Evidence that Electromagnetic fields from high voltage powerlines and in buildings, are hazardous to human health, especially to young children

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Abstract:

Dr Neil Cherry was asked by a school in Florida, United States, to review of biological and epidemiological health effects of electromagnetic fields, especially for children with the proposed to have a substation constructed next to the school with high-voltage powerlines coming in. this review shows are many sally showing an extremely low-frequency electromagnetic fields reduced melatonin, enhance chromosome aberrations, damaged DNA strains and increase rates of cancer electrical and electronic workers, and children and adults in residential situations both from powerlines and from the fields in their own homes. Because we almost all live in homes with electric energy that means for the electronic fields which enhance the background cancer rate so that there is no not exposed group to be used as a reference group for epidemiological studies. Therefore the published studies significantly underestimate the relative risks levels. Very few people realize how many health effects of hourly rates from this background fields we live in. By taking all this information together it has concluded that the applied guideline/standard should be 1mG. Because many people live in fields above the 1mG guideline and the state level is zero, it is recommended to take the New Zealand Ministry of Environment approach to reduce exposures below the guideline. When actual exposures are less than the guideline they should be maintained and reduced to be “good”, below 33% (0.33mG) or “Excellent”, below 10% (0.1mG). This approach would significantly improve the public health effects, not only from cancer, but also for cardiac, neurological and reproductive health effects, all of which had been associated with exposure to these fields with dose-response relationships pointing down to zero exposure.

1. Introduction:

When Physics and Biology meet, a clear understanding emerges. A wise, senior and eminent medical epidemiologist solves a 50-year old dilemma by matching a mysterious peak of childhood leukemia with the introduction of electric wiring into homes around the world. In many diverse circumstances, a new insight emerges. By joining these understandings with laboratory experimental results and residential and occupational epidemiological studies, a robust, reasonable, consistent and sensible conclusion is reached.

Low frequency electromagnetic fields, whose frequencies, harmonics and sub-harmonics coincide with the range of frequencies used by our brains, hearts and cells. Subtly and at extremely low intensities, they strongly interact, through resonant absorption, with primary functions of our bodies with significant elevations in depression, sickness and death.

Authorities around the world treat low frequency electromagnetic fields as foreign external agents that have to be very intense to produce visible and discernable effects such as electric shock and burns. They make the mistake of then assuming that if these extreme acute effects do not occur then no other effects can occur. They then assume that people are safe at all lower field intensities. This approach ignores the basic science of biophysics. Cells use oscillating electromagnetic fields for many vital functions. Signals and substances that interfere with vital functions are hazardous and toxic.

Current standards do not protect people from many consistent and well established biological and health effects. The international guideline (International Commission for Non-Ionizing Radiation Protection, ICNIRP (1998)) for public exposure to 50 Hz fields is 1000 mG and for 60 Hz it is 833.3mG. These are set to avoid electric shock.

Childhood leukaemia is consistently significantly elevated at 2 mG relative to "unexposed" reference groups, RR = 2.0, 95%CI: 1.0-4.1, Feychting et al. (1995) and OR = 12.0, 95%CI: 1.1-137, Dockerty et al. (1998). Common Acute Lymphoblastic Leukaemia (cALL) in 2 to 4 year old children is highly elevated for children in the "unexposed" reference group where mean exposures are somewhat less than 1 mG, Milham and Ossiander (2001). Suicide in electrical workers is elevated by 23% for annual exposures of less than 0.2 mG, Van Wijngaarden et al. (1999). Van Wijngaarden et al. show that the suicide rate increases with mean exposure to an increase of 70 % above 1.1 mG. This shows that the level of no effect is very close to zero for 60 Hz magnetic field exposure. These studies are all linked by a common biological mechanism, reduced melatonin.

2. Biophysical Principles:

2.1 Electric and magnetic field exposures:

Power frequency (50/60 Hz, 1 Hz = 1 cycle per second) electric and magnetic fields are produced around wires, appliances and equipment powered by electricity. The electric field (E, V/m) is proportional to the voltage (V, volts) and the magnetic field (B) is proportional to the current (i, Amperes). B, in milliGauss [mG] or microTesla [μT]; 10 mG = 1 μT. In Figure 1 this is illustrated by showing the electric fields produced when devices are plugged in and the voltage is applied. The magnetic fields are added when the switch is turned on and the current flows to operate the appliances.

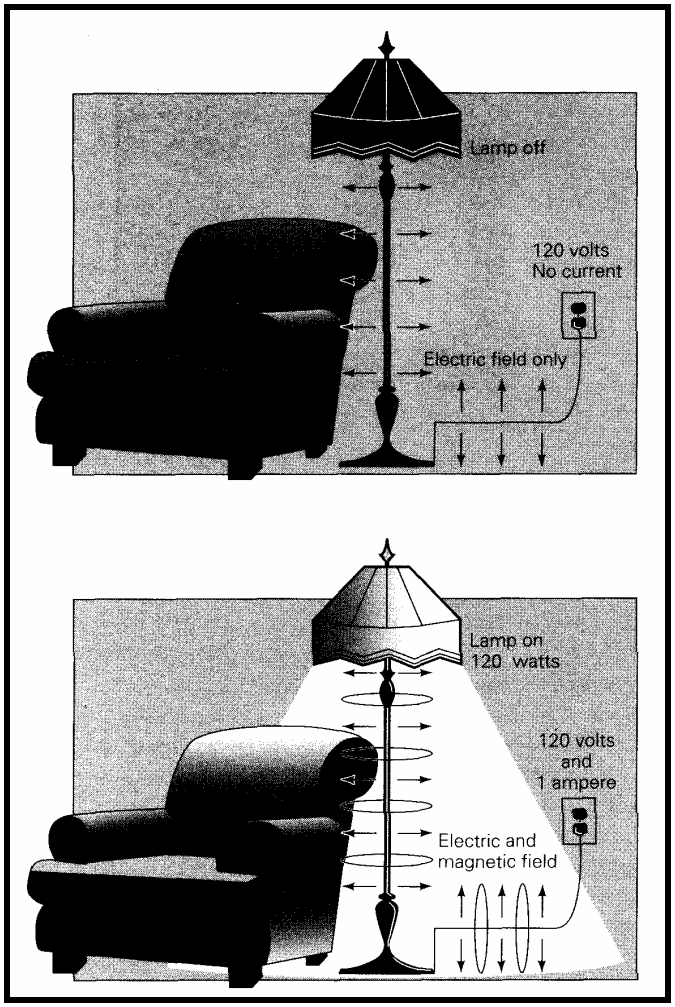

Figure 1: The electric field results from being plugged in and a voltage is applied between the plug and the "end" of the supplied device. When the devices are turned on the voltage produces a current flow that creates a magnetic field in addition to the electric field, Levitt (1995). Because the voltage is oscillating at 50/60 Hz, the magnetic field and electric fields are oscillating at 50/60 Hz, creating an ELF modulated electromagnetic field.

In North America household supplies are 60 Hz and 110 V, whereas in the U.K., Europe, Australia and New Zealand, 50 Hz and 240 V power supplies are used. This shows that the North American supplies are associated with higher currents and higher magnetic fields for a given power requirement.

Around high voltage powerlines the electric field is more constant as it relates to the supply voltage which is more constant. The magnetic fields are more variable because they vary as the current changes to deal with the varying electric power loads being supplied. The following table gives some examples of magnetic field intensities as a function of distance from high voltage power lines in the US.

In Figure 2 the fitted line underestimates the mean nocturnal fields for some children by as much as a factor of 2 to 5 in some cases. In this survey about half of the children went to a school near the powerline and the others went to a school far from the powerline. Personal daily mean and long-term mean exposures vary with the dominant daily activity exposures. For children this is the primarily the home and school exposure regime.

Examples of the typical daily exposure pattern for one of each of these cases is given in Figure 3.

Table 1: Magnetic fields as a function of distance from power lines, based on USEPA, 1992, cited in National Research Council, 1997. Note, at peak loads the fields can be doubled.

		Representative Magnetic fields at different distances from lines, mG.					
Transmission Lines, kV	Maximum magnetic field on Right-of-Way, mG	15.24m (50ft)	30.48m (100ft)	60.96m (200ft)	91.4m (300ft)	121.9m (400ft)	152m (500ft)
115	30	7	2	0.4	0.2	0.1	0.05
230	58	20	7	1.8	0.8	0.4	0.2
500	87	29	13	3.2	1.4	0.7	0.35
660	115	38	17	4.2	1.9	0.9	0.5
1000	150	50	22	5.4	2.4	1.2	0.6

An independent comparison in available from Norway, Vistnes et al. (1997), Figure 2.

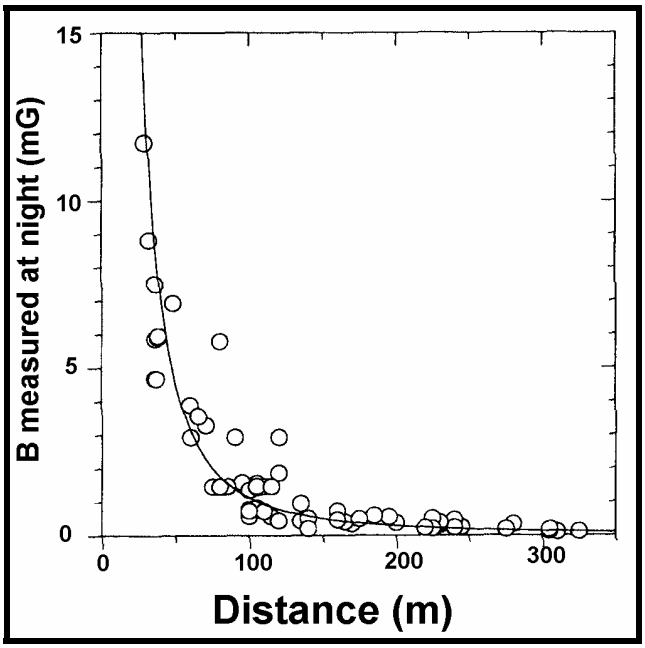

Figure 2: Geometric means of nighttime individual magnetic fields for 65 children living in the vicinity of a 300 kV powerline in Norway, Vistnes et al. (1997).

Figure 3 shows that in this case the field at home for child A was 3 to 8 mG and at school was between 0.1 and 2 mG. For child B going to a school near the powerline, the home readings varied between 0.5 and 1 mG and the school readings were mainly 10 to 30 mG and as high as 80mG on brief occasions.

In both cases the time at home is more dominant than the time at school. However, in the case of a school near the powerline, the child's average exposure by going to the school is significantly higher.

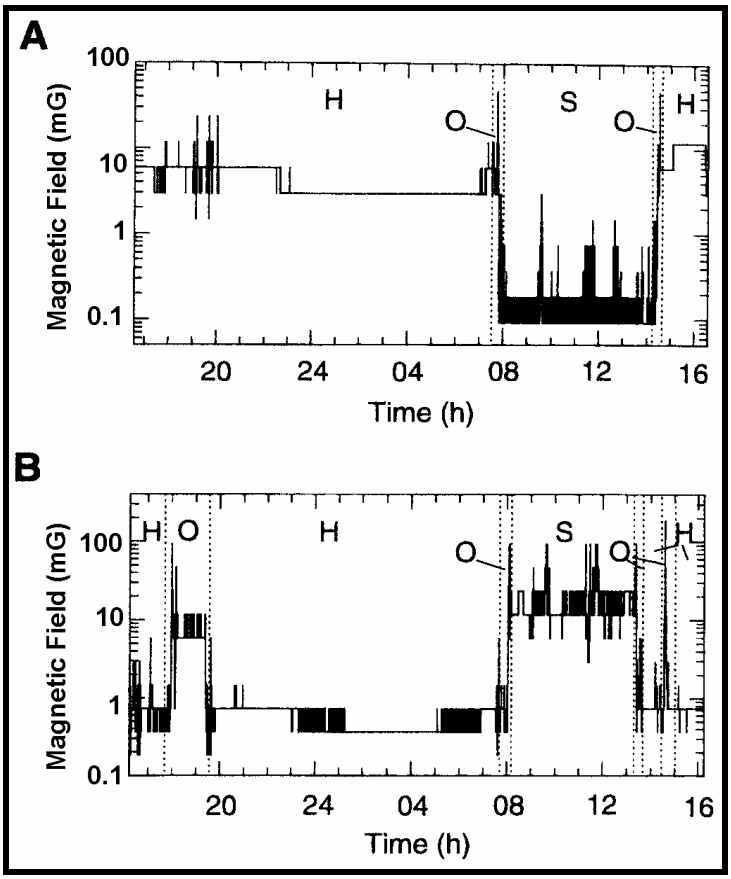

Figure 3: Examples of magnetic field recordings for child A, living 60 m from the 300 kV powerline and attending a school 300 m from the powerline, and child B who lived 175 m from the powerline and attended a school 25 m from the powerline, Vistnes et al. (1997). **H**: Home, **S**: School and **O**: Other.

A survey of Canadian homes was carried out to compare the typical and 48 hr average exposure of children across five provinces, Deadman et al. (1999). There were highly significant variations between the average home and school magnetic fields. The mean for homes was 1.41 mG, with the highest province being Quebec at 1.90 mG and the lowest being Alberta at 0.62 mG. For schools the average was 1.16 mG, with Manitoba being the highest at 1.56 mG and Alberta being the lowest at 0.70 mG. These show ranges of over a factor of 2 in the children's home and school mean magnetic field exposures.

For the surveyed Canadian children the median exposure is 0.83 mG and the 95%ile is over 4 times higher at 3.54 mG. The ratio between the 25%ile and the 95%ile is 7.53.

These surveys from the U.S., Norway and Canada show how varied are the mean 50/60 Hz magnetic field exposures for individual children, for homes, schools and regions. The exposure intensities vary over ranges for which extremely important and highly significant health effects are shown to occur. The ability and the need to minimize exposures is clearly evident. Keeping schools and homes well away from high voltage powerlines is a vital element of the risk reduction strategy that is necessary to reduce the incidence and risk of serious illness and death for children.

