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EDITORIAL

IARC evaluation of ELF magnetic fields: Public understanding of the 0.4-μT exposure metric

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Introduction

In its review of the possible health effects of extremely low frequency (ELF) magnetic fields, the expert scientific Working Group assembled by the International Agency for Research on Cancer (IARC) concluded that high levels of magnetic fields were associated with childhood leukemia, but it could not exclude the possibility "that a combination of selection bias, some degree of confounding and chance could explain the results" (IARC, 2002). An IARC press release called attention to a 0.4-μT[1] exposure value stating, "pooled analyses of data from a number of well-conducted studies show a fairly consistent statistical association between childhood leukaemia and power-frequency residential magnetic field strengths above 0.4 microTesla" (IARC, 2001). The Working Group based its conclusion largely on pooled analyses by Ahlbom et al. (2000) and Greenland et al. (2000) that combined data from selected individual epidemiology studies. These pooled analyses reported an association with childhood leukemia at magnetic field intensities greater than 0.3 and 0.4 μT, respectively, using $<0.1\,\mu$T as the reference level. No association was reported between childhood leukemia and magnetic field intensities below 0.3 or 0.4 μT, respectively.

The widespread interest and reporting of the IARC conclusion (particularly on the internet) has focused public interest on the 0.4-μT value. On the basis of our experience, there is a lack of understanding by the public (and sometimes even scientists outside this area of research) of the magnetic field exposure metric referenced by 0.4 μT, how this value relates to everyday exposures, and whether it is a common exposure. Specifically, the public has difficulty in understanding why this number cannot be directly compared to a single "spot" 50–60 Hertz magnetic field measurement taken at a school, playground, or residence, or to a calculation made to estimate a magnetic field level at a particular distance from an electrical facility. They typically ask questions such as, "The magnetic field level at the playground is 1 μT — doesn't this mean that my children are at risk for leukemia?"

[1]It is common for magnetic flux density to also be expressed in older CGS units of milligauss, where 1 milligauss (mG) = 0.1 μT

Regrettably, neither the IARC nor the other major organizations that have reviewed the epidemiology literature have made it sufficiently clear as to what is meant by the 0.4-μT value. The purpose of this Editorial is to remedy this gap in communication.

What does 0.4 μT mean? Single measurements vs. average calculated values

The public is most familiar with "spot" measurements of magnetic fields because they are either measured by power companies at their properties upon request or calculated to characterize future magnetic field levels as part of the permitting process for an electrical facility. However, these single values are not the same metrics that have been used by epidemiologists to describe population exposures. Thus, misunderstanding can be expected when members of the public compare a single measured (or calculated) magnetic field value, whether located at the edge of a transmission line right-of-way or some other location, to an epidemiologic estimate of time-averaged magnetic field exposure. Exposure involves consideration of the frequency and the duration of exposure, in addition to the magnitude of the field. To account for the frequency and duration of exposure, epidemiologists have typically estimated magnetic field exposure using a time-weighted average (TWA) metric, which gives measurements more or less weight depending upon the amount of time a person spends in the location where the measurement was taken or calculated.

Thus, although a spot measurement (such as a measurement taken near an appliance) reflects the contribution of that field source to one's exposure at that particular instant in time, it does not reflect one's overall average exposure to magnetic fields, that is, across a variety of environments (home, school, and travel) and time periods (day, week, month, and year). The distinction between them is important because spot values greater than 0.4 μT are relatively common, whereas TWA exposures greater than 0.4 μT are not common. In the United States, about 45% of the population is estimated to have exposures above 0.4 μT for up to 10 min/day, but only 3.6% have a TWA above 0.4 μT (EMF Rapid Program, 1998). The percentage of children estimated to have measured exposures at their residences greater than 0.4 μT even when transmission lines are nearby is

0.06% in Denmark and 0.24% in the United Kingdom, while 2.5% of residences in the United States had measurements greater than 0.4 μT (Greenland et al., 2000).

