

“Clean” Pollution: The Hidden Legacy of The Electromagnetic Wave

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Abstract— The near exponential increase in the use of household electric and electronic devices worldwide has subjected humans to a pervasive, yet paradoxically under-appreciated danger, the likes of which they have never before been subjected to in their evolutionary history. While the human frame has built-in defenses to handle the hazards of secondary metabolite chemical toxicants it is completely vulnerable and defenseless against this new threat. This review paper examines the putative role of the electric, magnetic and electromagnetic waves on human physiology and biochemistry at a multitude of levels, ranging from sub-cellular to systemic, and the means whereby these insidious deleterious effects may be ameliorated. EM radiation is a colorless, odorless, tasteless, residue less and invisible - it is thus a 'Clean' form of environmental pollutant.

Index Terms—ALS, Alzheimer’s disease, Electric field, Electromagnetic wave, Leukemia, Magnetic field, Melatonin, Pollution.

I. INTRODUCTION

Electricity pervades human civilization and every indication is that its demographic role will become even more ubiquitous in the near future. The usage of electricity, a monolithic power source, takes on a multitude of disparate and divergent forms ranging from fluorescent lamps, incandescent bulbs, micro wave ovens, MRI machines, electric generators, transformers, washing machines, computers and the pervasive cell phone; furthermore, as developing nations worldwide, which harbor the bulk of the earth’s population, rise in economic power, the percentage of the population using these devices will increase dramatically.

II. OVERVIEW OF THE ELECTROMAGNETIC FIELD

It is not generally appreciated by both the layman and scientists alike that an electric device does not have to be operational and running in order to set up an electric field. For instance, a table lamp plugged into a power outlet will have an electric field along its entire cable length, as a direct consequence of the voltage difference that exists along the cable. Such a static electric field measured in V/m can often take on considerable magnitudes. Some typical values are 180V/m for a stereo receiver, 60 V/m for a color TV, 5V/m for a light bulb all measured at a distance of 30 cm. The cut-off value for safety has been set at 5000V/m. In addition,

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once the device is switched on and electric current starts to flow in the circuit a second confounding factor comes into play – namely a magnetic field is set up by the moving current of electrons. This by itself should not pose a risk: for example, the human body is immersed on a chronic basis in the magnetic field of the Earth and one of no mean magnitude – a full 70 μ T. Most electric devices as commonly used do not even begin to approach this quantitative magnitude. For instance, a fluorescent lamp has a magnetic field strength of 0.5 to 2 μ T at a distance of 30cm, microwave oven 4-8 μ T, which constitute a miniscule fraction of that exerted by the planet. Why then, has there been so much public hysteria and recrimination directed so vociferously against power utilities of the dangers of E.M.F?

Even though field strengths fall off rapidly with distance, and furthermore despite the fact that at 30cm the magnetic fields raised by most domestic gadgets is a 100 times lower than the regulatory limit of 83 μ T at 60 Hz, there is still reason for alarm since, as will be seen, there appears to be no clear-cut threshold for the effects of electromagnetic radiation.

The reason presumably owes to the fact that the earth’s field is a static field, mostly invariant in magnitude on near geologic time scales spanning on the order of a million years. Electric devices on the other hand, operate on a.c current of 50 Hz, which means the associated magnetic field also reverses 50 times a second, in addition to, undergoing a magnitude change 50 times a second; and it is this pulsed magnetic field that evidently accounts for many of the detrimental physiologic effects that have been recorded in the scientific literature. In addition, an oscillating a.c current releases electro magnetic waves which travel at the speed of light and can range in frequency any where from 0 to 3 GHz. Also a *changing* magnetic field can set up an electric field and vice-versa,(a fact dramatically displayed when a lightning strike throws a magnetic needle out of kilter) and thus in common electric device usage the human body must contend with both types of fields at the same time.

Other important sources are given below:

Source	Typical maximum public exposure	
	Electric field (V/m)	Magnetic flux density (μ T)
Natural fields	200	70 (Earth's magnetic field)
Mains power (in homes not close to power lines)	100	0.2
Mains power (beneath large power lines)	10 000	20

These waves have been divided into 3 categories:

1).E.L.F (0 to 300 HZ) which are emitted by over head transmission lines (10-20 μT under the line, or 10kV/m), household appliances, domestic distribution lines etc. The main frequencies in the ELF frequency range are 50 Hz in Europe and 60 Hz in North America.