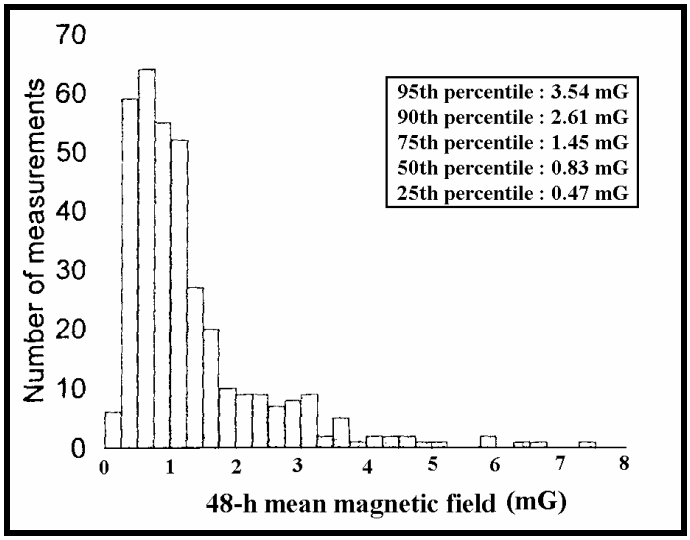

Figure 4: Frequency distribution of measured 48-hr average childhood magnetic field exposures from 382 Canadian children, Deadman et al. (1999).

2.2 How fields interact with human bodies:

Figure 5 shows how the electric field is concentrated into human bodies because of the conductive material, mainly water, that allows the field to carry a current to earth, parallel to the electric field lines. On the other hand, magnetic fields induce circular currents perpendicular to the magnetic field lines. The fields are oscillating at 50/60 Hz so that the induced currents within our bodies are also oscillating at these frequencies.

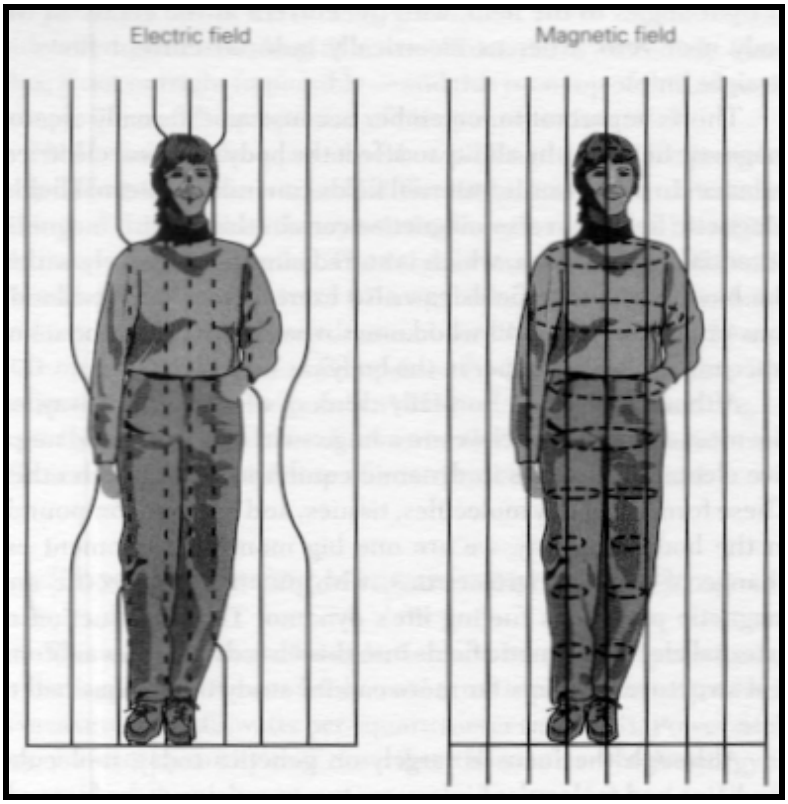

Figure 5: Low frequency electric and magnetic fields induce weak electric currents in humans and animals. The dotted lines show the directions of the induced currents, parallel to the electric field and perpendicular to the magnetic field, Levitt (1995).

2.3 Radiofrequency signals from high voltage powerlines:

A second, but not well known interaction between powerlines and humans, is the radio frequency fields that are emitted by high voltage powerlines. You may have noticed the static noise on your car radio as you drive under or alongside a high voltage powerline.

A survey of radiofrequency (RF) fields from powerlines has been carried out in Italy, Vignati and Giuliani (1997). They found that 100 to 400 kHz signals were most common. The researchers used the rapid drop in dielectric constant with increasing RF frequency to show that the induced current was much higher for RF signals than for ELF signals. This is confirmed, Figure 9, below.

Because of this much stronger coupling of the RF signal to muscular tissue than the 50/60 Hz fields they showed that a 100 kHz field with a strength of 0.1 mG has induces the same current as a 1000 mG 50/60 Hz field. Allowing for this factor of 10,000, the smaller measured RF fields induced similar or higher fields in the tissue that the magnetic field. Vignati and Giuliani stress that they are not questioning the health effects. Rather, they are raising the possibility of an alternative or synergistic biophysical mechanism.

2.4 Resonant Detection of ULF/ELF fields:

Resonant detection of oscillating fields is a classic physics process used by telecommunication technologies using aerials, tuned oscillators, phase-locked loop circuits signal encoders and decoders and amplifiers. An example of traditional aerial is the half-wave dipole. This is a length of conductor that is half the wavelength of the signal being received. Because this is based on matching the half wavelength it illustrates the strength of resonant absorption of multiples of the half wavelength ($L=\lambda/2$). At any multiple of L there is a resonant absorption peak as we scan across the frequency spectrum. These are called harmonics. Sub-harmonics, involving longer wavelengths and lower frequencies, also have resonant characteristics as multiples of oscillatory peaks coincide, after every second, third, fourth, cycle, etc. In these cases it is frequency matching rather than wavelength matching. An FM radio or TV tuner has a frequency oscillator that can have its primary frequency varied across the spectrum. When an incoming signal is detected a feed-back signal is generated that is proportion to the frequency difference between the incoming signal and the internal oscillator. This difference signal is fed back to the oscillator to vary the internal frequency. As the difference gets smaller the feed-back signal gets smaller and an automatic frequency tuning device has been created. This is called a phase-locked loop circuit.

Biology has preceded electronic physics because brains and cells use oscillating ion currents for the control of release of neurotransmitters and in the cell to cell communication systems. They use frequency encoders and decoders and phase-locked loop circuits to tune into external signals of a slightly different frequency, Ahissar et al. (1997).

Biological Systems detect and respond to external ULF/ELF signals using their built-in receiving and decoding systems (cell-to-cell communication, EEG, ECG). Table 2 summarizes observations of actual field levels involved in biological processes, Adey 1990.

Table 2: Bioelectric sensitivities to ELF fields, Adey (1990).

	Function	Tissue Gradient	Imposed field
Sharks and rays	Navigation and predation	10^{-8} V/cm	DC to 10 Hz
Birds	Navigation	10^{-7} V/cm	0.3 gauss
	Circadian rhythms	10^{-7} V/cm	10 Hz, 2.5 V/m
Monkeys	Subjective time estimations	10^{-7} V/cm	7 Hz, 10 V/m
Humans	Circadian rhythms	10^{-7} V/cm	10 Hz, 2.5 V/m
	Comparison With Intrinsic Cell and Tissue Neuroelectric Gradients		
Membrane potential	10^{5} V/cm		
Synaptic potential	10^{3} V/cm		
Electroencephalogram	10^{-1} V/cm		

Early claims that living cells could not detect fields less than the membrane potential, 10^5 V/cm, are demonstrably wrong. Not only does the brain's EEG signals operate using ELF oscillating signals whose field strength is a million times lower, 10^{-1} V/cm, but fish, birds, primates and humans detect and respond to ELF oscillating signals over a million times smaller than the EEG signal, 10^{-7} to 10^{-8} V/cm.

These processes involve non-linear, non-equilibrium reactions to resonant absorption of oscillating signals, Adey (1990). The oscillating signal oscillates across the cell membrane, triggering ion channels to increase or decrease the natural ion flows. In the brain this alters the neurotransmitters signals, changing the EEG pattern. The changes are transmitted to the hormonal glands that regulate the physiological reactions to emotions, daily cycles, etc. These glands produce hormones that signal the changes to the body organs and cells.

2.5 Human EEG frequency spectrum:

The neurons involved in emotion, thinking, memory and reaction use oscillating calcium ion and neurotransmitter signals primarily in the frequency range below 50 Hz, as shown by a typical EEG spectrum, Figure 6.

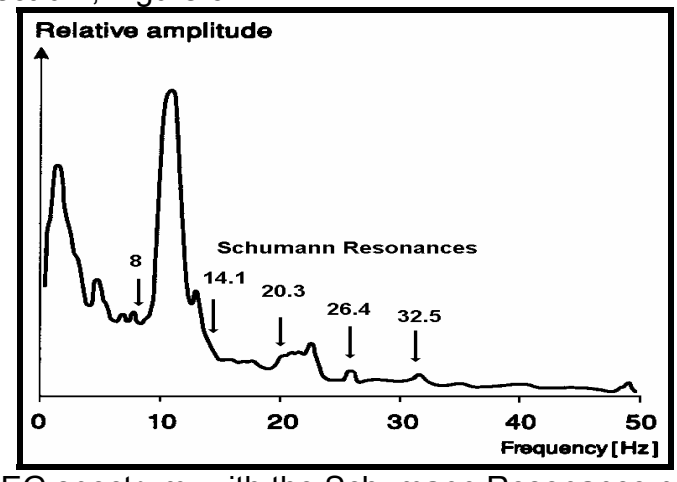

Figure 6: A typical EEG spectrum, with the Schumann Resonance peaks superimposed.

The human EEG shares the same frequency range as a natural ELF signal, the Schumann Resonances, that propagate around the world with a diurnal and seasonal pattern that follows the human diurnal melatonin pattern, suggesting that there could be a causal link between them. The intensity of the Schumann Resonance signal varies with Geomagnetic Activity (GMA) in a highly significantly correlated manner, Cherry (2001).

2.6 EMF reduces melatonin:

Many animal studies find that ELF fields reduce melatonin, Rosen, Barber and Lyle (1998). More than 13 studies show that people exposed to ELF fields have reduced melatonin, including, Pfluger and Minder (1996), Arnetz et al. (1996), Wilson et al. (1990), Graham et al. (1994), Davis (1997), Wood et al. (1998), Karasek et al. (1998), and Burch et al. (1997, 1998, 1999a, 2000), Juutilainen et al. (2000) and Graham et al. (2000). Hence this is a very well established effect of ELF electromagnetic field exposure.

GMA is highly correlated with reduced melatonin in humans, Figure 7, Burch et al. (1999).

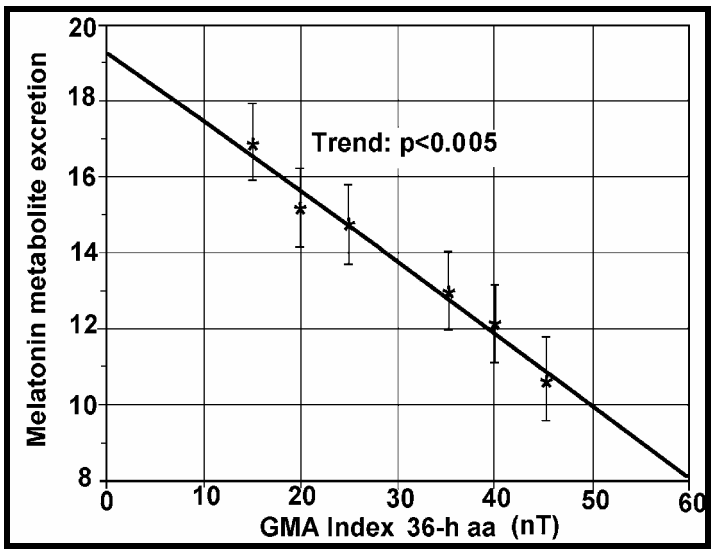

Figure 7: Reduction in the melatonin metabolite 6-OHMS in μg in urine from U.S. electric utility workers, as a function of the 36 hr global GMA aa-index, Burch et al. (1999).

A similar effect is found in workers exposed to 60 Hz fields, Figure 8.

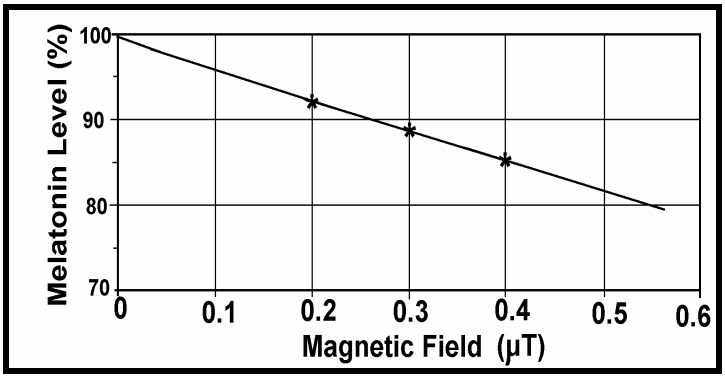

Figure 8: Reduction in melatonin in electrical workers exposed to 60 Hz magnetic fields, Davis (1997). Note 0.1 μT = 1 mG.

2.6 Whole body effects:

Since melatonin and serotonin are the primary circadian endocrine hormones, all vital organs, including the brain, hypothalamus, central nervous system, lymph system, immune system, heart, lungs, liver, kidneys, uterus, testes and fetus, have melatonin and

serotonin receptors. Hence substances that alter the melatonin/serotonin balance can affect organs throughout the body.

The biophysical mechanism for detecting and responding to external ELF signals, resulting in reduced melatonin, occurs through resonant absorption of the ELF signals in the brain. Calcium ions and neurotransmitters oscillate at the EEG frequencies. External ELF signals induce alterations in the calcium ion signals that in turn send signals to the pineal that alters the melatonin/serotonin balance. This is transferred to the body organs through the CNS and hormone/enzyme/ion cellular signalling system. In addition, the ELF signal systems in cells, also involve calcium ions, can be directly interfered with by external ELF signals of extremely low intensity through non-equilibrium resonant absorption processes at the cell membrane, Adey (1990).