The rationale for a TWA exposure metric

Epidemiology studies typically focus on long-term exposures because of our knowledge that chemicals and agents in the environment that are known to cause cancer require repeated exposures at elevated levels over long periods of time, for example, tobacco smoke, alcohol, and sunlight (Schottenfeld and Fraumeni, 1996). This knowledge, and the lack of any firm indication of what magnetic field exposure metric might be biologically relevant (e.g., NIEHS, 1998; IARC, 2002; Swanson and Kheifets, 2006), has led to the use of TWA exposure as a default exposure metric. Arithmetic and geometric mean TWAs are reported to be the magnetic field exposure metrics with the highest year-to-year correlation (Foliart et al., 2002) and are correlated with other, but not all, exposure metrics (Foliart et al., 2001; Verrier et al., 2005). But few epidemiology studies or reviews of these studies explicitly explain this rationale for the use of TWA exposure metrics.

Our experience with public communication has found that this rationale is best-conveyed using simple analogies, such as a comparison to diet (if we were interested in how a person's diet was affecting his or her health, we would not just look at what that person ate for breakfast one day, but we would be interested in what that person ate on average over a long period of time).

TWA exposure metrics in epidemiologic studies of childhood leukemia

Scientific reviews should convey not only the difference between the TWA and spot measurement metrics, but also how epidemiologic studies use varying methods to estimate TWA magnetic field exposure. Greenland et al. (2000) and Ahlbom et al. (2000) pooled and analyzed the data from selected case–control studies of childhood leukemia. The individual case–control studies compared the historical magnetic field exposures of children with and without leukemia as estimated by a variety of surrogate indicators including distance, exposure indexes based on combinations of voltage, conductors, and distance (i.e., wire codes), calculated values, and measured values. The pooled analyses used measurements or engineering calculations to estimate the child's historical exposure in the residence occupied closest to the time of diagnosis. Ahlbom et al. (2000) took the measurements and calculations from nine studies to estimate the "average exposure during the last year [prior to diagnosis]", computed as the geometric mean. Greenland et al. (2000) analyzed 12 studies (8 of which were also analyzed by Ahlbom et al. (2000)) to estimate the relationship between "time-weighted average exposure," that is, the arithmetic mean value, up to 3 months prior to diagnosis of childhood leukemia. Thus, regardless of the exact procedure used to estimate exposure in the study, the common goal of the individual studies and the pooled analyses was to estimate the long-term average exposure of the children to magnetic fields. To facilitate understanding, the 0.4-μT value referenced by IARC should always be identified as an average value that was estimated using surrogate indicators of historical exposure.

Recommendation

To date, only the conclusions of the reviews by the National Radiation Protection Board of Great Britain (NRPB, 2004)[2] and the World Health Organization (WHO) (2007) specify that the association between childhood leukemia and magnetic field exposures above 0.4 μT refer to a TWA exposure metric.[3] No review, including the NRPB and WHO reviews, has sought to explain the rationale or meaning of this metric or how this exposure metric differs from spot values in ways that are easy for the public to understand.

It is well known that a lack of clear definitions for exposure terms presents communication challenges for risk assessors (Zartarian et al., 2005). To avoid confusion, it is essential that reports and other material issued by scientific organizations convey these otherwise obvious points in a way that the public can understand. Analogies may be helpful in conveying the distinction between instantaneous and average exposure metrics to the public, such as comparing magnetic field measurements to taking measurements of personal exposures to temperature (while temperatures encountered outdoors during a day, week, or season may vary considerably, the average temperature of the air during these periods, for example, can be very different from any instantaneous measurement). This example can be compared to brief encounters with the magnetic fields from a refrigerator or television or walking under a distribution or transmission line, which would not significantly alter the long-term exposure of a person to magnetic fields, as reflected in their daily TWA exposure.

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[2]The NRPB has now merged into the Radiation Protection Division of the Health Protection Agency.

[3]"In the context of possible adverse health effects from EMFs, the conclusions of published expert scientific reviews have identified only one reasonably consistent epidemiological finding…an apparent increased risk of childhood leukaemia with **time-weighted exposure** to power frequency magnetic fields above 0.4 μT" (NRPB, 2004) (emphasis added).

"This classification [of possible carcinogen] was based on pooled analyses of epidemiological studies demonstrating a consistent pattern of a two-fold increase in childhood leukaemia associated with **average exposure** to residential power-frequency magnetic field above 0.3 to 0.4 μT. The Task Group concluded that additional studies since then do not alter the status of this classification." (WHO, 2007) (emphasis added).

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