2). I.F(300Hz to 100 KHz) which are associated with VDU terminals(cathode ray tubes of TV, computers) and card readers, and the anti-theft terminals used at the exits of shops and hotplates..

3) R.F. which range from 100 KHz to 300 GHz. Mobile phones, television and radio transmitters produce RF waves. Microwaves are RF waves in the GHz range (2.45GHz) and are used in microwave ovens. MRI machines operate at 63 MHz.

The energy (E) content of an EM wave is directly proportional to its frequency (ν), the proportionality constant being the Planck's constant ($h = 6.626 \times 10^{-34}$ Joule-seconds) and the governing equation is $E = h\nu$.

III. PHYSIOLOGIC AND BIOCHEMICAL EFFECTS OF ELECTROMAGNETIC FIELD

Some perspective of the amount of energy that EM waves deposit in body tissues can be obtained by putting their energy values in the broader context of the radiations that man is naturally exposed to in the environment.

The table below gives a brief listing:

Power density mW/cm^2	Long term physiologic effects	Notes
0.01	No effects(but note that in France symptoms have been reported in people living within 300 meters of a Cell tower)	Cell tower emits $0.01\text{mW}/\text{cm}^2$ at 100 meters distance.
1	No effects	
5	No effects	Accepted standard for microwave oven leakage at 2 inches distance, equivalent to $0.05\text{mW}/\text{cm}^2$ at 20 inches distance.
10	No effects	Accepted standard for maximum continuous exposure to radiated emissions (cell phones, etc.)
30	Heat is felt	
100	Cataracts can be produced	Intensity of Summer sunlight
1000	Pain is produced	
5000	Cooking commences	Lasagna cooked in 5 minutes

These numbers while seemingly reassuring are deceptive. It may appear that since the bulk of electric devices have a power output less than that of ordinary sunlight, they are perfectly innocuous. But it must be borne in mind that unlike sunlight that does not penetrate the skin surface, EM

radiation can and does deposit its energy deep inside tissues. The ubiquitous use of cell phones (which operate in the microwave range of frequencies) makes them particularly dangerous in this regard. The antenna of a cell phone can easily deposit $50 - 100\text{mW}/\text{cm}^2$ inside the skull and this includes the eyeball. The eye is particularly vulnerable in this regard since the lens of the eye is devoid of a vasculature that can carry away the deposited heat, and as a result a coagulation of the proteins of the lens can result producing cataract in the long term. The gravity of the situation is underscored by the fact that the proteins present in the eye lens called crystalline are held at super-saturation and readily precipitate out of solution from the cytoplasm, resulting in lens clouding when subjected to a variety of environmental stressors – a simple physical blow to the head often suffices to throw them out of solution !!. It is one of the fundamental paradoxes in the recorded literature of the biological effects of EM radiation that the bulk of the negative pathologic effects have been noted in association with E.L.F from which *a priori* one would have predicted the least effects.

For example, a clear correlation, and presumably a causative one, has been observed between the E.L.F put out by overhead power lines and the development of childhood leukemic cancer (Wertheimer et al 1979, Savitz et al 1988). It has been found that a doubling in childhood leukemia incidence occurs for magnetic fields over $0.4\text{ }\mu\text{T}$ (Ahlbom et al 2000). This finding is disturbing given that 43% of homes with magnetic fields greater than $0.4\text{ }\mu\text{T}$ lie in propinquity to overground or underground circuits of 132 kV or more. In addition for people walking directly below these power lines the electric field experienced can exceed 2 to 5 KV/m and the magnetic fields can reach as high as $40\text{ }\mu\text{T}$. Even ordinary household devices can build up substantial magnetic flux densities; at a distance of 5 cm from a vacuum cleaner a magnetic flux density as high as $40\text{ }\mu\text{T}$ has been recorded.