2.8 Induced calcium ion efflux:

One of the first biological mechanisms to be identified, confirmed and established is calcium ion efflux (positive and negative), Blackman (1990). One of the early results, Bawin and Adey (1976):

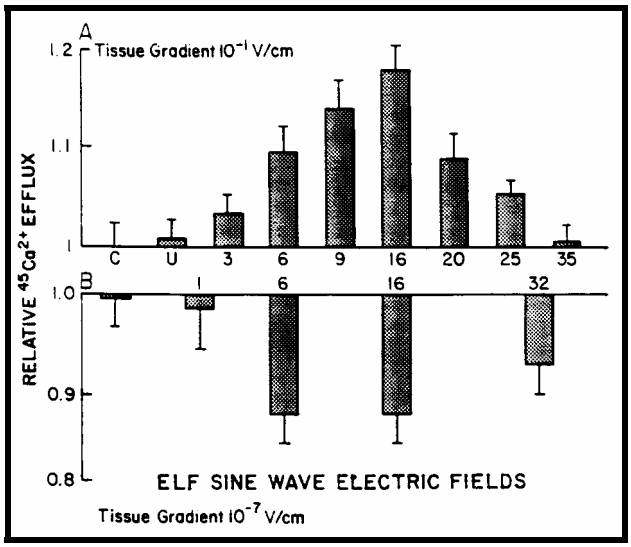

Figure 9: ELF induced calcium ion efflux from (A) an ELF modulated 147 MHz signal and (B) an ELF signal in the EEG frequency range, Bawin and Adey (1976).

This is a resonant phenomenon that only operates in the normal mammal temperature range. It is dependent on the earth's geomagnetic field strength and orientation and therefore varies from place to place and time to time.

Blackman et al. (1989) identified multiple power density windows for Ca^{2+} efflux, using a 50 MHz carrier modulated at 16 Hz. Their results, using units of mW/cm^2, are summarized as follows:

Enhanced efflux		1.75	3.85		5.57	6.82	7.65	7.77		8.82
No change	0.75	2.30	4.50	5.85	7.08			8.19	8.66	10.6	14.7

Lowest published intensity so far: 0.00015 W/kg (0.08 μW/cm^2). This involved a 30 min exposure of frog hearts to 16Hz modulated, 240 MHz RF, Schwartz et al. (1990).
Calcium ion efflux varies with modulation frequency at to at least 510 Hz, Figure 10.

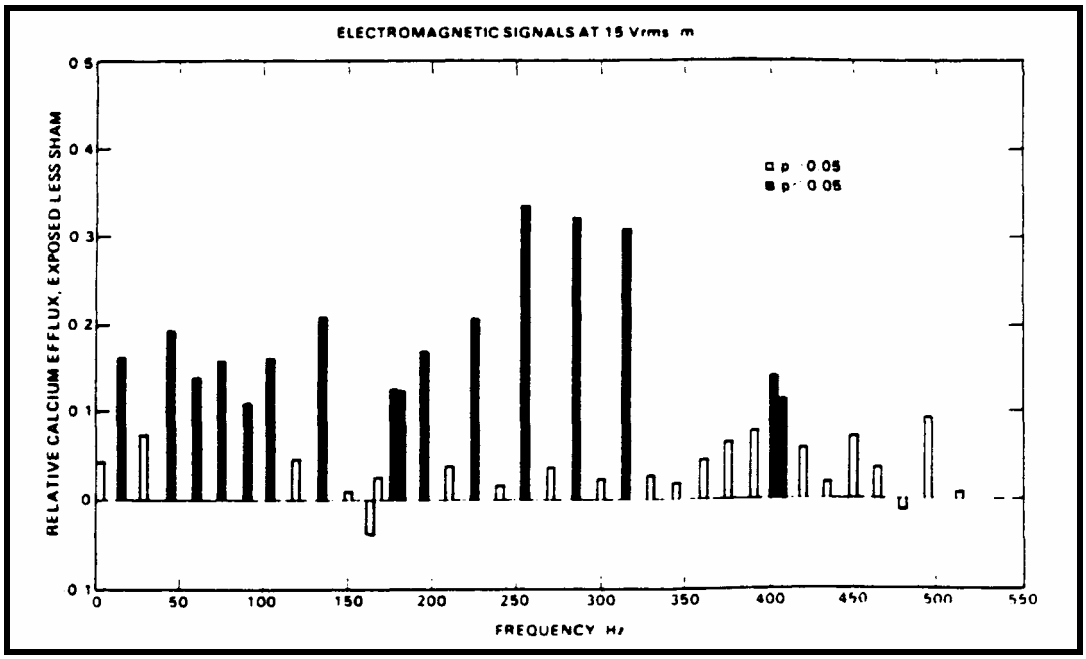

Figure 10: Significant calcium ion efflux induced by modulation frequencies up to 510 Hz, showing the window effect, Blackman et al. (1988). This includes 50 and 60 Hz.

In 1990, having reviewed the published research on calcium ion efflux to that data, Blackman (1990) concluded:

"Taken together, the evidence overwhelmingly indicates that electric and magnetic fields can alter normal calcium ion homeostasis and lead to changes in the response of biological systems to their environment".

2.9 Biophysical Summary:

There are well established theoretical and observationally confirmed mechanisms for external ELF signals to be resonantly absorbed in human tissue, especially the brain and heart, and cause reduced melatonin. Melatonin is the most potent naturally produced antioxidant that helps to protect cells from genetic damage that leads to cancer, neurological, cardiac and reproductive damage, illness and death.

Melatonin levels also affect the health of the immune system that also has a vital role in trying to maintain health. Since a damaged cell should be eliminated by programmed cell death, apoptosis, or by natural killer cells in the immune system, altered calcium ions negatively affect both of these processes. Calcium ion influx inhibits apoptosis and calcium ion efflux enhances apoptosis, Fanelli et al. (1999).

3. Genotoxicity:

Substances that reduce melatonin are genotoxic because of the reduced antioxidant effect allowing free radials to cause more genetic damage. Direct evidence of genotoxicity comes from observed chromosome aberrations (CAs) and DNA strand breakage assays.

3.1 Chromosome damage from ELF exposure:

El Nahas and Oraby (1989) observed significant dose-response dependent micronuclei increase in 50 Hz exposed mice somatic cells. Elevated CAs have been recorded in a number of workers in electrical occupations. In Sweden Nordenson et al. (1988) found significant CA in 400 kV-substation workers and with 50 Hz exposures to peripheral human lymphocytes, Nordenson et al. (1984) and human amniotic cells, Nordenson et al. (1994). Significant CA in human lymphocytes exposed to 50 Hz fields are also reported by Rosenthal and Obe (1989), Khalil and Qassem (1991), Garcia-Sagredo and Monteagudo (1991), Valjus et al. (1993) and Skyberg et al. (1993). Skyberg et al. collected their samples from high-voltage laboratory cable splicers and Valjus et al. from power linesmen. Other studies showing ELF associated CAs include Cook and Morris (1981), Cohen et al. (1986 a,b), Lisiewicz (1993), and Timchenko and Ianchevskaia (1995). This currently involves 14 studies.

3.2 ELF Exposure and DNA strand breakage:

Four independent laboratories have also published data on ELF induced DNA-strand breaks confirming that ELF EMR damages DNA-strands; Lai and Singh (1997a,b), Svedenstal et al. (1998), Phillips et al. (1998a), and Ahuja et al. (1997). Lai and Singh (1997b) also demonstrate the involvement of free radicals and the protective effect of melatonin.

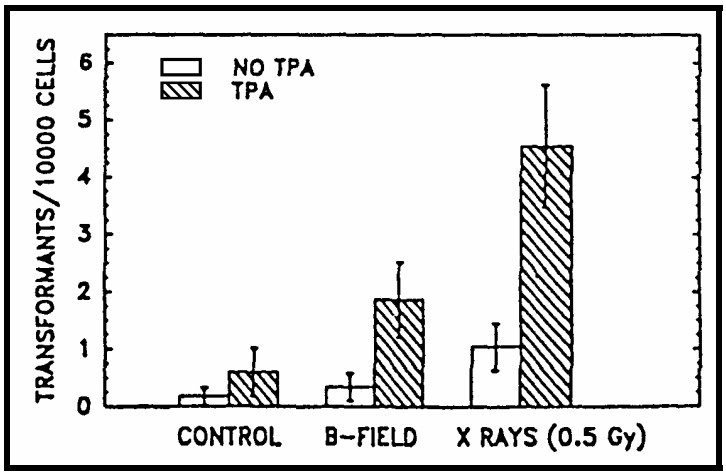

Figure 11: Induction of neoplastic transformation in C3H/10T1/2 cells by a 24 h exposure to 60 Hz magnetic field (2G) and 0.5Gy X-rays with and without TPA post-treatment exposure for 8 weeks, Balcer-Kubiczek (1995).

This research shows that ELF magnetic fields, X-rays and microwaves all reveal significant increased neoplastic transformation after a sustained several week exposure to the TPA cancer promoter chemical. Since all have also shown significantly increased chromosome aberrations and DNA-strand breakage, this also confirms that they are all genotoxic.

3.3 Direct Genotoxicity Conclusions:

With the evidence above that EMF reduces melatonin this confirms that reduced melatonin causes higher concentrations of free radicals which produce more DNA-strand breaks from EMR exposure from ELF frequencies. Increased DNA-strand breaks results in increased chromosome aberrations. Multiple evidence from independent laboratories

establishes that ELF exposures cause chromosome aberrations and DNA single- and double-strand breaks. One study shows the ELF fields cause transformation to cancer cells. This evidence very strongly and consistently supports the contention that ELF fields are genotoxic.

Genetic damage occurs cell-by-cell and repair mechanisms take place cell-by-cell. The more cells that are damaged and the poorer is the repair mechanism, the greater is the risk and incidence of damaged cells dying. Cell death is a very important process for damaging the brain. Not all damaged cells are detected and eliminated. Those that survive increase the risk and incidence of cancer, cardiac, neurological and reproductive diseases and death. This shows the role of cumulative exposures leading to cumulative increases in risk.

This also shows that when considering the population risks, since ELF signals are genotoxic, the safe level of no observed effects will only occur at zero levels of exposure of human populations, RCEP (p 20, 1998).

4. Immune system effects:

The vulnerable people are more susceptible to subtle damage. The vulnerable members of the population include the very young and very old people, and those who are already ill or have impaired immune systems through any of a wide range of causes. In addition to age affecting our immune system, there is considerable evidence relating EMF exposure to reduces immune system competence.

Tuschl et al. (2000) found that low frequency EMF significantly altered the number of natural killer cells and oxidative bursts of monocytes in exposed workers. Jonai, Villanueva and Yasuda (1996), Miziuk (1995) and Murthy, Rogers and Smith (1995) also found significant alterations of the immune systems by 50/60 Hz fields.

Marino et al. (2000) concluded that exposure to power frequency fields produced changes in the immune system that were both real and inconsistent. This is because they are complex and non-linear producing a deterministic chaos effect.

Del Signore at al. (2000) investigated the combined effect of traffic pollution and EMF exposure on the immune system of fertile atopic (allergic) women. Their results show that EMF exposure had a much greater influence on the atopic women that the pollution from traffic.

Figure 12 shows one of the reasons for this age-related vulnerability. The very young and the very old have very low levels of melatonin.

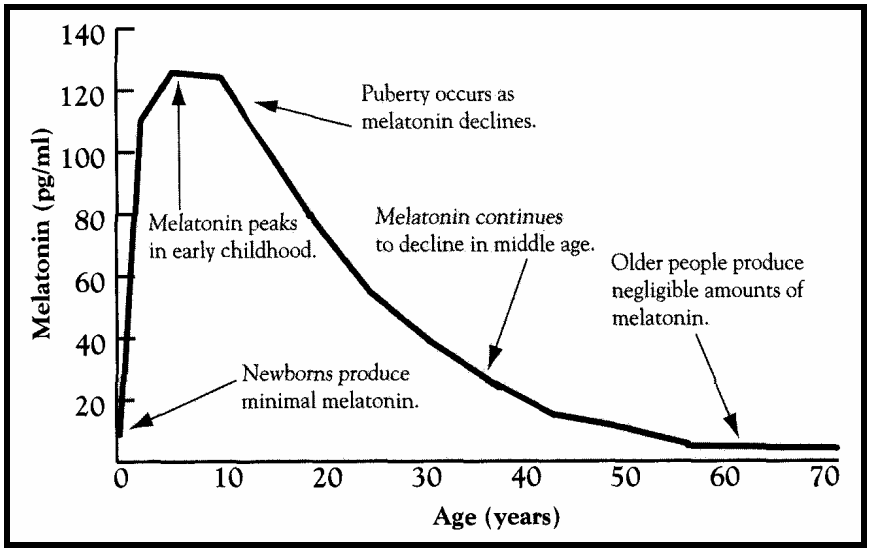

Figure 12: Melatonin production is very low at birth, peaks in early childhood and declines from puberty onwards, Reiter and Robinson (1995).

5. Historical and recent cancer rates:

Historical cancer rates are set out in the following section. Both incidence and mortality data are given by different authors. Incidence is considerably higher than mortality because the success of therapy. This ratio has changed considerably in recent decades but is not as large in the early data. Sometimes total numbers, rates per 100,000 person-years and per 1,000,000 person-years, are used.

A life-time of cumulative exposures to toxins and the reduced immune system, reduced sleep and reduced melatonin all lead to increased cancer risk, especially for those over 50 years of age, Figure 13.

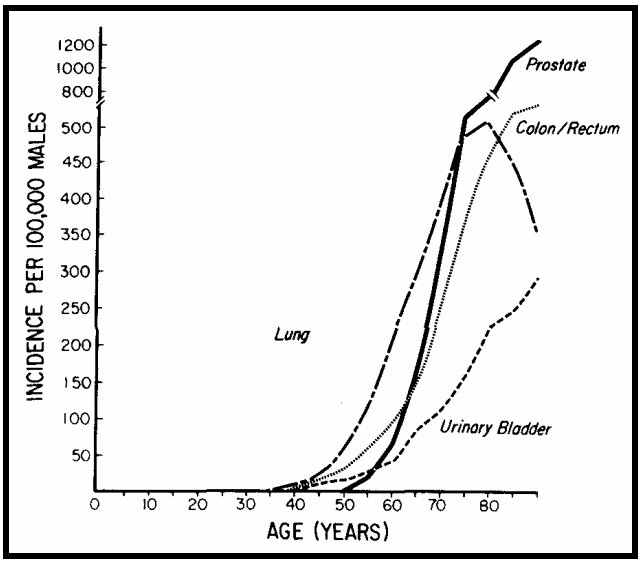

Figure 13: Age-specific incidence of the most common sites of cancer in men in the United States, 1973-1977, Young et al. (1981).

Age-specific childhood cancer rates are given in Figure 14, from the United States.

