

Natural and Human-activity-generated Electromagnetic Fields on Earth

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Natural background Electromagnetic Field (EMF) Levels on Earth

Many scientists and almost all of the general public seem to be unaware of the vast change that has taken place in our electromagnetic environment over the last few generations. This short poster is intended to set these changes into context.

The general belief that there is likely to be little or no risk to health from commonly encountered levels of EMFs does not come from a scientific understanding of all the pathways in which low levels of electromagnetic fields may be able to interact with biological systems. However, this opinion has led to a general acceptance that adverse health effects are impossible.

Apart from visible light and infra-red heat, life on Earth has developed in an environment of fairly static geomagnetic fields and weak natural time-varying electromagnetic fields.

Natural low-frequency EM fields come from the sun, thunderstorm activity and currents circulating in the core of the Earth. In the last 100 years, man-made fields at much higher intensities and with a very different spectral distribution have altered this natural EM background.

As a result, humans are being exposed to an effectively novel exposure, and we have no way of knowing what level of long-term risk that this may, or may not, pose to health.

How do natural levels compare to man-made levels?

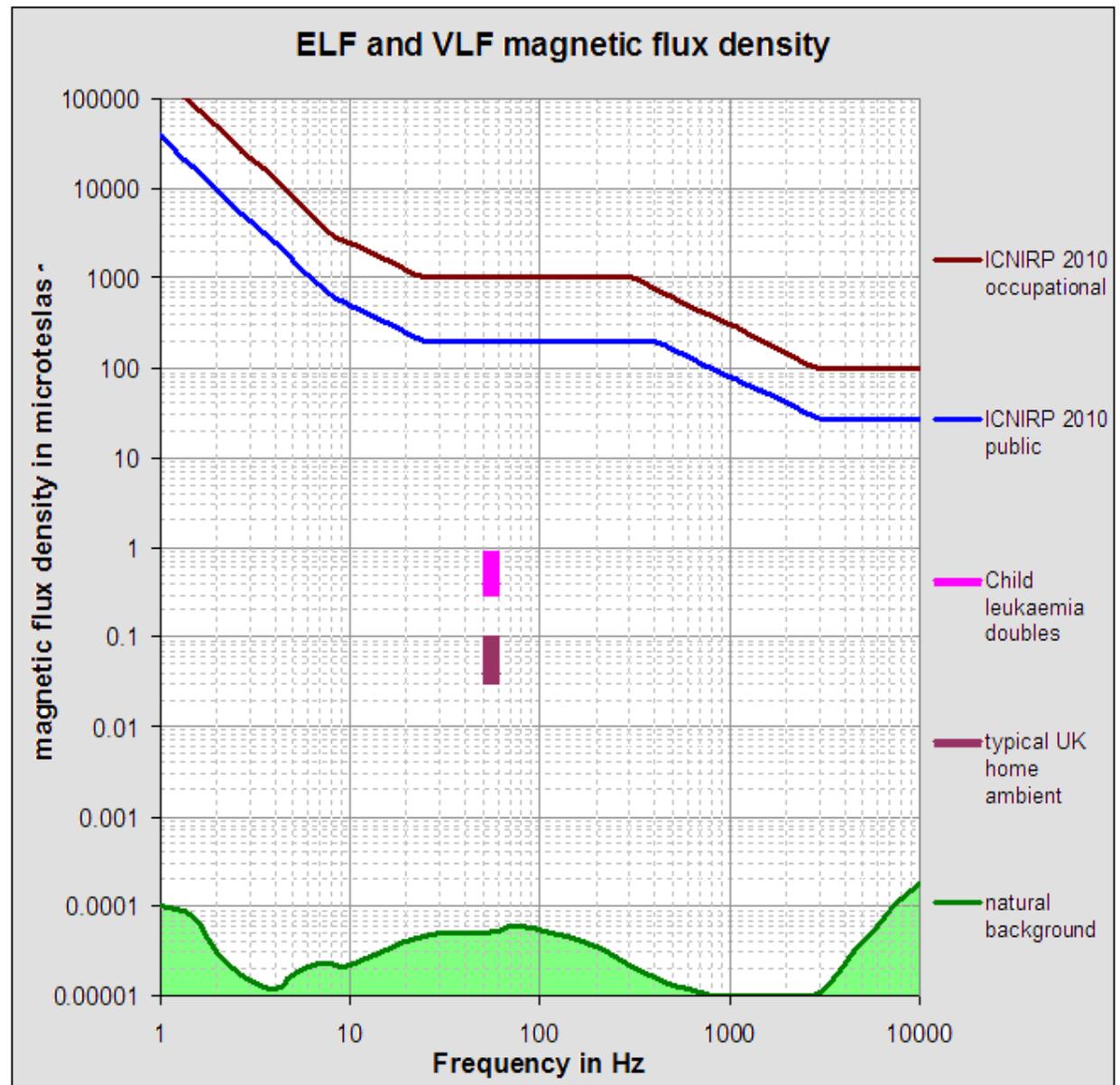
ELF levels are usually measured in units of magnetic flux, and the natural background levels are about 50 picoteslas.

