Are 50/60 Hz magnetic fields carcinogenic to humans?

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Magnetic fields are present everywhere in our environment. They are commonly measured in Tesla (T), the international unit for magnetic flux density. One Tesla is a very high magnetic field. Human exposures to such high fields occur only with magnetic resonance imaging machines (MRI machines - which are used for medical imaging), which produce magnetic field levels up to a few Tesla. To describe magnetic fields in our normal environment, a more appropriate unit is the micro Tesla (the symbol is μT) which is one millionth of a Tesla (0.000001 T)

The earth's natural magnetic field is about 50 μT, and always points in the same direction, close to the north. In homes, the use of electricity produces magnetic fields but at much lower levels, typically around one tenth of a micro Tesla or 0.1 μT. Since the current flowing in power lines and electrical wiring is an alternating current, the magnetic field changes direction constantly, at a frequency of 60 or 50 cycles par second (60 or 50 Hz) depending on the country. The frequency is 60 Hz in North America and 50 Hz in Europe.

What triggered the idea that residential magnetic fields would increase the risk of cancer?

Unlike most carcinogens, the hypothesis that magnetic fields could be a human carcinogen was not triggered by an unusually high incidence of a particular cancer among a group of individuals exposed to high fields. Neither was it suspected on the basis of any scientific observations from experimental studies or biophysical considerations. The hypothesis was generated in 1979, by a so-called "hypothesis generating" epidemiological study carried out in Denver, Colorado. The authors were looking for possible environmental factors around the houses of children who had cancer. They reported a statistically significant association between the presence of a dense electrical network around the house and the risk of various childhood cancers including leukemia. They suggested that the magnetic field produced by the current flowing in the power lines might be the reason for this association. The study results were received with scepticism for various reasons.

Firstly, the magnetic field intensities involved in the study were extremely small (about 0.2 μT). The first effect known to occur in humans appears at field levels of 10,000 to 15,000 μT in the form of faint flickering visual sensations, caused by a small electric current induced by the alternating magnetic field in the retina. This phenomenon is harmless and also occurs occasionally during magnetic resonance imaging (MRI) procedures. It was also known from experimental studies on animals that it takes magnetic field levels above 50,000 μT to be hazardous. Above this level, the electric current induced in the body is strong enough to cause muscle contractions and cardiac excitation.

Secondly, humans have been exposed to alternating magnetic fields ever since electricity came into common use, i.e. more that 125 years ago. Prior to the Denver study, there had been no anecdotal evidence or scientific evidence of any kind suggesting that magnetic fields at home or in the workplace could be deleterious to human health, and certainly no suggestion that they could be carcinogenic. In particular, health surveillance programs of electrical workers chronically exposed to magnetic fields of much higher intensity (up to 1500 μT) had not revealed any harmful effect.

Finally, the design of the Denver study was rather exploratory by nature and subject to many possible sources of errors, a common situation with epidemiological studies.

Despite the scepticism, the study was given very serious consideration and led to a vast international research effort for assessing a possible carcinogenicity effect of power frequency magnetic fields.

If 60 Hz magnetic fields were a carcinogen, what should we expect to observe according to what we know in the fields of physics, biology, toxicology and carcinogenesis?

1. An increased risk of cancer in most tissues

The magnetic field penetrates the body easily without any significant distortion and is not attenuated by the presence of biological tissues. Consequently all tissues and cells of the body are exposed to the same magnetic field level. If the 60 Hz magnetic field were a carcinogen, we should expect to observe an increased incidence of cancer for a majority of tissues and cell lines, much like what occurs with gamma rays and X-rays. The control mechanisms of cell differentiation and proliferation that prevent the transformation of a normal cell into a cancer cell are very similar across cell lines and across species. As a rule, if a carcinogen reaches a particular tissue and creates sufficient damage to these control mechanisms, cancer risk increases in that tissue.

2. Other signs of toxicity

As with all known carcinogens, we should expect to detect some of the primary or elemental damage to cells that transform a normal cell into a cancer cell. True carcinogens generally trigger a series of mutations that gradually transform a population of normal cells into a cancer cells. These intermediate stages are generally observed with true carcinogens. An agent capable of causing cancer, that does not leave any clues of its passage in the body, has never been found.

Carcinogenicity is only one of many aspects of the toxicity of a particular chemical or physical agent. Carcinogens also cause an array of chronic or acute pathologies at similar doses. For example, solar irradiation causes skin cancer but also causes burns, premature aging of the skin and photosensitization. Cigarette smoking causes cancer but also chronic bronchitis, vascular and heart diseases. Asbestos causes cancer but also pulmonary fibrosis.

3. Carcinogenicity in animals at the same exposure level

Human beings are mammals and their respective physiology is very similar. It is no surprise that among the hundred or so human carcinogens confirmed so far, all of them, with no exception, have been shown to be carcinogenic to animals. For physical agents like ultraviolet light or ionizing radiation, extrapolation from animals to humans has been shown to be even more reliable than for chemicals. Indeed, the damage to the cell is the same and does not depend on potential metabolic differences between species that sometimes occur with chemicals. For a physical carcinogen, we should also expect that the dose at which an eventual carcinogenic effect is observed in animals is generally similar to the dose producing a carcinogenic effect in humans.

4. An increased risk with age and exposure level

As with all known carcinogens, one should expect the cancer risk to increase in proportion to the duration and the intensity of the exposure. Almost all carcinogens have been discovered among groups of people highly exposed for long period of time. Carcinogenesis is a long process: it takes time, typically 10 to 20 years, for a cancer to occur. For cancers caused by an exposure to a particular environmental factor, the risk increases with age.