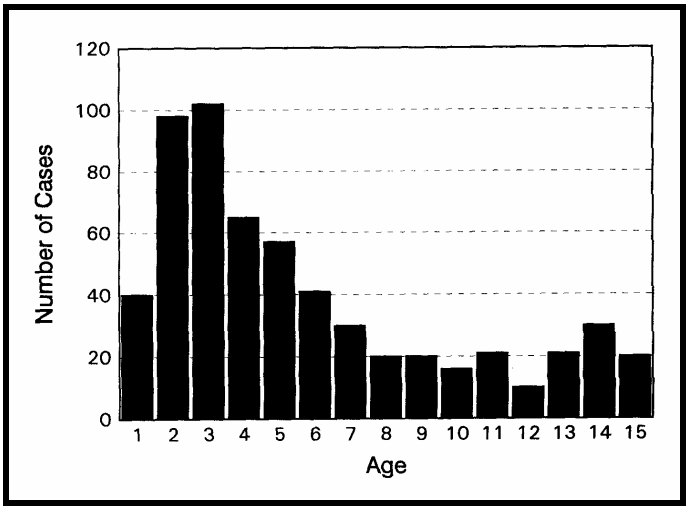

Figure 14: Age incidence of childhood leukaemia in the United States, Rubin (1983).

In Figure 14 there is a strong peak for ages 2-4 years and a smaller peak for 13-15 years. Childhood cancer rates are typically highest in the 0-4 yrs age group. Is this peak normal of is it specific to the United States? It was found by Freedman et al. (1974) that in the southern (SW/SE) metropolitan area of England in 1961-65 the annual incidence rate per million for childhood leukaemia, was 47.6 for 0-4 year olds and 32.2 for 5-14 year olds. The age-specific distribution of childhood cancer in Britain is given by Court-Brown and Hill (1961), Figure 15.

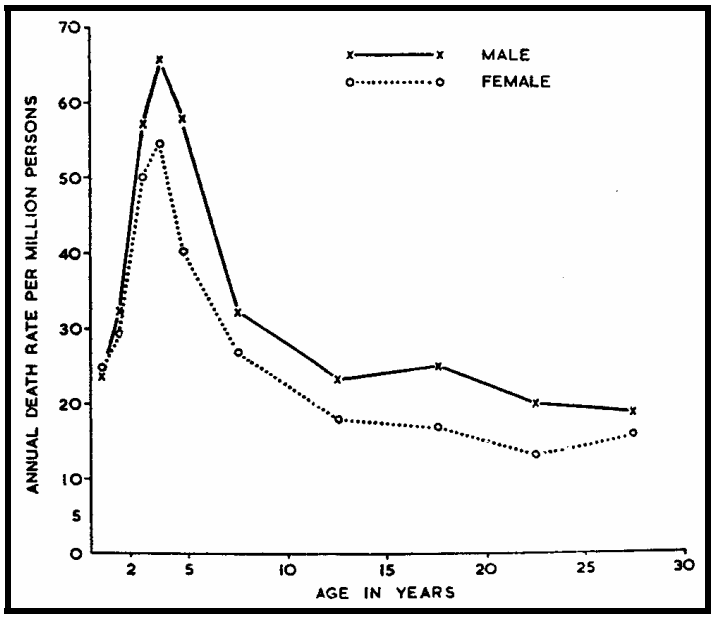

Figure 15: Age-specific death rates from leukaemia under the age of 30 years, by sex in England and Wales, 1945-1959, Court-Brown and Hill (1961).

Hence the 2-4 year old early childhood leukaemia peak occurs in both the US and UK. Court-Brown and Hill (1961) show that it is almost entirely due to acute lymphoblastic leukaemia (ALL) with a small contribution from acute myeloid leukaemia (AML). These are severe and usually fatal childhood cancers. Why does this peak occur and what causes it are vital questions. Is it avoidable? Can we save the lives of millions of children?

Court-Brown and Hill present the historical sequence of the age-specific childhood leukaemia in England and Wales, Figure 16. This shows that in the 1910-20 decade the

leukaemia rates we between 10 and 14 per million with no 2-4 year old peak. Over time the cancer rate rises significantly and the peak develops. It is well developed from 1940 onwards. By the decade of the 1950's the 2-4 year old leukaemia mortality peak is over 60 per million, 6 times higher than the 1910-20 decade. Court-Brown and Hill present only the two decades of the 1940's and 1950's for the US data. In this period the peak is evident and the rates are similar to the UK rates.

Hence in both the UK and US from 1900 to 1959 there was a very large increase in childhood cancer with the development of a new 2-4 year old peak of leukaemia. It was primarily ALL with a little AML.

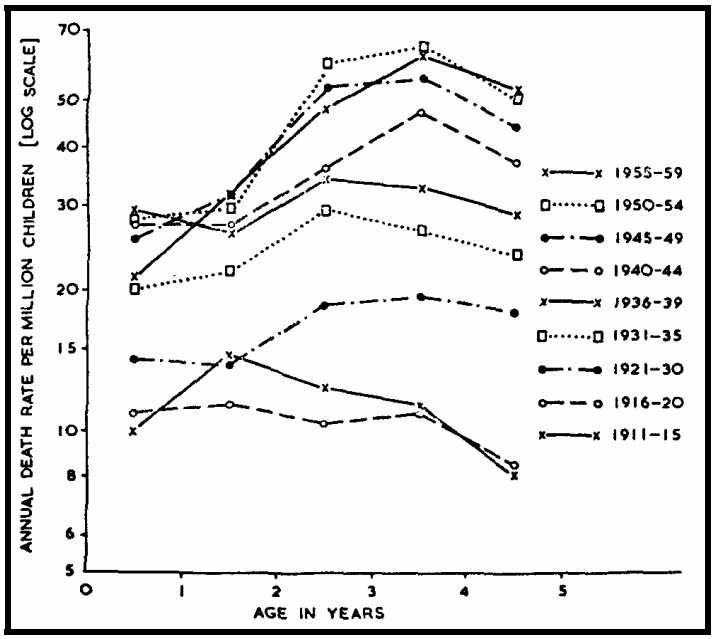

Figure 16: Leukaemia morality at ages 0-4 years for children in England and Wales between 1911-15 and 1955-59, mean values for both sexes, Court-Brown and Hill (1961).

The evolution of the US peak is shown in Burnet (1958), Figure 17.

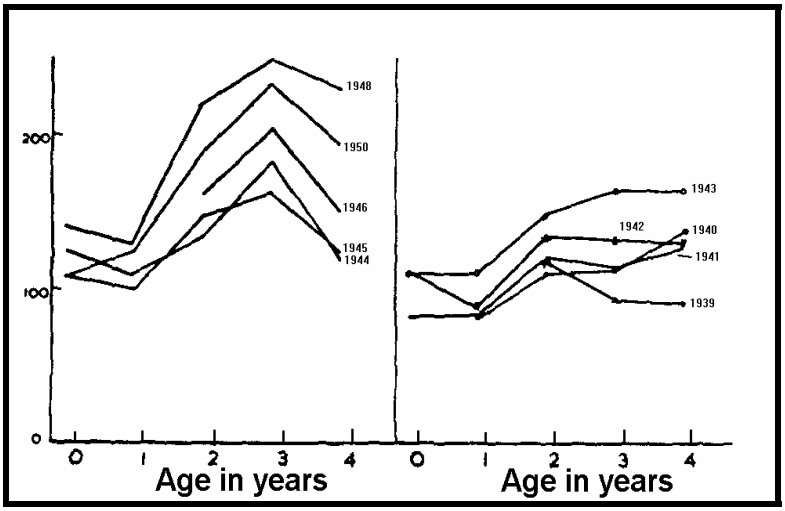

Figure 17: Childhood leukaemia incidence (per million) in the United States by cohorts of children born in the years shown, indicating the absence of a three-year peak before 1943, Burnet (1958).

The US peak occurred slightly later than the UK peak but the rates were very similar by the end of the 1940's. Note that the US data is incidence and the UK data is for mortality. The US leukaemia mortality rate for the 3 year old peak was 70 per million for white children in 1950-54 while the incidence for all children was about 230 per million in 1950, Figure 17. The progressive increase and the evolution of the 2-4 year old peak is common. The upward trend of infants, children and young adults leukaemia mortality from 1911 to 1959 in the UK and Wales is given in Figure 18.

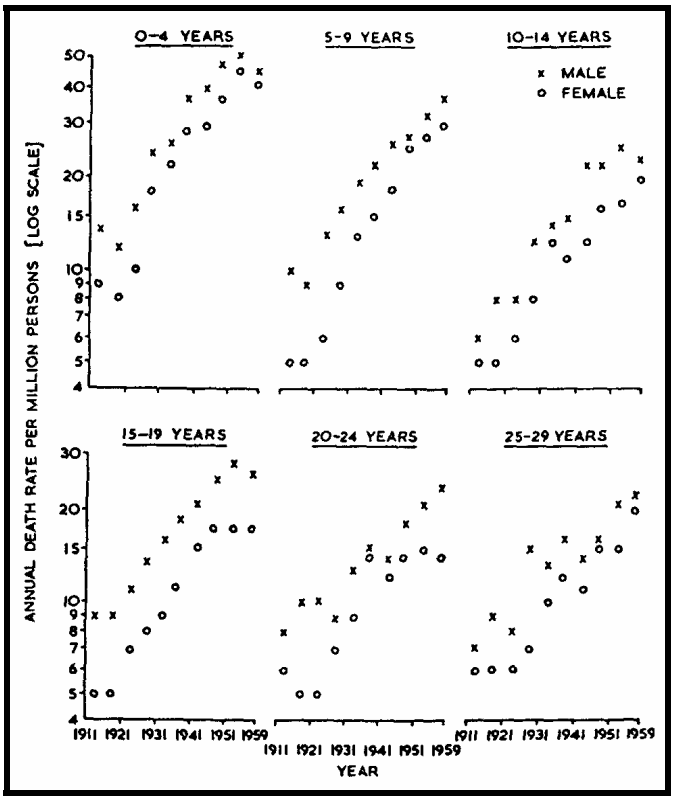

Figure 18: Trend in leukaemia mortality with time for England and Wales for 5-year age-groups by sex, from 1911-1959, Court-Brown and Hill (1961).

Figure 18 shows that for all ages shown the cancer rates had risen significantly and progressively from 1910 to 1959 by a similar proportion, a factor of 5 to 6. This suggests the likelihood of a common cause.

The peak for 2-4 year olds rose to about 60 per million by the 1950's with the 0-4 year olds at around 40 per million. By 1974-76 the 0-4 year old leukaemia incidence for boys was 70 per million and for girls 47 per million, averaging 59 per million, Stiller and Draper (1982). Hence the rise continues through the 1970's and it is still continuing in terms of increasing incidence of childhood cancers, Figure 19.

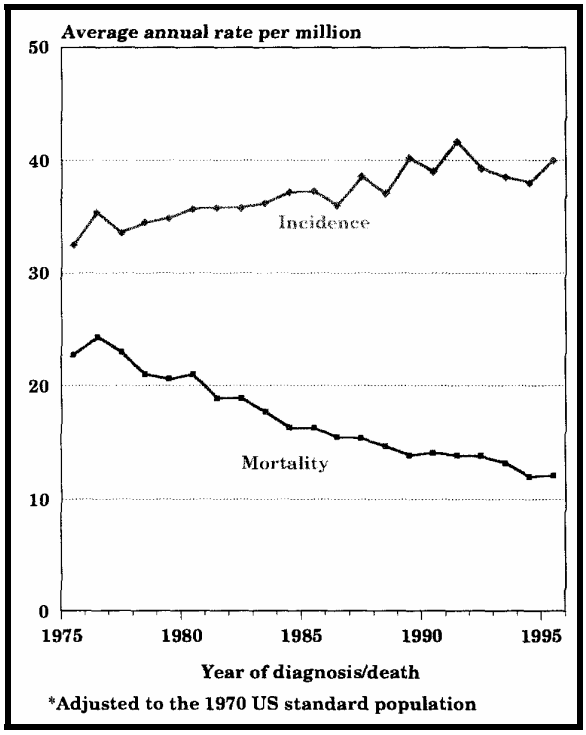

Figure 19: Trends in childhood leukaemia age-adjusted rate, age <20 years, all races, both sexes SEER incidence and US mortality, 1975-95.

From Figure 19 it is clear that prior to 1975 the mortality of all childhood leukaemia was closer to the incidence. The numbers per million are much higher in the early childhood group (0-5 years), especially because of the 2-4 year peak. Around 80% of this peak was cALL.

Looking at the total childhood cancers incidence, Schmidt (1998) notes that by the 1970's the U.S. childhood cancer incidence rate (0-14 years) was 120 per million. It has continued to rise to be over 140 per million by the early 1990's, Figure 20.

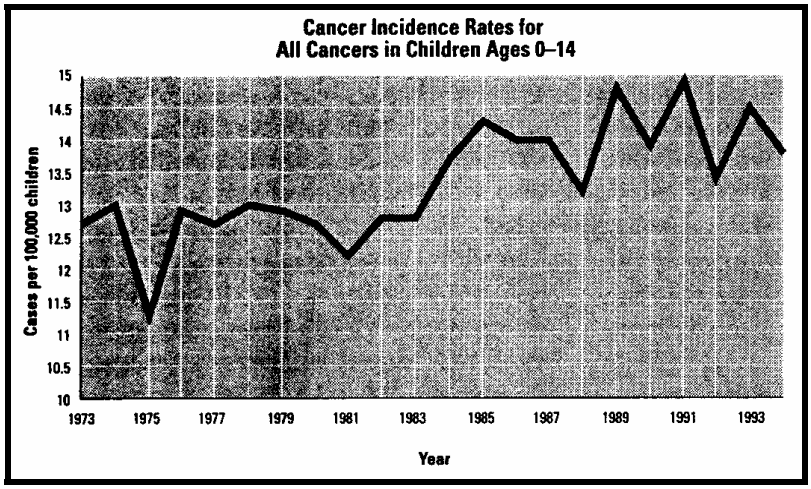

Figure 20: Total childhood (0-14 years) cancer incidence in the United States, Ries et al. (1997).

The incidence of childhood leukaemia and all cancers is continuing to rise while the mortality is declining as therapies become more and more effective, Figure 19. This shows the continuing increase of leukaemia incidence and the significantly more effective cancer

therapy reducing the mortality rate for all childhood (<20 years) leukaemia. The therapy success reduced the mortality from 72% to 30% between 1975 and 1995.

Hence the incidence of almost all childhood cancers is continuing to rise and the cause is still debated. Schmidt (1998) identifies the prime candidates for childhood cancers that are similar to those cited for adult cancers. They are listed as genetic abnormalities, ultraviolet radiation, ionizing radiation, electromagnetic fields (EMFs), viral infections, certain medications, food additives, tobacco, alcohol and a number of industrial and agricultural chemicals. A short-list of toxic agents needs to be chosen that can explain the rise in cancer from 1900-1960 and the emergence of a 2-4 year old cALL peak in the middle of this period for the UK.