Note the logarithmic scales on the graph - each main grid line is 10-fold higher!

The average background level at mains electricity of 50 & 60 Hz in modern homes is now about 40-70 nanoteslas, some 1000-fold higher, and it can be much higher.

These man-made ELF fields did not exist until after the 1920s, and elevated levels were rarely found until after the Second World War.

A doubling in the incidence of childhood leukaemia is associated with residential exposures above 0.3 to 0.4 microteslas.



Natural and man-made RF electromagnetic power densities on Earth plus current ICNIRP safety guidelines

Power Density
W / m² / Hz

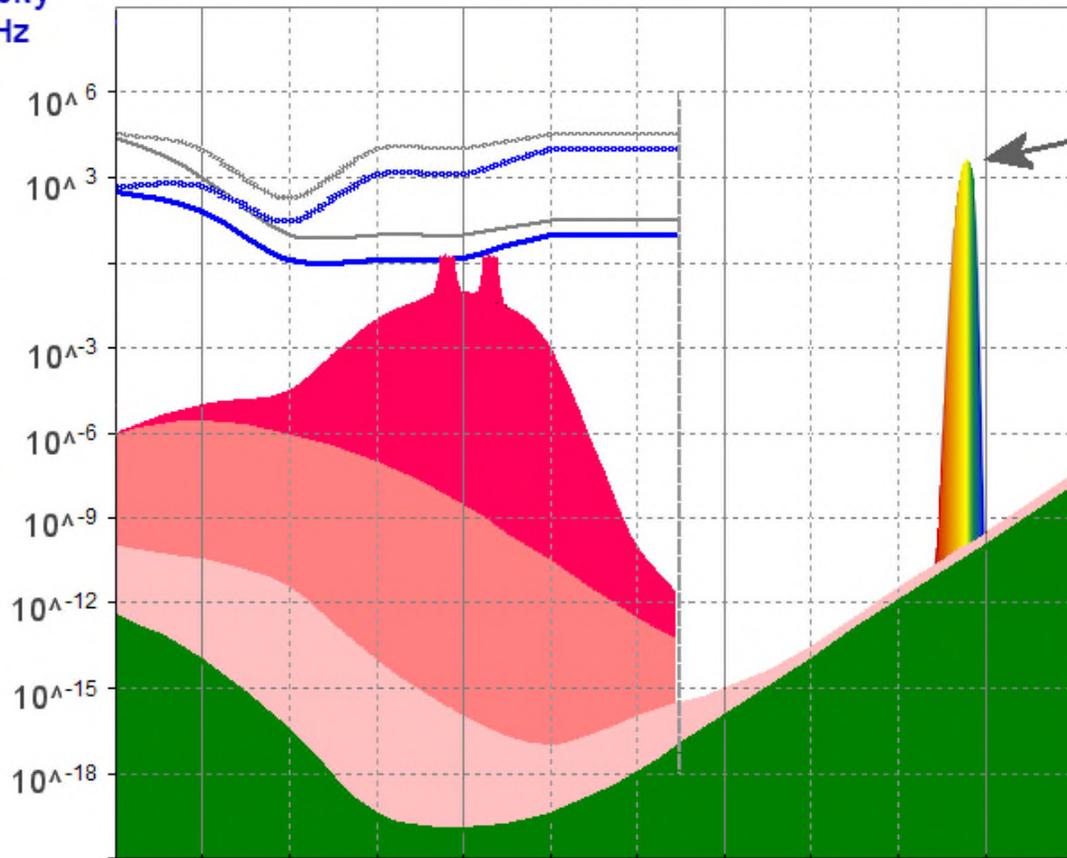
1 000 000

1 000

1

0.001

0.000 001



Sunlight on a hot
clear-sky summer day
c. 2000 W / m² / Hz

LEGEND

- ICNIRP (occup. peak)
- ICNIRP (occupational)
- ICNIRP (public peak)
- ICNIRP (public)
- 2010, typical
- 1980s, typical
- 1950s, typical
- natural background

Frequency 10⁶
1MHz

10⁹
1GHz

10¹²
1THz

10¹⁵
1PHz

Average ambient radiofrequency (RF) power density levels have increased in urban areas by 1,000,000,000,000-fold. In a WLAN (WiFi) equipped school classroom with 2 Access Points and 20 laptops the average power density is in the order of 10 to 100 microwatts per square metre.

Commonly found peak power densities in both urban areas in the UK and in WiFi classrooms are now in the range 1 to 100 milliwatts per square metre, which represents a 100,000,000,000,000,000 - fold (10^{17} -fold) increase in exposure over the last 100 years and a million-fold increase in the last 30 years.

Note that the total energy levels are almost the same as very bright sunlight that would cause sun-burn and ionising radiation that could damage cells. Individual photons have much less energy but people are being daily hit by billions more of these less energetic photons.

Based on energy considerations, the annual absorbed dose from natural background radiations is about 2 mGy which involves a transfer of 2 mJ kg⁻¹ to tissue. The current ICNIRP mobile phone SAR is 2 W kg⁻¹ this amounts to a total energy transfer of 2000 mJ kg⁻¹ per second (=2 J kg⁻¹ s⁻¹), albeit from photons with quite low individual energies. We believe that the possible long-term effects of this massive influx of photon/electron energy on a person's well-being cannot readily be discounted.