In addition several studies have provided persuasive evidence that exposure to ELF-EMF can accelerate the development of the neuro-degenerative disorder Alzheimer's disease (Sobel et al 1995, 1996). Also a connection to EMF exposure and the acceleration of the disease Amyotrophic lateral sclerosis has been documented (Davanipour et al 1997). Especially disquieting is the observation that ELF-EMF(composed of a 60Hz electric field and a 60Hz magnetic field) exposure lowers the blood levels of the hormone melatonin(Reiter et al 1988; Rogers et al 1995). Melatonin is one of the most potent of free radical scavengers and any reduction in its level, by compromising the anti-oxidant defenses of the body, would be expected to have deleterious biochemical consequences. This idea is reinforced by the finding that exposure of a breast-cancer cell line to a $1.2\text{ }\mu\text{T}$ magnetic field annulled the protective effect of melatonin on cancer cell division (Blackman *et al*, 2001). Further proof that EMFs act by enhancing the levels of free radicals is the observation in snails of a rise in the levels of the pro-oxidant destroying enzymes catalase and glutathionine reductase when the invertebrates were positioned under overhead power lines. The effect was even observed when a weak $0.75\text{ }\mu\text{T}$ magnetic field was imposed over a period of 40 days, clearly bespeaking the oxidative

stress that EMF can generate. (Regoli *et al*, 2005)

The magnitude of magnetic field exposure varies substantially across the population. The average exposure over a 24 hour period for US citizenry is $0.09\mu\text{T}$. The exposure exceeds $0.1\mu\text{T}$ in 44% of the population; another 14% experiences a field of $0.2\mu\text{T}$, and less than 1% is subjected to $0.75\mu\text{T}$.

These sobering findings have been corroborated by other studies: a 70% increase was found in childhood leukemia for homes located 200 meters (656 ft) from an overhead power lines, and in addition at distances between 200 meters (656 ft) and 600 m (1,969 ft) an increased risk of 23% was noted. (Draper *et al*, 2005). Furthermore, in a long term study of cell phone users it has been demonstrated that such usage, over a decade long period, predisposes to the growth of acoustic neuroma, a benign form of cancer that arises in the Schwann cells that invest the vestibulocochlear nerve in a mantle of myelin (8th cranial nerve) (Hardell *et al*, 2005a,b). Exposure to even low levels of ELF radiation - 60 Hz, $10\mu\text{T}$ for 24 to 48 hours - has been shown to cause DNA damage (Lai *et al*, 2004b). Equally worrisome are the results of an epidemiologic survey that show that the likelihood of tumor formation is greater on the side of the head on which the cell phone is usually used and that cell phone usage over a period of ten years can substantially increase the risk of tumor formation (Lonn *et al*, 2004). Regular use of mobile phones over periods greater than 10 years has been associated with an increased risk of gliomas (Schuz *et al*, 2006). Scientists have found an increased number of DNA strand break after exposure of diploid human fibroblasts to 1800 MHz radio waves after exposure times of 24 hours on a cycle of 5 minutes exposure followed by 10 minutes non-exposure (Diem *et al*, 2005).

Additionally, it has been shown that exposure of the brain to microwave radiation results in a compromised function of the blood-brain barrier, presumably at the level of the capillary endothelial cell, and increased permeability into the brain, a fact documented by dramatic autopsy photographs (Salford *et al*, 1994; Persson *et al*, 1997;). Given that it is the blood-brain barrier that keeps toxins in the blood from entering into and damaging the brain (Purves *et al*, 2001), and given the huge number of pollutants ranging from automobile exhaust to cigarette smoke to polluted food and water that urban man ingests on a daily basis, it is readily seen how this could lead to further damage to the brain as these toxins now gain unrestricted access to the brain tissue, potentially increasing the frequency of degenerative neural diseases like Parkinson's and Alzheimer's and Lou Gehrig's disease in the long term. *In vitro* studies corroborate and consolidate the potential damaging effects of EMF since it has been shown that negative effects in cell culture can be reproducibly and consistently seen at magnetic field intensities of $100\mu\text{T}$ and electric field strengths of 1mV/m , values that are well within the ranges of electric equipment.

Nor are these damaging effects restricted solely to humans. Numerous studies have established and documented the pernicious effects of EMF on a variety of living systems ranging from prokaryotes to eukaryotes. For instance, there is

a persuasive evidence that plants growing in the vicinity of overhead transmission lines (132KV and 220KV) produce a disproportionate number of diploid pollen, which would predispose them to sterility (Zaidi *et al*, 2003). Additionally scientists have found a 2-fold increase in lymphoma incidence in mice exposed 60 minutes a day for 18 months to 900 MHz RF fields (Repacholi *et al*, 1997). Furthermore, in the duckweed exposed to 60Hz/100Hz sinusoidally varying magnetic field an accumulation of the amino acid alanine was noted. Since Alanine is accumulated by plants only under conditions of stress this is clear unequivocal evidence that the magnetic field does indeed constitute a stressor to living systems. (Monselise *et al*, 2003). Yet again, in rats, an increased rate of mammary tumors has been found when the mutagenic chemical DMBA was used concurrently with a $100\mu\text{T}$, 50 Hz magnetic field (Thun-Battersby *et al*, 1999).

