and childhood leukemia rates have been used to argue both for and against a causal association.

The possible reasons for a presumed greater sensitivity of children are also hypothetical and are presented as such. ICNIRP noted that children might be more vulnerable than adults; but presently no data exist showing special effects of radiofrequency radiation on the nervous system of children, while the few modeling studies carried out on the absorption of electromagnetic energy in the heads of children and adults have provided contradictory results (Gandhi 1996; Shonborn 1998)

Concerns about children and adolescents having a higher susceptibility to EMF have been raised. The following unique physiological characteristics of children have been discussed as possibly putting them at higher risk of problems related to EMF exposure:

- The children's nervous system is still in development
- Their brain tissue has a greater conductivity due to its higher water content
- Children's heads would - for anatomical reasons - absorb more radiofrequency energy than that of an adult
- Children have a longer life time of exposure

Presently, there are no evidence-based arguments for a higher sensitivity of children to HF EMF compared with adults. Additionally, most known effects related to non-ionizing EMFs are deterministic in their nature and have a threshold for a given effect. Exposure above official guidelines and limit values are unlikely to be harmful.

Epidemiologic Studies

Because there is no established mechanism for EMFs to cause cancer, there is no basis for choosing an exposure-response relationship. The existing epidemiology of EMFs (Ahlbom 2000; Greenland 2000) does not seem to follow a linear exposure-response relationship, with the observed increase in risk largely limited to higher fields (Kheifets et al. 2006). While exposures and reported leukemia rates have both risen dramatically over the 20th century, they have done so at different times, with the major increase in leukemia rates preceding exposure increase by 20-30 years. Childhood leukemia rates appear to have increased perhaps by 30% from the 1960s or 1970s to the present in Europe and the US. Over the same period, modeling suggests average population exposure to magnetic fields have increased much more, perhaps fourfold. If this

increase in leukemia incidence rates were solely attributable to EMFs, almost all the increase, composing 25% or less of current leukemia cases in recent years, would be attributable to EMFs.

Not all groups support the opinion that childhood exposure to EMF is free of risk. A review article by Hardell and Sage states that there is a continuous increase of risk with increasing levels of average magnetic field exposure (Hardell and Sage 2008). Risk estimates reach statistical significance at levels of 0.3-0.4 uT. The overall odds ratio in 9 studies was 2.1, 95% confidence limit 1.3-3.3. A low number of children are exposed at these or higher levels. The balance of evidence suggests that childhood leukemias associated with exposure to power-frequency ELFs either during pregnancy or early life. There is a possibility that other exposure metrics are much stronger related to childhood leukemia and may account for a substantial proportion of cases, perhaps up to 80% of all cases. The population attributable fraction ranges between 1 and 4% assuming only exposures above 0.3-0.4 uT are present.

In the pooled epidemiologic analysis by Greenland (2000), the estimated OR for childhood leukemia was 1.68 (95% CI 1.23, 2.31) for exposures greater than 0.3 uT as compared to exposures less than 0.1 uT, controlling for age, sex, and socioeconomic status.

Epidemiologic studies looking at the relationship between RF field exposure and childhood leukemia have yielded inconsistent results. Problems with these studies include small sample size, lack of information on exposures, short follow-up periods, and the limited ability to deal with potential confounders. RF fields are harder to characterize than ELF fields and RF signals from new wireless technologies involve increasingly complex frequencies and modulation patterns.

The results of a case-control study of childhood leukemia in relation to exposure to power-frequency electric and magnetic fields (EMF) showed that exposure to personal magnetic fields were not related to risk of leukemia (adjusted odds ratio (OR) = 0.95, p for trend = 0.73) or acute lymphatic leukemia (OR = 0.93, p for trend = 0.64). There were no clear associations with predicted magnetic field exposure 2 years before the diagnosis/reference date or over the subject's lifetime or with personal electric field exposure. A statistically nonsignificant elevated risk of acute lymphatic leukemia was observed with very high wiring configurations among residences of subjects 2 years before the diagnosis/reference date (OR = 1.72 compared with underground wiring, 95% confidence interval 0.54-5.45). These results provide little support for a relation between power-frequency EMF exposure and risk of childhood leukemia (McBride et al. 1999).