ICNIRP guidelines

Most countries base their exposure restrictions on the reference guidelines set by ICNIRP in 1998 and revised in 2010. Currently the levels are based on the knowledge of direct acute effects such as electric shock and tissue heating as ICNIRP does not believe that the large body of peer-reviewed scientific reports showing real biological effects at much lower exposure levels provide “conclusive” evidence to be used for setting public exposure guidelines.

The ICNIRP guidelines for extremely low frequency (ELF) exposure currently set maximum exposure guidance for the general public at 200 microteslas – 4,000,000 times above the average exposure levels less than 100 years ago. There are many examples of adverse health related effects occurring at ELF magnetic field exposures well below the current ICNIRP levels.

For RF exposure, ICNIRP guidelines allow the general public to be exposed to 10^{18} -fold, i.e. 1,000,000,000,000,000,000 times, more than the natural background level less than 70 years ago. Short-term peak values are allowed 1000 times higher than this.

Historic impacts of large scale novel exposures

There are a number of historical case studies where the suggestion that novel exposures may pose a health hazard has been met with derision from the wider scientific community.

This includes currently well established risks such as cigarette smoke, ionising radiation and asbestos.

Although it would be inappropriate to make an assumption that a novel exposure must be considered to pose a risk until proven otherwise, in each of these cases the early human epidemiology was consistently indicating a possibility of harm.

A well known early example was the transmission of cholera through water, identified by Dr John Snow in London in 1854. The initial reaction to the idea that the disease could be transmitted through the water supply was viewed with anger and incredulity, yet once the water pump in question was disabled, the association soon became difficult to refute. It was decades later before science was able to start to understand precisely how this transmission had worked in practice.

Since then, science has gained a wealth of understanding in all areas relevant to human health, from physical interactions with cellular tissues to cellular biology and genetic manipulation. Unfortunately, there is no way of knowing how many crucial gaps in knowledge there still are.

It is therefore unjustified to assume we have all the knowledge required to determine a mechanism of action as it is to claim that epidemiology alone can prove causality.

Further Discussion

One of the core tenets of the scientific method is to let reality speak for itself and allow long-held theories to change when necessary. This places a burden on the researcher to be precise about what a given piece of work says and to be clear about its limitations, without claiming a greater significance than is warranted.

However, this approach cuts both ways: any claim that science already has all the tools and understanding to identify any possible mechanism for a given health association cannot be justified.

An association may be real, but science may be decades away from understanding the biological or cellular processes behind the relevant mechanism, and waiting for those decades to pass before guidelines or restrictions are set in place to prevent harm has proven repeatedly problematic in the last century.

Research into cancer related effects from both ELF and RF electromagnetic fields has now accumulated to the level where the International Agency for Research on Cancer (IARC) has classified both of them individually as Class 2B possible carcinogens. The limitation of the classification is not based on the inconsistency of the epidemiological data, but the lack of supporting experimental research, mechanistic hypotheses and related studies.

For ELF fields in particular, the association between an exposure of 400 nanoteslas and an increase in the risk of childhood leukaemia is very consistent across time and across many countries. The consistency has remained even after more recent studies attempted to remove or control for suspected biases and confounding factors. The mechanism by which ELF electromagnetic fields could lead to cancer is not understood, but despite this there are no alternative explanations that explain the association more plausibly than causality, despite many attempts to discover one.

There are also a number of remaining associations between ELF exposure and neurodegenerative diseases and other cancers, where some of the associations are as strong as the childhood leukaemia one.

ICNIRP and other international bodies have set standards designed to protect the public from fully established health effects caused by known mechanisms, and these standards will always have their place.

However, the presentation and adoption of these standards are leaving policy makers with a false understanding that humans are safe from adverse health effects provided these levels are not exceeded.

In theory, data analysis and risk assessment is supposedly the domain of scientists and the published literature, and the risk management decisions fall to policy makers.

In practice, policy makers do not usually have sufficient scientific understanding to evaluate the range of risks that an association may entail, and therefore request clarification from scientists, only to be advised that further action to minimise exposure is unnecessary as the “risk is not yet proven beyond reasonable doubt”.

The solution to this problem is not straightforward, but in the absence of scientific certainty, deterministic outcomes are a useful starting point, where a best case and a worst case scenario can be presented in their entirety.

Using ELF electromagnetic fields as an example, this would range from no adverse health effects, to a doubling of childhood leukaemia, a doubling in Alzheimer’s and Amyotrophic Lateral Sclerosis (ALS), and a smaller increase in adult breast cancer, adult leukaemia, miscarriage, depression and suicide. The cost to society of each of these risks can be calculated from the base risk of the disease in society and the worst case estimate of an increase in risk from the existing research to date.

Where there is more available evidence, good analysis into likely outcomes can predict more realistic costs to society from public exposure. Policy makers would then have a more complete picture upon which to decide on the most appropriate course of action, taking into account the many other factors that need to influence their decisions.