These agent need to have exposed nearly the whole populations slightly earlier in the UK that the US and in Australia, Burnet (1958). In the US black families were exposed much later than white families. In the Gaza Strip the childhood ALL peak occur in the 1970's, Ramot and McGrath (1982). It cannot be UV radiation because the effect is higher in mid-latitudes than the tropics. Ionizing radiation has been investigated and ruled out, Burnet (1958). Food additives, medications, industrial and chemical toxins are primarily a post Second World War exposure agent ruling them out for the early cancer effects. No viral agent has been identified to occur and expand in parallel to these cancer patterns. It is widely recognised as a disease agent of affluent development. Tobacco and alcohol would qualify for this but there is no evidence to link them directly to the child cancers and the emergence patterns.

The sole remaining agent is electromagnetic fields that in terms of domestic, urban and rural development have spread with the electrical reticulation programs in the UK and US, and other developed countries. This appears to have occurred in the correct manner to explain the complex patterns. The average field exposure has increased progressively increased during the 20th century, with initiation taking place prior to the development of the ALL peak and the progressive spread of reticulation progressively exposing more and more families. Initially electric light was the main service, followed by radio and electric irons. In rural areas cooking and heating was provided by fires in stoves and hearths and in urban areas by gas. In the post-war period and all electric home became more and more common. Radio and TV, electric appliances, personal computers, portable phones and mobile phones continue the ongoing increase in exposure to electromagnetic filed and, most recently, the move to more and more RF/MW exposure.

Court-Brown and Hill consider that the data ***"may suggest that a new leukaemogenic agent was introduced"***, into Britain about 1920. An analysis that directly relates the extent of electrification with the 2-4 year old ALL peak would resolve the question robustly.

Since this childhood peak of cALL is now occurring in more and more well developed countries this link to a carcinogenic agent is extremely important and could save millions of infant's lives annually. This it also resolves the issue of the parallel leukaemia and cancer growth over the 1910-1959 period, and the period to the present. It leads to the identification of the disease agent that could well be causing the majority of all cancer in the first period and much of the present cancer. It would also be contributing to the continuing rise of cancer rates after 1959 if its exposure levels are still rising.

6. The mysterious childhood cancer peak for 2-4 year olds:

Through a detailed analysis of the U.S. childhood leukaemia data from the 1920's to the 1960's, an association was found with the extent of homes' electricity reticulation country by country and state by state, Milham and Ossiander (2001).

Milham and Ossiander (2001) proposed the hypothesis that the causal agent for this new childhood cancer peak was the electromagnetic fields in the homes created by electric power domestic reticulation. This explains the time delay between the UK and the US. It also explains the time delay between white and black households in the US. It also explains the Australian situation with the potential to apply country by country and state by state.

The 2-4 year old cALL peak did not exist before domestic electric reticulation occurred and was formed case by case after it did occur. As the proportion of homes connected the new cALL peak mortality rate rose proportionally. The formation of the year-3 peak and rise in leukaemia mortality is confirmed, Figure 21. It went higher and higher over time.

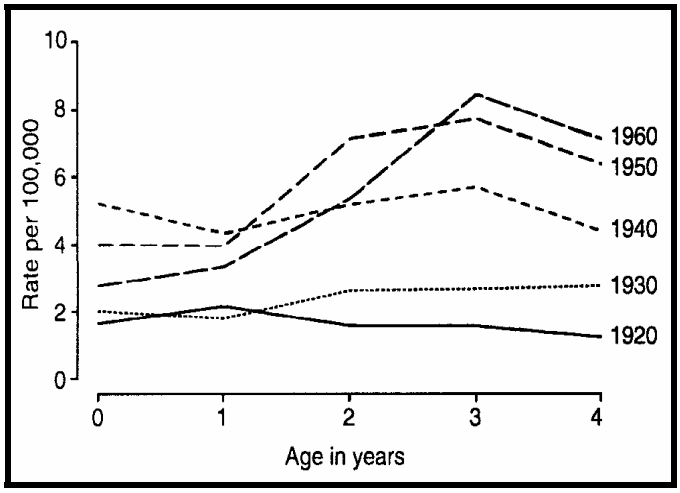

Figure 21: Childhood leukaemia mortality for the United States whites by single years of age 0-4, for each 10 years from 1920, Milham and Ossiander (2001).

By obtaining the data in state by state development of electrical reticulation the early childhood age-specific leukaemia rate plotted as a proportion of the number of homes electrified. For the 1928 to 32 period this is in Figure 22 and the period 1949-52 in Figure 23.

The early period, Figure 22, shows the initial absence of the 2-4 year peak but a progressive increase in the early childhood leukaemia rate with increasing percentage of electrical reticulation.

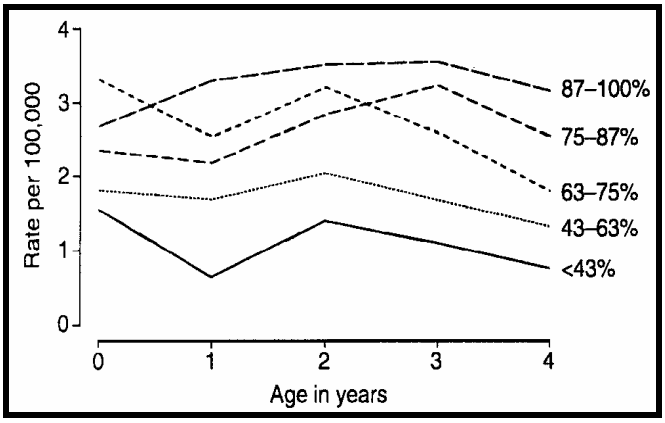

Figure 22: Childhood leukaemia mortality rates for all races 1928-32, by percent of residential electrification and age of death, Milham and Ossiander (2001).

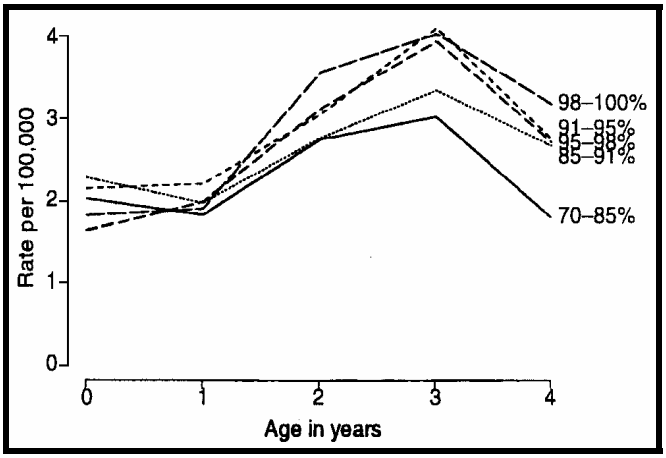

Figure 23: Childhood leukaemia mortality rates for all races 1949-51, by percent of residential electrification and age of death, Milham and Ossiander (2001).

Figure 23 shows that the 2-4 year old peak is well developed in the 1949-51 data and there remains a gradient with higher leukaemia mortality rates with the increasing proportion of residential electric reticulation. This is direct, robust, confirmation of the hypothesis. The early childhood ALL leukaemia and all leukaemia mortality is attributable to the electromagnetic fields in homes produced by electrical reticulation.

Milham and Ossiander state that worldwide occurrence of this peak of childhood leukaemia follows the introduction of electrification. For example, Ramot and McGrath (1982) found a dramatic shift from childhood lymphoma to leukaemia (ALL) that occurred in the Arab population in the Gaza Strip after the introduction of electric power reticulation to homes. Milham and Ossiander (2001) state:

"The authors conclude the childhood leukaemia peak of common acute lymphoblastic leukaemia (cALL) is attributable to residential electrification. 75% of childhood cALL and 60 % of all childhood leukaemia may be preventable."

This means that the all early childhood leukaemia (<5 years) increase from 1900 to 1995, from less than 10 per million to more than 77 per million in 1995, an increase by a factor of 7.7, a factor of 4.6 is attributable to household EMF exposures. For cALL the early childhood incidence has risen from about 7 per million in 1900 to around 70 per million in the SEER data for white children in the US in 1995. This factor of 10 increase has a factor of 7.5 attributed to household 50/60 Hz fields.

7. Identified biological mechanism:

It is not necessary to identify a biological mechanism for classifying a causal effect, Hill (1965). However, it is helpful to strengthen the classification beyond doubt if a plausible biological mechanism is identified and supported by sound science.

Reduced melatonin from 50/60 Hz EMF exposure is the core biological mechanism. Section 2.6 above documents multiple independent studies confirming that this is an established biological effect of 50/60 Hz EMF exposure. Melatonin is a highly potent free radical scavenger and a primary regulator of the competency of the immune system, Reiter and Robinson (1995). Hence agents that reduce melatonin cause enhanced rates of DNA strand breakage and reduced immune system repair efficiency. Electrification of homes produces more light-at-night and higher ELF oscillating electromagnetic fields, both of which are proven to reduce melatonin. Normal household light-at-night delays the onset of sleep. People still sleep in the dark but in electromagnetic fields that also reduce melatonin during sleep.

Because the melatonin/serotonin balance is the primary circadian regulator, the daily awake/sleep, metabolic, respiratory, cardiac and activity cycle is modulated though melatonin and serotonin receptors in all our vital organs, especially the brain, hypothalamus, central nervous system, lungs, heart, reproductive organs and fetus. The mother's melatonin passes through the placenta to the fetus in her womb regulating the daily cycle of the fetus and protecting the fetus from oxidative free radical damage. Reducing mother's nocturnal melatonin will increase the risk of fetal genetic and immune system damage.

Cancer develops in three main stages, initiation, promotion and progression, Weinstein (1988). Cancer development usually takes decades. In very young children the cancer development rate is much faster because their cell cycle is much quicker, their immune system is undeveloped and their melatonin production is very low. Cancer can be initiated in the fetus in utero. This is likely to be the case for early childhood ALL and AML. The promotion phase can commence in utero and continue after birth if the exposure to the toxic agent continues. For EMF it does. The rapid cancer development produces some leukaemia case in the 1st year of life, with the rate continuing to rise to peak in years 3 to 4.

Infante-Rivard (1995) noted that some of the highest ELF exposed mothers were those using industrial sewing machines, Sobel et al. (1995). Since molecular biology had showed that disruption of the HRX gene at 11q23 was related to an in-utero event that could cause infant leukaemia, Dr Infante-Rivard decided to investigate the incidence of ALL in sewing machine workers in Spain. From 128 cases of ALL they found a highly significantly elevated Odds Ratio for pregnant women working at home on sewing machines, OR = 7.0, 95%CI: 1.59-30.79. This was adjusted to OR = 5.78, 95%CI: 1.27-26.25 using household income and mother's education. Note that the household income is related to ELF fields from wiring and appliances. For those working in industry during pregancy, OR = 4.2, 95%CI: 1.0-17.7.

Three more recent epidemiological studies confirm this biological mechanism by finding that household EMF and EMR exposures elevate and significantly elevate cALL.

Hatch et al. (1998) found that pregnant mothers who used electric blankets or electric heating pads during their pregnancies had significantly elevated incidence of children with cALL, OR = 1.59, 95%CI: 1.11-2.29, and OR = 1.46, 95%CI: 1.10-1.98, respectively. Hatch et al. also found that the small children's EMF/EMR exposure from the TV produced dose-response increases in cALL with distance from the TV and with hours per day of watching TV. Being less than 6 ft and more than 6 hours, OR = 4.67, 95%CI: 1.64-13.36. For video games connected to the TV for an hour or more a day, OR = 1.87, 95%CI: 1.13-3.10. This confirms the early initiation during pregnancy and the advancement with EMF/EMR exposures after birth.

This was independently confirmed by Green et al. (1999). Green et al. (1999) found a dose-response for all leukaemia and for ALL for children in Ontario with measured average residential magnetic fields. All leukaemia was doubled from 0.5 mG average fields compared with <0.3 mG, OR = 2.0, 95%CI: 0.6-6.8. For 1 mG it was significantly 4-times higher, OR = 4.0, 95%CI: 1.1-14.4. This confirms that the higher the domestic EMF fields the higher the ALL and all leukaemia incidence rate.

A study involving careful household magnetic field measurements in relation to childhood cancer incidence in New Zealand, found that electric blanket use by the child elevated a number of cancers. For leukaemia, OR = 2.2, 95%CI: 0.7-6.4; for CNS cancers OR = 1.6, 95%CI: 0.4-7.1 and for other solid cancers, OR = 2.4, 95%CI: 1.0-6.1. For the leukaemia risk related to the child's bedroom magnetic fields, for those ≥2 mG compared with the those with <1 mG, the adjusted OR = 12.0, 95%CI: 1.1-137. The similar figure in relation to dayroom measured magnetic fields was OR = 5.2, 95%CI: 0.9-30.8, Dockerty et al. (1998). When the readings were combined into a time-weighted average exposure, using the <1 mG as the reference (OR = 1.0), a dose-response increase in childhood leukaemia incidence was found. For 1mG - <2 mG, adjusted OR = 1.5, 95%CI: 0.3-7.2. For ≥2 mG the adjusted OR = 3.5, 95%CI: 0.5-23.7.

Hence the biological mechanism is supported by independent occupational and residential epidemiological studies showing that both the pregnant mother and the young children exposed to domestic EMF/EMR exposures induces significant increases in leukaemia and common Acute Lymphoblastic Leukaemia (cALL).

8. Implications for recent and current epidemiological studies:

8.1 Background EMF and cancer rates:

Milham and Ossiander link the early childhood cALL peak to electromagnetic fields of less than 1 mG in homes. The low level is estimated because in rural homes when the electric power lines were introduced it was primarily used for the radio, lighting and ironing, not for heating and cooking. This shows that the initial fields were likely to be lower than 0.1 mG because of the very small current loads in the early homes where the childhood peak cancer was first observed. Current domestic fields, e.g. from the Canadian survey, range from 0.62 to 1.9 mG, an increase of about 6 to 19 times since 1910. This range covers the estimated residential childhood cancer increase range (7 to 10 times).

Milham and Ossiander note that modern studies are limited by the low level EMR exposed, cancer elevated, reference groups. No one is unexposed and residential exposures <0.3 mG have already elevated childhood leukaemia and cALL by factors of 7 to 14. Assuming an elevation factor of 10 for cALL, if the background cALL rate for <0.3

mG was 10 times smaller, then this ratio would be 10 times larger (OR = 20.0) and it would become highly significant. For the 1 mG threshold the Odds Ratio would rise to OR = 40.