The National Research Council agrees that there is no clear, convincing evidence to show that residential exposures to electric and magnetic fields (EMFs) are a threat to human health (1998). After examining more than 500 studies spanning 17 years of research, the NRC Committee on the Possible Effects of EMFs on Biologic Systems found that there is no conclusive evidence that EMFs play a role in the development of cancer, reproductive and developmental abnormalities, or learning and behavioral problems. The Research Council’s report says that studies show a weak but statistically significant correlation between the incidence of childhood leukemia and wire configurations. It never has been demonstrated that this apparent association was caused by exposure to EMFs, however. Outside wiring correlates poorly with measurements

of actual fields inside the home, in that it accounts for only a fraction of the fields inside. Scientists have tried unsuccessfully to link leukemia to EMFs by measuring fields inside of homes of children who had the disease. The results "have been inconsistent and contradictory and do not constitute reliable evidence of an association".

Data Selection and Analysis

School Data

Within the four urban Utah counties (Davis, Salt Lake, Utah, and Weber) the various school districts maintain approximately 940 physical facilities. Data on the location, type and operational status of these facilities were obtained from the Utah Automated Geographic Reference Center (AGRC), Utah Department of Technology Services (UDTS). From those data, 770 grade schools were identified. Each school was contacted by the Environmental Epidemiology Program (EEP), Utah Department of Health (UDOH). The EEP identified 85 (11%) schools with cell towers on campus. Of those, 34 (40%) were elementary schools.

Child Population Data

Annual estimates of childhood population for each US 2000 census block group geographic area for Utah were derived by linear regression and extrapolation from US 1970, 1980, 1990 and 2000 census reports. Population data were aggregated for use by the EEP in five year age groups (0-4, 5-9, 10-14, 15-19, etc.) The location of these data is represented by the US 2000 census block group area centroid.

Child Cancer Data

Cancer data for cancers events in Utah from 1973 through 2005 were obtained from the Utah Cancer Registry. Those data have previously been geo-referenced to the US 2000 census block group areas containing the residential addresses of cases. The location of cancer data is represented by the US 2000 census block group area centroid.

Selection of Exposed Population

Information about the geographic distribution of the child population attending cell-tower or non-cell-tower campuses was not available. The EEP reasoned that children generally attend the school closest to their residential address. To determine the closest school, Voronoi polygons were constructed for each school. Voronoi polygons are constructed so that each point location within the polygon boundaries is closer to the school the polygon is centered on then any other school. These kinds of polygon structures are often used to delineate areas of influence for point locations. Populations within the Voronoi polygons and a 0.5 kilometer buffer around the polygon of school campuses with cell towers were considered exposed. The 0.5 kilometer buffer was used to include students who may choose to attend a school that is not the closest school. Census block group centroids representing exposed populations of children contained by the buffered school Voronoi polygon were considered the exposed childhood population.

Data Analysis

The Rapid Inquiry Facility was used to evaluate the occurrence and risk of cancer for the exposed childhood population compared the non-exposed childhood population attending school in the four urban counties. Information about when cell towers were installed on school campuses was not available. The cell phone industry started marketing 3rd generation cell phones in the mid-1990s. During that time cell phone technology became widely available to the

consumer public prompting a rapid expansion of the cellular infrastructure. While it is possible that some schools had cell-tower installations prior to 1995, that year was considered to be a reasonable beginning point in time for exposure. Therefore, children 5-14 years of age in the exposed population for elementary schools with cell towers and children 5-19 years of age in the exposed population for all grade schools (elementary, middle, junior high and senior high schools) with cell towers were evaluated for increased risk of cancer. The rates of brain and hematopoetic tissue cancers were evaluated for the exposed populations.

RESULTS

The relative risk (RR) is defined epidemiologically as the risk of developing a disease relative to exposure. It describes the probability of an event occurring in an exposed group as compared to a non-exposed group. If the RR equals 1, then the exposed and non-exposed populations are at an equal risk of developing the disease. If the RR is < 1, then the event is less likely to occur in the exposed population than in the control (or non-exposed) population. Similarly, if the RR > 1, then the even is more likely to occur in the exposed population than in the control; in this instance, the presence of the cell tower on the school property could be attributed to the increase in event cases.

For the four urban counties examined along the Wasatch front, the incidence of brain cancer and leukemia were not found to be statistically significantly elevated for children aged 5-14 years of age (Table 3). The risk of developing these diseases in the population examined is also not significant. Leukemia was further broken down into various types of leukemia. Although both Hodgkin's lymphoma and acute and chronic myeloid leukemia have relative risks greater than 1, these values were not statistically significant and therefore the risk of developing these diseases solely from residing in a neighborhood or attending a school with an EMF tower is unlikely. There were no observed cases for Non-Hodgkin's lymphoma, multiple myeloma and monocytic leukemia; therefore, no analysis could be performed on individual leukemia.