The importance of this central discovery cannot be overstated for it underscores the fact that living as we do in a veritable sea of man-made pollutants, humans would be predicted to be far more vulnerable to the cancer promoting properties of EMF than would otherwise be the case. It is in light of this alarming and disturbing correlation that the multitude of negative findings of the relationship between EMF and cancer should be interpreted. An animal that may show no oncogenic response to an EMF in the pristine environmental setting of a research laboratory, whose cleanliness may rival that of a hospital, may well succumb to cancer if it were exposed to a field of identical strength in a real world polluted environment. The effects of EMF, or lack thereof, should not be misconstrued in isolation but must be examined in the light of the potential for synergistic interaction with other oncogens. EMF could well be a pathological case of the proverbial straw that broke the camel's back.

Apart from these standardized controlled studies, a large body of anecdotal evidence exist which clearly attests to the detrimental consequences of chronic EMF exposure. To cite but one example, in an elementary school in Fresno, California, USA, ten classrooms had to be evacuated permanently when it was found that 10 teachers who had taught in those rooms for extended periods of time had developed cancer. These rooms were located approximately 110 feet way from high voltage overhead power transmission lines. The gravity of the situation has been recognized by regulatory agencies worldwide and the safety limits for exposure set in most countries now are $450\mu\text{W}/\text{cm}^2$ at a frequency of 900 MHz, and $950\mu\text{W}/\text{cm}^2$ at 1900 MHz. The limit is frequency dependent.

The evidence for the role of IMF in carcinogenesis, if any, is sketchy at best and will not be discussed further.

IV. MECHANISM OF ACTION

One of the greatest stumbling blocks to any unanimity in the scientific community to the acceptance of a putative oncogenic role for EMF is the unavailability of a plausible biochemical mechanism for EMF's inimical effects. The photons of EMF simply do not pack enough energy to break chemical bonds, unlike ionizing radiation like U.V. and gamma which can; which fact has readily been adduced as

the causative basis for the latter's well known damaging effects. To break a chemical bond requires an energy of at least 10 eV, while the energy of a microwave oven operating on 2.45 GHz is only 0.00001 eV, grossly inadequate to produce any ionization of bio-molecules. EMF seems harmless, yet paradoxically enough the literature in support of the damaging role of EMF is rich and substantial. A 60 Hz, 10 μ T magnetic field imposed for 24 to 48 hours has been shown to cause DNA damage(Lai *et al*, 2004b); EMF exposure results in micronucleus formation(Simko *et al* 2001)and chromosomal damage(Winker *et al*, 2005), lysosomal membrane instability(Regoli *et al*, 2005), all of which effects acting in concert could readily account for the cancer-promoting properties of EMF. Multiple lines of collateral and circumstantial evidence exist to buttress the hypothesis that EMF acts indirectly to wreak its insidious effects. EMF apparently promotes free radical formation (Rollwitz *et al*, 2004), for when an iron chelator is employed concurrently, the effects of the radiation are substantially muted (Lai *et al*, 2004b). And it is well known that iron is a free radical formation initiator. Furthermore a 60 Hz EMF can counteract the cancer suppressing properties of the anti-cancer drug Tamoxifen in human breast cancer cells (Harland *et al*, 1997), the inference therefore being that EMF could potentially interfere also with the natural cancer defense mechanisms built into the cell such as apoptosis – programmed cell death which selectively and pre-emptively eliminate potential cancer cells before they can attain an overt, virulent configuration. The discovery that the DNA damage caused by ELF fields can be suppressed by the addition of antioxidants clearly indicates that EMF can exert its inimical effects by promoting free radical formation (Wolf *et al*, 2005).

In addition, a great deal of cell signaling – misfiring of which is responsible for cancer – is carried out by specialized molecules in the body called second messengers – a classic example of which is calcium²⁺. It has been shown that in lymphocytes that have been stimulated by a mitogen – the first step in the elimination of cancer cells from the tissue spaces by the body's own anti-cancer defenses – the rate of calcium transfer across membranes is greatly accelerated, and that this movement of calcium, presumably in the process of carrying cellular signals is interfered with by the presence of an EMF. This finding should not surprise us. It is a well established fact of physics that a charged particle moving in a magnetic field, instantaneously experiences a mechanical force, perpendicular in direction both to the magnetic field and the path of travel, disrupting its direction of motion. The failure of the calcium ion to pass through membranes due to a disruption of their movement would have profound and amplificatory consequences for the cell, for its effects would swiftly cascade up the control chain and wreak havoc on the delicate and multiple hierarchical controls feed back loops the cell depends on for its very survival. Aberration of function followed by cancer formation would be an expected and predicted outcome.