8.2 Cancer prevention principles:

In considering cancer prevention, Weinstein (1988a) states: ***"It is obvious that the simplest approach to cancer prevention is to avoid exposure to causative agents, whether they be tumor initiators, promoters or agents that enhance progression of cells to increasing degrees of malignancy. On the other hand, this simple approach will not always be feasible, either because the causative agent cannot be readily removed from the environment, the precise agent is not known with certainty or individuals have already suffered significant exposure".***

With electromagnetic fields avoidance is not possible but massive reductions is possible. Domestic magnetic fields range from <0.2 mG to more and 4 mG, Deadman et al. (1999), a range of over 20. Hence a reduction of a factor of 5 to 10 is feasible and practical, reducing the cancer risk accordingly. The causative agent is now identified as domestic electromagnetic fields, enhanced by powerlines and occupational exposures. The present strongest block is the attitude of authorities that continue to deny the existence of the strong causative relationship between EMF and childhood and adult cancer so that preventative measures that are available are not applied. Hence the avoidable illness and death, that has grown and continued for over 90 years, continues to damage and kill innocent and valuable people. For a massive number of people it is already too late. Now is the time to accept the scientific evidence of risk and set in place strategies to significantly reduce the risks.

8.3 Recent reviews:

The link between electromagnetic fields and leukaemia is overwhelmingly supported by many epidemiological studies. NIEHS (1999) found that since the early 1980's about 100 occupational studies and 40 residential epidemiological studies of the EMF-cancer association had been published. Of the approximately 500 separate risk ratios published in these studies, six are elevated for every one that is reduced, Milham and Ossiander (2001). A meta-analysis of 16 childhood leukaemia studies, Wartenberg (1998), concludes that:

"the data provide relatively strong and consistent support for a relatively weak elevated risk of leukaemia for children living in proximity to power lines".

A 1999 review on the World Health Organization Bulletin, Angelillo and Villari (1999) concludes from a meta analysis that for wiring configuration codes the pooled relative risk is RR = 1.46, 95%CI: 1.05-2.04, p=0.024. For measured 24 hr average magnetic fields the pooled relative risk is RR = 1.59, 95%CI: 1.14-2.22, p=0.006. They concluded that:

"enough evidence exists to conclude that dismissing concerns about residential EMFs and childhood leukaemia is unwarranted".

A pooled analysis found for children exposed to 4 mG or more, RR = 2.00, 95%CI: 1.27-3.13, p = 0.002. They conclude that this highly significant result ***"is unlikely to be due to random variability",*** Ahlbom et al. (2000).

Combining all the studies the results show a dose-response increase, 1 to <2mG, RR = 1.08 (0.88-1.32), 2 mg to <4 mG, RR = 1.12 (0.84-1.51), ≥4mG, RR = 2.08 (1.30-3.33). After adjusting for age, sex, car exhausts, etc. ≥4mG, RR = 3.24 (1.22-8.63).

None of these reviews recognized that the background EMF related cancer rates were already highly elevated. All of these figures use the reference cancer rate level of people exposed to <1mG, for which we have already seen is significantly elevated by residential and other ubiquitous EMF exposures. Thus these rate ratios are gross underestimates of the actual effects and the levels of significance are very much higher. Hence the conclusions should be very much stronger.

8.4 Childhood cancer conclusions:

All of these recent reviews find significant increases in childhood leukaemia from domestic electromagnetic fields and from high voltage power lines. Their results must be seen against the already significantly raised childhood cancer in the community because of the residential, suburban and urban exposures to electromagnetic fields. In addition there are now more than 11 studies showing dose-response increases in childhood leukaemia as a function of exposure to EMF. This is overwhelming evidence of a causal relationship between extremely low intensity EMF exposure and childhood leukaemia and cALL. This very strongly supports the Milham and Ossiander conclusion that residential fields have significantly attributed to childhood leukaemia, especially acute lymphoblastic leukaemia and all childhood leukaemia.

8.5 Historical rises in adult cancers:

The occupational studies also provide strong and consistent evidence that EMF occupational exposure is causally related to increases in leukaemia, breast and brain tumour. This also shows that the progressive elevation of household electromagnetic fields has contributed to a significant amount of the increase in leukaemia, breast, brain tumour and other cancers in the adult population over the period from about 1920 onwards, Figure 18 and Figure 24.

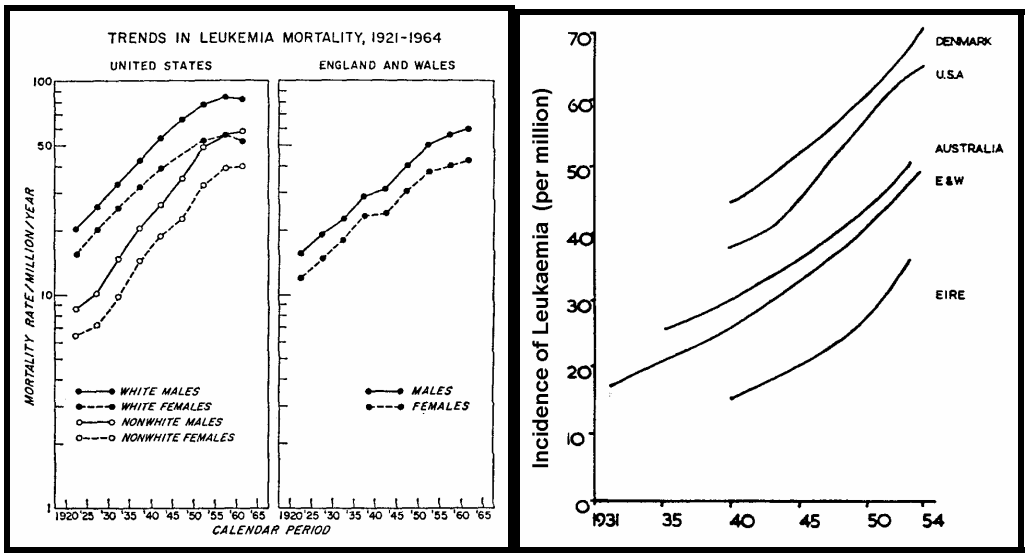

Figure 24: Historical trends in leukaemia mortality for several groups and countries, Fraumeni, and Miller (1966), left, and Burnet (1958), right.

The historical rise in childhood leukaemia is paralleled by the same exponential rises in adult leukaemia in all developed countries given in Figure 24. A high proportion of this increase is reasonably also attributable to the progressive increase in household electromagnetic fields following the introduction of domestic electric reticulation. This is supported by the many occupational studies showing significantly elevated adult leukaemia and brain tumor, as well as many other cancers.

8.6 RF exposures add to the residential exposures:

The initial rises are during periods of electrification of homes, businesses, towns and cities. In the post war period this continued more and more into rural areas. Over this period there was the addition of radio and TV signals and radar exposing people around airports. Military studies such as Robinette et al, (1980) and Szmigieski (1996) show significant increases in all cancer with radar exposed personnel and highly significant increases in leukaemia. Leukaemia is also elevated in residents living in the vicinity of Radio/TV towers, Hocking et al. (1996), Dolk et al. (1997a,b) and Michelozzi (1998).

In the post-Second World War period continued electrification of homes occurred as the ideal of an "all electric" home was dominated. During this period too, the growing public exposures to radio, TV and radar signals grew significantly as the electronic media rapidly expand. In the 1990's mobile telephone systems and personal usage has significantly increased personal exposures to microwaves which are also genotoxic shown from over 20 published studies, including several studies for mobile phone radiation itself.

Hence as for childhood leukaemia and other cancers, the reference groups for occupational studies are pre-exposed groups whose leukaemia and cancer rates are already elevated by over a factor of 5 to 7 between the 1920's and 1960's. With further rises of cancer after from the 1960's to 1990's this factor is somewhat even higher, at least double, i.e. giving an overall increase of 10 to 14. Comparing current occupational cancer rates with pre-1920 cancer rates gives extremely high and extremely significant increases in relative risk.

8.7 Adjustments for the elevated background exposures and cancers:

It is currently impossible to compare occupational cancer rates with a "unexposed" contemporary reference group. It is shown above that the domestic EMF exposure increased the cancer from 7 to 10 times over 95 years. To illustrate the under-estimate of health effects examples are given by using only 3 to 5 times risen cancer in the average population used as the reference "unexposed" group. Then estimates of the relative cancer rates in recent studies can be adjusted to assess the impact of these assumptions.

For example in Savitz and Loomis (1995) there were 439 leukaemia/lymphomas in the US utility worker study when 532.4 were expected, giving SMR = 0.82, 95%CI 0.75-0.91. Assuming that the expected 1920 leukaemia/lymphoma rate is 5 times less than the expected rate in 1995, then the expected rate would be 106.5. This would give an SMR = 4.12, 95%CI: 3.34-5.09, $p<0.0000001$. If the appropriate elevation was a factor of 3 then SMR = 2.47, 95%CI: 2.08-2.94, $p<0.0000001$

Similar elevations in childhood leukaemia would also occur from being near high voltage powerlines for a good proportion of the day. For example, Verkasalo et al. (1993) found increased risks of CNS, leukaemia and lymphoma cancer in children living near high

voltage power lines. For all cancer and average magnetic field of 0.1 to 1.9 mG gave SIR = 0.94, 95%CI: 0.79-1.1, and for ≥ 2mG, SIR = 1.5, 95%CI: 0.74-2.7. If the expected reference cancer rate was 3-times less then these become, SIR = 2.82, 95%CI: 2.01-3.95, p=0.000002 and SIR = 4.47, 95%CI: 1.12-17.78, p=0.018. These adjustments show how seriously these and almost all other studies underestimate the elevation and significance of the increased cancer by using a pre-exposed and EMF elevated cancer group as the control group.

9. Other serious EMF/ELF health effects:

9.1 Other cancers:

Many other cancers are associated with ELF resident and occupation exposures, including elevated breast cancer, testicular cancer, and childhood brain tumor from electric blanket use, Vena et al. (1994), Verreault et al. (1990), Preston-Martin et al. (1996). A totally independent team of Swedish medical scientists, reviewed almost 100 epidemiological papers published up to July 1994, Hardell et al. (1995). They state:

We concluded that there are possible associations between:

(i) an increased risk of leukaemia in children and the existence of, or distance to, power lines in the vicinity of their residence,
(ii) an increased risk of chronic lymphatic leukaemia and occupational exposure to low frequency electromagnetic fields and,
(iii) an increased risk of breast cancer, malignant melanoma of the skin, nervous system tumours, non-Hodgkin lymphoma, acute lymphatic leukaemia or acute myeloid leukaemia and certain occupations.

9.2 Breast Cancer and EMF/EMR exposures:

Both males and females exposed to electromagnetic fields and radiation have shown increased breast cancer in multiple studies, Tables 3 and 4.

Table 3: Male breast cancer associated with EMR exposure.

Group	SIR/RR/OR	95%CI(p-value)	Reference
Electrical Occupations	OR = 1.8	1.0-3.7	Demers et al. (1991)
Electricians, telephone linemen, electric power workers.	OR = 6.0	1.7-21	"
Radio communication workers.	OR = 2.9	0.8-10	"
Electronic workers	Increased Risk		Guenel et al. (1993)
Swedish Railway workers	RR = 4.9	1.6-11.8	Floderus, Tornqvist and Stenhund (1994)

There are now more female breast cancer studies.

Table 4: Female Breast cancer associated with EMR exposure

Group	SIR/RR/OR	95%CI/(p-value)	Reference
Radio-telegraph operators	SIR=1.5		Tynes et al. (1996)
Electrical Engineers	OR = 1.73	0.92-3.29	Loomis, Savitz and Ananth (1994)
Electrical technicians	OR = 1.28	0.79-2.07	"
Telephone installers repairers, line work	OR = 2.12	1.17-4.02	"
Electrical Workers	OR = 1.38	1.04-1.89	"
Radiofrequency EMR			
Low Exp. White	OR = 1.15	p<0.05	Cantor et al. (1995)
High Exp. White	OR = 1.14	p<0.05	"
Low Exp. Black	OR = 1.23	p<0.05	"
High Exp. Black	OR = 1.34	p<0.05	"
High Exposure ELF	OR = 1.43	0.99-2.09	Coogan et al. (1996)
Pre-menopausal	OR = 1.98	1.04-3.78	"
Post-menopausal	OR = 1.38	0.82-2.17	"
Computer equipment operators, high Exp.	OR =1.80	1.04-3.12	[Trend p = 0.06]
Electric Blankets, heavy use, pre-menopausal	RR = 1.43	0.94-2.17	Vena et al. (1994)
All women	OR = 1.45	1.08-1.94	"
> 2 years of use	OR = 1.60	1.15-2.22	"
> 5 years of use	OR = 1.56	1.09-2.25	"
Positive Estrogen receptor aged 45 - 55 years.	RR = 1.12	0.78-1.43	Gammon et al. (1998)
Powerline, Sweden			
> 0.2 μT, men	RR = 2.1	0.3-14.1	Feychting et al. (1998)
>0.2 μT, women < 50 yr	RR = 1.8	0.7-4.4	"
>0.01 μT, women with + estrogen receptor	RR = 1.6	0.6-4.1	"
>0.01 μT, women with + estrogen receptor,	RR = 7.4	1.0-178.1	"

aged < 60 years			
Occupational Exposure, Norway			
Total Sample, 2 methods:			
Cumulative Hr of Work	**RR = 1.14**	**1.1-1.19**	**Kliukiene et al. (1999)**
Job Matrix estimate	**RR = 1.08**	**1.01-1.16**	**"**
Aged <50yrs (Hours)	**RR = 1.20**	**1.11-1.29**	**"**
Aged 50 yrs (Matrix)	**RR = 1.12**	**0.98-1.28**	**"**
Occupational Exposure, Sweden			
Recent reading >0.25μT			
Total Sample	**RR = 1.0**	**0.6-1.7**	**Forssen et al. (2000)**
Aged < 50 yrs	**RR = 1.5**	**0.6-3.5**	**"**
Aged<50yr, ER+	**RR = 3.2**	**0.5-18.9**	**"**

There is consistent and significant increases in Breast Cancer in EMF/EMR exposed populations of women and men. Increased risk is under-estimated by the given Relative Risks. Women under 50 years of age have more EMR induced breast cancer than other women in the same age range. When women are older than 50 the background rate of breast cancer increases, reducing the relative differences in the EMR exposed group. EMR is especially active in initiating and/or accelerating estrogen receptor positive breast cancer.