What has been done to test the hypothesis raised by the 1979 epidemiological study?

Since the publication of the 1979 study, suggesting an association between extremely weak magnetic fields and childhood cancer, more than 150 epidemiological studies and more than 50 animal studies have been published. Most epidemiological studies have been carried out among utility and electrical workers where average fields are up to 20 times the residential exposure, and peak short term exposure up to 10,000 times the residential exposure level. Some studies have also been carried out among the general public including about 20 studies on childhood cancer.

Long term animal studies tested the carcinogenicity at field levels typically between 1,000 and 5,000 μT (50,000 times the average residential level) applied about 20 hours a day for 2 years. The unusually high exposure levels used in animal studies were made possible by the fact that magnetic fields do not produce any signs of general toxicity even at these levels.

In addition, hundreds of theoretical analyses of experimental studies have tried to identify a possible underlying biophysical mechanism to explain the eventual carcinogenic effect of magnetic fields.

The amount of data generated by this international research effort is impressive.

What are the main conclusions?

Nothing to support the hypothesis...

1. No evidence of general carcinogenicity

Epidemiological studies carried out among exposed workers failed to show an increased risk of cancer. One of the largest studies – if not the largest - carried out among a cohort of more than 225,000 electrical utility workers looked at past exposure to magnetic and electric fields. There were 4154 cases of cancer in this group that were subjected to statistical analysis. The cancer risk (all types of cancer) among the highest exposed group was no different from the lowest exposed group. Other studies compared cancer mortality rates of exposed workers of electrical utilities from various countries including United States, Canada, France and United Kingdom to cancer mortality rates of the general public. Results consistently showed a cancer rate 20 to 30% lower among workers, a normal observation known as the "healthy worker effect".

Several epidemiological studies have looked for carcinogenicity among adults in the general public for specific cancer sites. Considering the lower exposure level in general and the lack of data on concomitant occupational exposure, these studies are less informative. Despite these limitations, no consistent increases in cancer risk were reported.

2. Large sophisticated epidemiological studies failed to confirm the observation reported in the Denver study.

In an attempt to confirm the association between childhood cancer and the presence of electrical lines around the home, some 20 epidemiological studies using more sophisticated methodologies tried to replicate this observation. Instead of relying on the mere presence of electrical lines around the house, magnetic fields were actually measured inside the houses, sometimes in the children's bedrooms or directly with a dosimeter worn by the children for 48 hours. The largest studies carried out in United States, Canada and United Kingdom failed to show an association between the measured magnetic field and childhood leukemia. These studies also tried to replicate the original finding by using the same approach based on the description of the electrical lines around the house. No association was found. Then, epidemiologists attempted to pool the results of the best studies. By transforming the original data to make them more comparable, a statistically significant association between childhood leukemia and exposure to field levels above 0.4 μT was reported. Since the estimation was based on relatively few cases, the estimation was not very precise. The authors concluded that a causal association could not be confirmed since they suspected that some methodological errors might explain the results.

3. No general of specific carcinogenicity in animals.

Long term animal studies were carried out using standard protocols (National Toxicology Program) with male rats (2 experiments); female rats (3 experiments) male mice (1 experiment) and female mice (1 experiment). All those studies reported no effect on the

incidence of benign or malignant tumours including leukemia. The highest exposure group varied from 1,000 to 5,000 μT.

Another hypothesis put forward is that magnetic fields do not increase the incidence of cancer themselves, but rather modify the effect of another carcinogen. Over 20 animal studies have been carried out so far to test this hypothesis, subjecting animals to a known carcinogen and then to magnetic fields. As a whole, the results are negative.

4. Strong evidence of absence of any significant biological effect at environmental levels

Despite hundreds of in vitro and in vivo experiments no damage nor physiological effect has been identified at field levels typical of residential (0,1 μT) or occupational exposure (a few μT). Physicists have explored by theoretical studies and experimental work many potential fundamental mechanisms of interaction between magnetic fields and matter and none of these mechanisms have been deemed to be operational to a significant extent at environmental levels.

5. Strong evidence of absence of toxicity at very high level

No signs of general of specific toxicity have been reported in animals (rats and mice) chronically exposed for 2 years from a few weeks of age (in one case, since in utero conception) to field levels up to 5,000 μT (50,000 times higher than the average residential level). Comparisons of group mean body weights and body weight gains demonstrated no significant differences between any group exposed to magnetic fields and the controls. No differences in behaviour were noted between the exposure groups.

A few experimental studies have been carried out on human volunteers at high field levels (100 to 1,000 μT). The subjects were not able to perceive the presence of the fields and no adverse effects were reported.

Conclusion

If 60 Hz magnetic fields were a carcinogen capable of causing childhood leukemia, they would have to cause significant damage to the cell division process of lymphocyte precursors in the bone marrow of children at extremely low field levels. One would have to conclude that the fields do this damage by an unknown mechanism, leaving no discernible effect at the cell level and no other pathology even at doses 12,500 times higher. It would be the first carcinogen to spare all other tissues in children and adults and animals. It would be the first carcinogen to act exclusively in children. It would also be the first carcinogen for which the effect decreases with intensity and duration of exposure.

Clearly, these assumptions are not reasonable. We can safely assume that the hypothesis raised by the Denver study in 1979 is not tenable anymore and very likely to be a false alarm, a situation which is not uncommon with exploratory epidemiological studies. The exceptional amount data accumulated over the last 30 years confirms what common sense

would have suggested: residential magnetic fields levels are far too low to influence human biology.

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