Table 3. The risk and rate of cancers for children ages 5-14 living near (assumed attending) an elementary school with a cell tower on campus from 1995 – 2005.

Type of Cancer	Observed Cases	Expected Count	Relative Risk (RR)	95% Confidence Level		Rate
				LCL	UCL	

Brain cancer	11	16.11	0.68	0.34	1.22	1.99
All heamopoetic	25	25.67	0.97	0.63	1.44	4.49
Hodgkin's disease	4	3.33	1.2	0.33	3.07	0.71
Non Hodgkin's lymphoma	No cases observed					
Multiple myeloma	No cases observed					
Lymphocytic leukemia (acute & chronic)	11	12.47	0.88	0.44	1.58	1.99
Myeloid leukemia (acute & chronic)	4	2.1	1.9	0.52	4.88	0.71
Monocytic leukemia	No cases observed					

Although the results for elementary school children aged 5-14 show no statistically significant elevations in either brain cancer or leukemia with proximity to EMF towers, an additional analysis was completed for a larger age group of children. This analysis examined children aged 5-19 and included all public schools (elementary, middle, junior high and senior high) with cell towers on the premises for increased brain cancer and leukemia risk.

The results from this analysis show that, as in the elementary school results, there is no increase in these types of cancer from the presence of the EMF tower. The RR values calculated are not statistically significant for the cancers that can be compared. The increase in age group still did not yield any cases of Non-Hodgkin's lymphoma, multiple myeloma or monocytic leukemia. Although both all heamopoetic cancer and acute and chronic myeloid leukemias resulted in RR values greater than 1, they are not significant and therefore do not represent an increased risk in developing these cancers from solely being exposed to an EMF tower.

Table 4. The risk and rate of cancers for children ages 5-19 living near (assumed attending) a grade school with a cell tower on campus from 1995 – 2005.

Type of Cancer	**Observed Cases**	**Expected Count**	**Relative Risk (RR)**	**95% Confidence Level**		**Rate**
				LCL	**UCL**	
Brain cancer	32	45.81	0.7	0.48	0.99	1.84
All heamopoetic	101	94.72	1.07	0.88	1.3	5.72
Hodgkin's disease	32	22.9	1.4	0.96	1.97	1.21
Non Hodgkin's lymphoma	No cases observed					
Multiple meyloma	No cases observed					
Lymphocytic leukemia (acute & chronic)	35	36.31	0.96	0.67	1.34	2.01
Myeloid leukemia (acute & chronic)	11	10.7	1.03	0.51	1.84	0.63
Monocytic leukemia	No cases observed					

CONCLUSIONS

The adverse health effects related to exposure of ELF/EMF have been a concern for populations residing near these towers. This especially became a concern following the construction of these towers on public school properties across the country. After a thorough examination of the current literature and recent findings related to health effects, we found that, although opinions vary in the field, ELF/EMFs have not been correlated to any adverse effects in either children or adults residing in neighborhoods with these towers associated with them.

The results of the current study are in agreement with results from previously conducted studies on the correlation between exposure to EMF and adverse health effects. When examining the rates of brain cancers and leukemia in children aged 5 through 14 residing near or attending elementary schools associated with EMF towers, the relative risk of developing these types of cancers are not statistically significant. When breaking down the individual types of leukemia further, there is a small increase in risk, especially for Hodgkins's leukemia and acute and chronic myeloid leukemia (i.e. RR > 1); however, the increased risk is not statistically significant. Also, due to the fact that there are numerous exposure scenarios that could ultimately result in these diseases, the increased risk cannot be solely correlated to EMF exposure.

In addition to the above experiment, both the age of the children examined and the type of public school included were widened to include children aged 5 through 19 and elementary, middle, junior high and senior high schools with EMF towers on the premises. The results for this experiment were similar to the results obtained for the previous experiment; the risk associated with both brain cancer and leukemia were not statistically significant. When the individual types of leukemia were further broken down, there was a small increase in risk for all heamopoetic cancers and acute and chronic myeloid leukemia; however, the increase in risk was small and not significant.

The results from this current study, in conjunction with results in the literature, show that there is no definitive correlation between exposure to EMF fields and adverse health effects. The results directly show that there is no statistically significantly increased risk for children residing near and attending public schools with these EMF towers on their premises. Due to the conclusive results from this study, coupled with additional studies in the literature, no further action or research will be taken.

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