These studies also strongly confirm that EMF/ELF fields are genotoxic and carcinogenic.

Therefore the fields need to be strongly minimized to reduce the serious health effects.

10. Dose-Response Relationships for ELF effects:

Dose-response relationships are strong evidence of causal relationships, Hill (1965), Beale et al. (1997). Beale et al. found dose-response relationships between resident measured 50 Hz magnet field exposures to high voltage power lines in Auckland, New Zealand, and some psychological and mental health effects.

10.1 Neurological effects:

The brain as an active ELF electromagnetic organ with clear evidence of interference through resonant absorption, altered calcium ions and EEG patterns. In residential situations these effects are ever present, subtle and not appreciated, even though we now know they are highly significant. Their effects have merged with the background and people are left wondering about all the possible causes of many rising neurological health effects. Occupational studies show significantly elevated neurological diseases in workers chronically exposed to low intensity, but higher than average, ELF electromagnetic fields.

These too are against pre-elevated background levels of disease associated with residential fields. Evidence of acute effects gives strong confirmation of the link to the fields.

Graham and Cook (1999) carried out a double-blind experiment on 24 healthy young men who were asked to sleep in a facility that had or not had exposure to a 283 mG 60 Hz field. One exposure regime used intermittent fields, one used continuous fields and one used no field. Multiple EEG measurements were taken to monitor the sleep activity. They observed significant alterations in the sleep EEG with intermittent 60 Hz exposures, including less total sleep time (p=0.003), more waking time (p=0.002), lower sleep efficiency (p=0.003), less REM sleep (p=0.018) and much longer REM latency (p=0.04).

This shows that the healthy human brain detects and responses to high intensity ELF fields with altered EEG and sleep efficiency. This supports the hypothesis that large populations who are chronically exposed to much lower field intensities will also have neurological effects, including reduced melatonin. This is predicted to produce neurological disease and death.

Sleep Disturbance:

Sleep disruption occurs in a dose-response manner with a threshold below 0.1nW/cm^2. ie. very close to zero, Figure 25.

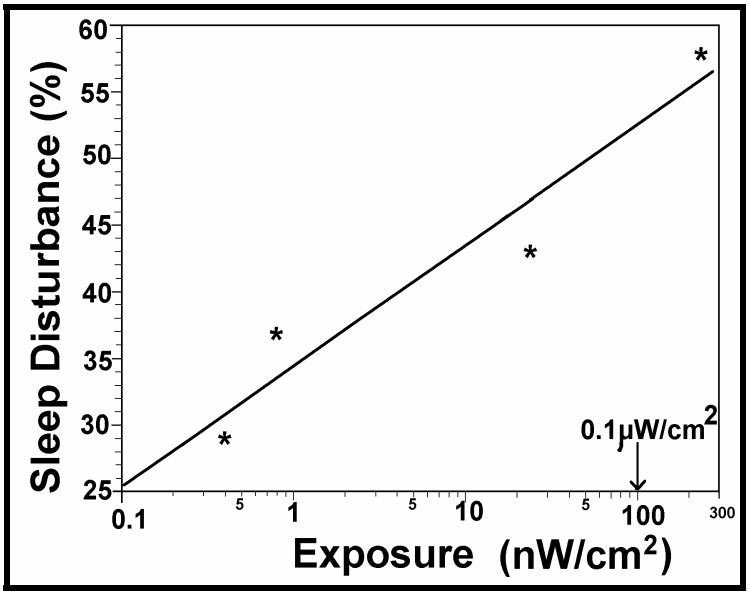

Figure 25: Dose-response relationship for Sleep Disturbance at Schwarzenburg with exposure in nW/cm^2. Note: 1nW/cm^2= 0.001μW/cm^2

Occupational studies show that ELF fields do damage the brain and produce significant and dose-response increases in serious neurological health effects. A Danish study reports a dose-response increase in Multiple Sclerosis in electric utility workers, Figure 26.

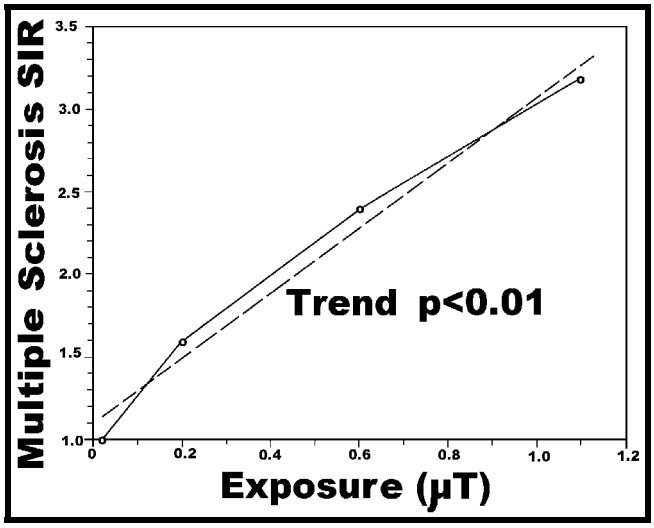

Figure 26: Dose response relationship of Multiple Sclerosis for a small group (N=15) of men occupationally exposed to typical peak magnetic fields in a Danish utility company, Johansen et al. (1999).

These results are supported by two independent studies. Deapen and Henderson (1986) found that electrically related occupation had significantly increased Amyotrophic Lateral Sclerosis (ALS) disease, OR = 3.8, 95%CI: 1.4-13.0. Davanipour et al. also found dose-response increased ALS in electrical occupations for the 75th percentile and total exposure OR = 7.5, 95%CI: 1.4-38.1, and average exposure OR = 5.5, 95%CI: 1.3-22.5.

In a larger study of Danish utility workers, Johansen (2000) found dose-response increases in Senile dementia, Motor Neuron Disease, Pre-senility, and Epilepsy.

10.2 Suicide in U.S. Electric Utility Workers:

A very large study of men working in U.S. electric utility companies included monitoring time weighted average ELF exposures of 2842 people and the identification of 536 deaths from suicide and 5348 controls. For recent exposure and 1 to 5 years of recent exposure there were significant dose-response relationships with cumulative exposure to electromagnetic fields. The recent exposure result is shown in Figure 27.

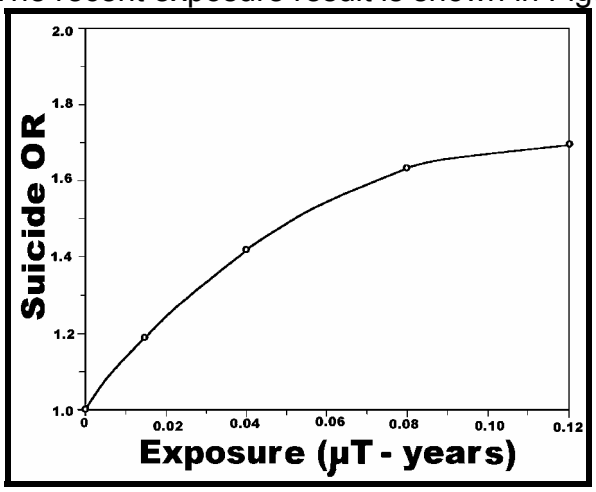

Figure 27: Dose response relationship of Suicide after recent monitored exposure to cumulative 50 Hz magnetic fields for men <50 years, adjusted for work, class, location and exposure to sunlight and solvents, Van Wijngaarden et al. (2000).

This confirms the results of Reichmanis et al. (1979) and Perry et al. (1981) who found a highly significant association between suicide and the exposure to magnetic fields from High Voltage Powerlines when above 0.4 mG. Baris and Armstrong (1990) also found RF exposure shows a significant 53% increase in suicide for British Radio and Radar Mechanics, and 156 % increase for Telegraph radio operators.

These studies are also supported by several studies finding significant increases in clinical depression in people living the vicinity of high voltage power lines, Dowson et al. (1988), Perry and Pearl (1988), Perry et al. (1989), Verkasalo et al. (1997) and Beale et al. (1997).

An example of neurological and hematological effects from occupational EMF exposure:

A survey of neurovegetative and hematologic disorders was conducted in a population (n = 13) exposed occupationally to environmental electromagnetic fields; the population was matched with 13 control subjects. The exposed subjects worked at least 8 hr/day for 1-5 yr in premises located above transformers and high-tension cables, and the subjects were submitted to low-frequency electromagnetic fields (i.e., 50 Hz) of 2mG to 66 mG. The subjects were matched with respect to socioeconomic category, sex, and age with a control population of subjects that worked in premises outside of the immediate vicinity of transformers or high-tension cables.

The exposed population had a significant increase in degree of certain neurovegetative disorders (i.e., physical fatigue, psychical asthenia, lipothymia, decreased libido, melancholy, depressive tendency, and irritability). In addition, the population experienced a significant fall in total lymphocytes and CD4, CD3, and CD2 lymphocytes, as well as a rise in NK cells. Leukopenia and neutropenia were also observed in two persons permanently exposed to doses of 12-66 mG. The disorders disappeared when exposure stopped, and they reappeared on re-exposure. This shows a causal effect.

Non-linear response for neurological effects at extremely low exposure levels are evident in the three studies presented here for sleep disturbance, multiple sclerosis and suicide.

10.3 Cardiac Effects:

The heart is also an electromagnetic organ with an electric pulse initiating a cascade of calcium ions that cause the cells in the heart to contract and produce a heart beat every second or so throughout our lives. This is monitored by the electrocardiogram (ECG).

Savitz et al. (1999) found crude dose-responses for Cardiac Arrhythmia related heart disease in U.S. utility workers exposed to measured 60 Hz magnetic fields. They also observed a significant linear dose-response in heart attack mortality, Figure 28.

Ptitsyna et al. (1996) found that electric train drivers in Russia, exposed to above average ULF fields determined from an exposure monitoring program, had significantly higher mortality from coronary heart disease than diesel train drivers and the general population. Sastre, Cook and Graham (1998) found that 60 Hz magnetic fields significantly reduced Heart Rate Variability, a measure of the autonomic nervous system that regulates the neuronal and cardiovascular reflexes. Reduced HRV is a known risk factor for cardiac

disease. Pfluger and Minder (1996) found that electric train drivers in Switzerland had significantly reduced melatonin.

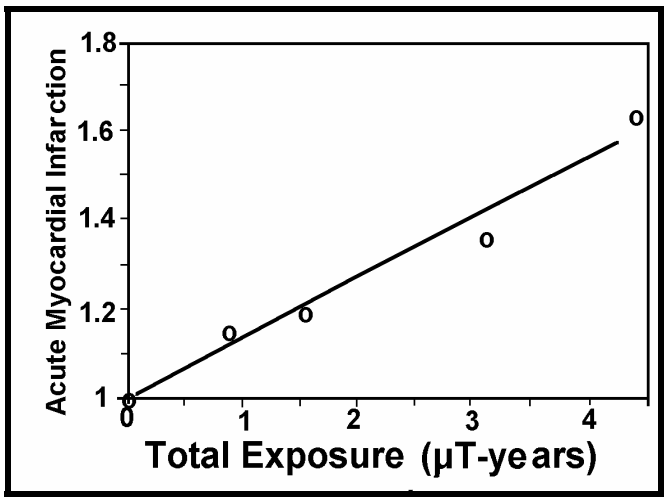

Figure 28: Acute Myocardial Infarction as a function of cumulative exposure to 60 Hz fields in U.S. electricity utility workers, Savitz et al. (1999).

Hence there is very strong evidence of cardiac effects from 50/60 Hz exposures.

9.4 Cancer effects:

The U.S. Utility study also found a dose-response increase of brain tumors in 60 Hz field exposed workers, Figure 29.

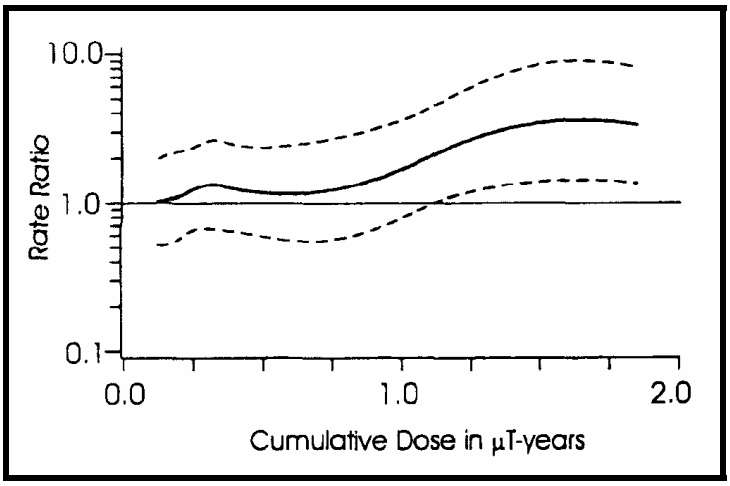

Figure 29: U.S. electric utility workers dose-response increase in brain tumours for occupational exposure for 2 to 10 years in the past, Savitz et al. (2000).

Minder and Pfluger (2001) found that the Swiss railway line engineers had significantly higher rates of leukaemia, RR = 2.4, 95%CI: 1.0-6.1, with a significant dose-response with cumulative exposure. Shunting yard engineers had significant higher brain tumours, RR = 5.1, 95%CI: 1.2-21.2.

There are over 75 studies showing that EMR across the spectrum increases the incidence of brain tumour, 48 showing significant increases and 16 showing dose-response increases. The dose-response relationships are summarized in Table 5.

Table 5: Studies showing dose-response relationships for EMR exposure and brain tumor:

- Denver, United States, power lines — Wertheimer and Leeper (1979)

Childhood)	Birth Address	RR = 1.83, p=0.04	n=22
CNS tumors)	Death Address	RR = 1.76, p=0.017	n=30

Dose related for children living at same address.