Furthermore it must be emphasized that potentially dangerous cancer cells arise in the body on a daily basis as a result of mutation. Multi-cellular organisms however have efficient detection mechanisms in place that eliminate these

rogue cells via immune surveillance mechanisms. It has been found that the proliferation of immune cells – a necessary preliminary in the defense strategy of the immune system when it comes in contact with a foreign body such as a cancer cell – is associated with a change in the calcium transport characteristics across the immune cell membrane and that this rate of transport is altered by the presence of a magnetic field. For instance when an annular culture plate of lymphocytes was placed in a solenoid through which an alternating current of 60 Hz was passed, simulating the effects of a typical powerline of 200 gauss magnetic field, it was found that the rate of the transport of this ion was either enhanced or inhibited depending on the intensity of the field(Harland *et al*,1997).

V. CONCLUSION

The central leitmotif that emerges from the diverse, often contradictory, occasionally confusing, plethora of studies that have examined the relationship between EM exposure and pathology is that the relationship between EMF and cancer, and the multitude of other assorted disorders ascribed to it, is tenuous at best, and non-existent at worst. Yet the authors of this review have deliberately refrained from citing any of the studies that have found no association between EMF and cancer, or any of the other effects attributed to it. In a review paper that purports to be objective, this may strike one as a cardinal blunder and omission. Yet it is not subjective bias that leads the reviewers to adopt this unorthodox approach but several rather persuasive reasons of a wholly compelling nature which led them perforce to such draconian measures. Firstly a not insignificant number of studies in this area are conducted at the behest of, and financial backing by, electrical utility companies and the objectivity of such studies, when the investigators are under intense pressure to look for and find non-causal relationships is questionable at best, and downright shady at worst. This is not to cast aspersions on their moral integrity, which by and large are conscientious and of sterling character, but merely represents a comment on a reality of current research that is regrettably no longer deniable. Secondly, and far more cogently, is the fact that the ability of *Homo sapiens* as a species to tolerate and resist any environmental insult exist on a gaussian curve of susceptibilities. The fact that the bulk of urban citizenry do not experience any detrimental effects in the short term by no means obviates the very real possibility that that segment of the population positioned on the long tail-end of the adaptational response curve are not vulnerable to the EM field. It's a peculiarity of the gaussian curve that it is asymptotic at its tail ends, thus greatly extending a tiny, but significant portion of the population to extreme vulnerabilities. Given the pervasive presence of electric devices and the huge population sizes involved, even a 0.1% increase in cancer incidence due to EMF exposure in these defenseless segments translates instantaneously and disturbingly into several million lost lives – mortality numbers which are seen only in the theatre of war, and which none of us dismiss as insignificant. Moreover, a negative finding can readily result from a faulty methodology, while a positive finding is far harder to dismiss on grounds of

incorrect experimental design. To use a common analogy, the fact that the overwhelming majority of people do not die of sunstroke in the searing temperatures of an Indian summer does not gainsay the fact that some do; and to adduce the former as proof that summer heat is perfectly harmless would be tantamount to an absurdity and falsehood. In a sufficiently small population, it is entirely possible, purely by chance, to have a cohort, all of whose members are resilient to summer heat and thus a total absence of deaths hardly constitutes categorical proof that the sun is an innocuous agent!!

Nonetheless, since this is review article, it may be pertinent to put on record here that for literally every positive finding of a causal relationship between EMF and cancer, neuroma, cataract etc., there have been reports often multiple, of a lack of correlation, let alone causation between the two parameters examined.

In summary, while safety standards of exposure have been established, there is little room for complacency. EM radiation is peculiar in that it is odorless, colorless, tasteless, residue less, invisible – it is thus a “clean” form of pollution, and furthermore, unlike chemical pollutants, which persist in the environment long after their generating source has been removed, the EM field ceases to exist the instant its generating source is switched off. It is this invisible, ephemeral dimension of its existence that it makes it all the more dangerous, for that which is neither seen nor felt is dismissed and neglected - much to our collective detriment and peril.

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