- Electrical Occupations in Maryland, U.S. — Lin et al. (1987)

	Glioma/Astrocytoma		Other Brain Tumors	
Definite Exposure	2.15 (1.10-4.06)	n = 27	1.54 (0.68-3.38)	n = 15
Probable exposure	1.95 (0.94-3.91)	n = 21	1.30 (0.60-2.78)	n = 19
Possible exposure	1.44 (1.00-1.95	n =128	0.94 (0.68-1.31)	n = 87
No exposure	1.0	n =323	1.0	n =286
	Trend p<0.01		Trend p<0.05	

- Eastern U.S. Electronic Industries — Thomas et al. (1987)

Astrocytic brain tumours RR=4.9 (1.9-13.2)

		Duration Employed (yr)			
		Unexposed	<5	5-19	≥ 20
	RR	1.0	3.3	7.6	10.4
Solder fume adjusted	RR	1.0	1.65	3.8	5.2

(trend p<0.05)

- East Texas, Males Glioma — Speers, Dobbins and Miller (1988) n=202

Transportation, communication and utilities industries	OR = 2.26 (1.18-4.32)	
Electricity or electromagnetic fields	OR = 3.94 (1.52-10.20)	Trend: p<0.01

- Los Angeles County, Occupational exposure — Preston-Martin et al.(1989)

High exposure to electric and magnetic fields n=272

Glioma	OR=1.8 (0.8-4.3)	p for trend =0.05
Astrocytoma, >5 years empl.	OR=4.4 (1.2-15.6)	

- Los Angeles Country, electrical industry — Mack et al. (1991) n=272

Astrocytomas RR = 10.3 (1.3-80.8) trend, p=0.01

- San Francisco, Sutra Tower (FM/TV) — Selvin et al. (1992)

Children < 21 yrs RR = 2.87, (1.30-6.32), p<0.01 n=35

Comparing <4.5km and >4.5 km Trend p <0.001

- Canada, Provincial Residential Electric Consumption (REC) — Kraut et al. (1994)

Childhood brain cancer significantly increases with REC in a dose-response manner.

- U.S. Electrical Workers — Savitiz and Loomis (1995)

Mortality Dose-response OR = 1.94 per μT-yr

- U.S. Computer exposures — Beall et al. (1996)

Computer Programmers (>10 yrs)	OR = 2.8 (1.1-7.0)	Trend p = 0.04
Engineering/Technical (>10 yrs)	OR = 1.7 (1.0-3.0)	Trend p = 0.07
Glioma, All subjects, 5yr progrm.	OR = 3.9 (1.2-12.4)	Trend p = 0.08

- United States, office workers — Milham (1996)

Transformer fields	SIR = 389 (156-801)	N=410
		Exposure trend p=0.0034
		Employment period trend p<0.05

- Ontario Hydro male employees (Adjusted ORs) — Miller at al. (1996)

Brain Tumour	Mod. Field	OR = 1.27 (0.32-5.41)	
	High Field	OR = 1.33 (0.52 -10.8)	Both show trends.
Benign Brain Tumour	Mod. Field	OR = 5.38 (0.42-69.3)	
	High Field	OR = 5.64 (0.3-105)	

- French electric utility workers — Guenel et al. (1996)

Allowing for a 10 year latency, V/m-yrs

<166	OR = 1.0	n = 22
166-229	OR = 1.67 (0.67-4.19)	n = 14
230-294	OR = 1.79 (0.60-5.36)	n = 9
>294	OR = 2.15 (0.63-7.26)	n = 7

- Norway — Tynes and Haldorsen (1997)

Children	<0.05μT	0.05-<0.14μT	>0.14μT	n=10
RR =	1.0	2.6 (0.5-12.0)	2.3 (0.8-6.6)	p=0.07

- United States Electric Utility Workers — Savitz et al. (2000)

A cumulative exposure to ELF fields in the past 2-10 years, shown in Figure 29 above.

- Cell phone users in Denmark — Johansen et al. (2001)

Duration of digital subscription		<1 yr	1-2yrs	≥3 yrs
Relative to reference group	SIR	0.7	0.9	1.2
Relative to <1 yr group	RR	1.0	1.29	1.71

- Canadian Electrical Workers — Villeneuve et al.(2002)

Highest average exposure	<0.3μT	≥0.3μT	≥0.6μT
All Brain Cancer OR(adj)	1.0	1.12 (0.83-1.51)	1.33 (0.75-2.36)
Glioblastoma multiforme	1.0	1.48 (0.89-2.47)	5.36 (1.16-24.78)
Other Brain Cancers	1.0	1.10 (0.58-2.09)	1.58 (0.56-4.50)

Average exposure	<0.3μT	≥0.3μT-<0.6μT	≥0.6μT
All Brain Cancer OR(adj)	1.0	1.13 (0.72-1.79)	1.50 (0.69-3.28)
Glioblastoma multiforme	1.0	1.99 (0.83-4.81)	12.59 (1.50-105.6)

- Finland cellphone users — Auvinen et al. (2002)

	Phone usage								Increase in OR	
	Ever		<1 Year		1-2 Years		>2 Years		Per Year	
Cancer Type	OR	95%CI	OR	95%CI	OR	95%CI	OR	95%CI	OR	95%CI
Analogue phone										
All Brain tumors	1.6*	1.1-2.3	1.6	0.7-3.6	1.5	0.9-2.8	1.6	0.9-2.8	1.2*	1.0-1.3
Glioma	2.1*	1.3-3.4	1.6	0.5-5.1	2.4*	1.2-5.1	2.0	1.0-4.1	1.2*	1.1-1.5
Meningioma	1.5	0.6-3.5	2.3	0.6-9.2	1.6	0.4-6.1	1.0	0.2-4.4	1.0	0.6-1.5
Other Brain tumors	0.9	0.2-2.2	0.7	0.1-6.4	0.6	0.1-2.6	1.4	0.4-4.3	1.1	0.8-1.4
Salivary gland cancer	1.0	0.3-4.0					4.4	0.3-71.6	1.3	0.7-2.5

	Phone usage								Increase in OR	
	Ever		<1 Year		1-2 Years		>2 Years		Per Year	
Cancer Type	OR	95%CI	OR	95%CI	OR	95%CI	OR	95%CI	OR	95%CI
Digital phone										
All Brain Tumors	0.9	0.5-1.5	0.6	0.2-1.6	1.2	0.6-2.3	0.6	0.1-4.5	1.0	0.7-1.5
Other Brain tumors	0.8	0.2-2.7			0.9	0.2-4.0	4.9	0.3-79.0	1.0	0.4-2.3
Salivary gland cancer	1.7	0.2-16.0			5.0	0.3-80.0			1.5	0.2-11.9

This gives overwhelmingly strong evidence that EMR/EMF induces Brain and CNS cancer in children and adults in a causal manner. This further reinforces the conclusion that electromagnetic fields and radiation are carcinogenic.

This is true for young children for brain tumours and leukaemia. Of the many childhood leukaemia studies showing consistent leukaemia increased from ELF electric and magnetic fields exposures at least 11 have shown dose-response relationships. These include Wertheimer and Leeper (1979), Savitz et al. (1988), Coleman et al. (1989), London et al. (1991), Verkasalo et al. (1993), Feychting, Schulgen and Ahlbom (1995), Linet et al. (1997), Dockerty et al. (1999), Green et al. (1999), and Bianchi et al. (2000). The recent integrative summary, Ahlbom et al. (2000), also gives a dose-response. One example of a childhood leukaemia dose-response is given in Figure 30.

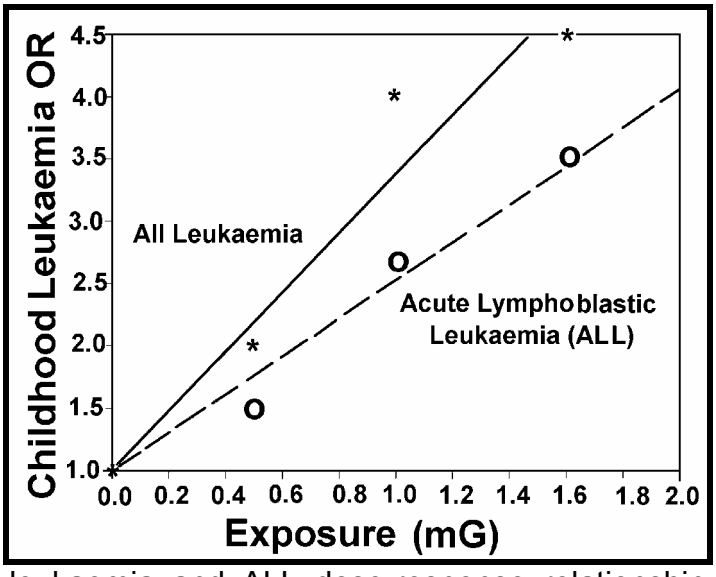

Figure 30: Childhood leukaemia and ALL dose-response relationship in the Canadian Residential related to the measured magnetic fields for the time of diagnosis, Green et al. (1999). For the ALL the trend is highly significant, $p<0.02$ and for all leukaemia, $p<0.05$. Note that the Odds Ratio of OR=1.0 is related to the already elevated background level.

All of these studies under-estimate the effects because the reference control populations are also living in elevated fields from the household wiring which has been proved to significantly elevate cALL by a factor of approximately 7.5 and all childhood leukaemia by a factor of about 4.6.

11. Summary, conclusions and recommendations:

Through over 100 elevated risk ratios, over 40 significantly elevated risk ratios and over 11 dose response relationships, childhood leukaemia is causally related to residential exposures to electromagnetic fields produced by domestic wiring and appliances and significantly elevated by proximity to high voltage powerlines. This is confirmed by the established mechanisms that ELF modulated EMF reduces melatonin and alters the calcium ion homeostasis in cells, and by multiple independent studies showing that 50/60 Hz fields damage chromosomes, break DNA strands and impair the immune system competence.

Residential electric wiring, creating residential electromagnetic fields that are typically somewhat less than 1 mG when the common Acute Lymphoblastic Leukaemia early childhood peak was first produced in the United Kingdom in the 1930's and the United States in the 1940's. This has been assessed to cause at least 60 % of all childhood leukaemia and over 75 % of the cALL. Being proven to be carcinogenic for cALL, household electric fields, through a small but ubiquitous reduction in nocturnal melatonin, cause a wide range of cancers, cardiac, neurological and reproductive disease and death. All of these are confirmed by many occupational studies and dose-response relationships with a near zero threshold for artificial, humanly generated, electromagnetic fields and radiation.

Those diseases that have shown a progressive and significant increase in the pre-1960 period and continue to do so, are similar to the early childhood ALL and leukaemia and are largely attributable to domestic electromagnetic field exposures, enhanced in recent decades by occupational EMF exposures. This is compounded by significantly elevated and highly genotoxic radiofrequency/microwave exposures from radio and TV transmissions, radars, and the mobile phone system. The EMF attributable increased factors for childhood leukaemia and ALL of 4.6 to 7.5 are likely to be applicable to most of the relevant diseases and mortality.

Hence utility workers in the Substation and maintaining the powerlines are acutely and chronically at risk of serious health effects. People who live or work in the vicinity of the substation or the high voltage line are also significantly at risk, including children who will reside within the zone where the induced magnetic field is around 1 mG or higher. Every person is at risk of neurological effect from living, working or going to school in fields of 0.2 mG or more, a 22 % increase in suicide risk for example, Figure 24. This is a reduced melatonin-related effect and hence is also associated with increased depression and learning difficulties for children. This is especially true for nocturnal exposures because of reduced melatonin. Under these circumstances it is a common practice to set an achievable management guideline that will produce a significant reduction in health effects (but not zero health effects), Table 6, MFE (2000).

Table 6: Environmental Performance Indicators Programme air quality categories.

Category	Measured value	Comment
Action	Exceeds the guideline value	Exceedences of the guideline are a cause for concern and warrant action if they occur on a regular basis.
Alert	Between 66% and 100% of the guideline value	This is a warning level, which can lead to exceedences if trends are not curbed.
Acceptable	Between 33% and 66% of the guideline value	This is a broad category, where maximum values might be of concern in some sensitive locations, but are generally *at a* level that does not warrant dramatic action.
Good	Between 10% and 33% of the guideline value	Peak measurements in this range are unlikely to affect air quality.
Excellent	Less than 10% of the guideline value	Of little concern: if maximum values are less than a 10th of the guideline, average values are likely to be much less.

Having chosen a target guideline, then measures can be taken to aim to progressively move below 10 % of the guideline where the risks are $1/10^{th}$ of the guideline levels of effects. This is termed an "excellent" category. People, including should live and work in "excellent" or at worst "good" environments. Children, who are more vulnerable, should be offered "excellent" protection.

I recommend the target limit chronic mean exposure level for children as 0.2 mG.

School and home environments should be assessed and where possible 90% of room space at head height, especially at the head position when sleeping or in school, should be less than 0.2 mG. Fields produced by the substation and powerlines should not increase the residential, school or working environment above 0.2 mG.

This is not based on 0.2 mG being completely safe. No level of exposure to artificial oscillating fields is safe. This is the same situation that we have for fine particle air pollution. Nature produces very few fine or super fine particles but we produce massive clouds of them through our burning in cars, homes, power plants and factories. The World health organization has looked at dose-response relationships that point to a zero exposure threshold and have concluded that the safe level of fine particles is zero.

Public health protection standards can be set based on the estimated or measured human dose of a given substance with either the no observed adverse effect level (NOAEL) for

that substance or the lowest observed adverse effect level (LOAEL). Then a safety factor is applied in the range 1 to 10,000 depending on the significance of the adverse effect and the extent of the exposure of general and vulnerable populations, the U.K. Royal Commission on Environmental Pollution: setting environmental standards (RCEP (1998)).

For genotoxic substances RCEP (1998) states that it is not possible to demonstrate that there is a threshold dose. This is clearly true for electromagnetic fields and radiation. The safe level of exposure to 50/60 Hz fields is zero.

The role of domestic wiring, high voltage powerlines and substations in increasing childhood cancers was first found in the 1979 study of Drs Nancy Wertheimer and Ed Leeper. In their discussion they state:

"As indicated, cancer cases were found in excess close to the "first span" wires issuing from the transformers. An even stronger trend was found for substations."

Wertheimer and Leeper (1979)

Recommendations:

For 50/60 Hz electromagnetic fields the recommended initial guideline is 1 mG

This recognizes that there are elevated risks at this level from the latest research cited above, for ALL OR= 2.7 and for childhood leukaemia OR = 4.0, Figure 30, Green et al. (1999).

This defines the target threshold for and "excellent" category of mean exposure of 0.1 mG. At this exposure the elevation of the risk childhood leukaemia is 25% and for ALL is 15 %. From the dose-response lines these are compared to and elevation of 240% for childhood leukaemia and 150 % for ALL at 1 mG. Hence a maximum limit value of 0.2 mG is recommended for the school environment. This would maintain the school's exposure to the "good" to "excellent" category.

The desirable level in homes, schools and workplaces is 0.1 mG, the "Excellent" category. The 0.2mG level is in the "Good" category. People should aim to live in the "Good" to "Excellent" categories. This is the level recommended for the school and domestic environments.

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