1999:

In 1999, at the conclusion of the EMF RAPID Program, the NIEHS reported to the U.S. Congress… 1 mV/m.

Pg. 26 Convincing evidence for causing effects is only available for magnetic flux densities greater than 100 μT [1000 mG] or internal electric field strengths greater than approximately 1 mV/m.

At and above this level [1 mV/m], the NIEHS Working Group [1998] accepts that biological effects relevant to cancer have been reported in ``numerous well-programmed studies". The effects the Working Group cites are ``increased cell proliferation, disruption of signal transduction pathways, and inhibition of differentiation". The NIEHS endorses this conclusion in its final EMF RAPID report [1999].

https://www.niehs.nih.gov/health/assets/docs_p_z/report_powerline_electric_mg_predates_508.pdf

2000:

The Possible Role of Contact Current in Cancer Risk Associated With Residential Magnetic Fields R. Kavet,* L. E. Zaffanella, J. P. Daigle, and K. L. Ebi, EPRI, Palo Alto, California Bioelectromagnetics 21:538±553, 2000.

Table 6 reports that 18 μA injected current produces an electric field of 3.5 mV/m averaged across bone marrow and 1.9 mV/m averaged across heart tissue, …

Of course, for hand-to-feet contact, current would double in a very well-grounded person.

2001:

Electric Fields in the Human Body Resulting From 60-Hz Contact Currents. Trevor W. Dawson*, Senior Member, IEEE*, Krys Caputa, Maria A. Stuchly**, Fellow, IEEE*, and R. Kavet 1020 IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING, VOL. 48, NO. 9, SEPTEMBER 2001

…estimated electric field in bone marrow from a modest level of contact current (18 μA) exceeds the benchmark of 1 mV/m.

The data shown in Tables IV–VI indicate that as little as 1–10 μA into the hand produces electric fields in the bone marrow of adult and child models that exceed the benchmark.

The results indicate that as little as 5 μA into the hand produces between approximately 20 mV/m (average) to 60 mV/m (95th percentile) within a child's lower arm bone marrow. Lower electric field values, but still greater than the benchmark 1 mV/m, are expected within the child's bone marrow at other sites.

[This means for every 1 μA, multiply by 5-13 to get the resulting mV/m. RATIO OF 1:5 TO 1:13 Remember, anything above 1 mV/m exceeds the benchmark.

2002:

Contact Voltage Measured in Residences: Implications to the Association Between Magnetic Fields and Childhood Leukemia. Kavet, Zaffanella Bioelectromagnetics 23:464 ^ 474 (2002)

For a child-sized model, the electric field averaged across the lower arm marrow segment was about 5 millivolts per meter (mV/m) per microampere (μA) of current, and the upper 5% of this tissue had an estimated field of 13 mV/m/μA;…

"…the electric field in bone marrow from as little as 1 μA contact current exceeds this 1mV/m benchmark."

2003:

the EMF health issue. *new insights to the possible link with leukemia.* *Robert Kavet, Robert Olsen, and Luciano Zaffanella. Health Phys., vol. 83, pp. 387-394, 2002. IEEE power & energy magazine ISSN 1540-7977/03/©2003 IEEE*

On the other hand, dosimetry modeling tells us that 10 μA of contact current into a small child's hand (a realistic estimate for some homes) can produce an electric field in portions of the bone marrow that exceeds 100 mV/m. Given the conclusion in the 1999 NIEHS report to Congress that biological effects may result from tissue electric field doses as low as 1 mV/m, contact current is a far more plausible exposure than magnetic fields.

[10 μA = 100 mV/m or 1:10]

T. W. Dawson, K. Caputa, M. A. Stuchly and R. Kavet, "Comparison of electric fields induced in humans and rodents by 60-Hz contact currents," in *IEEE Transactions on Biomedical Engineering*, vol. 50, no. 6, pp. 744-753, June 2003, doi: 10.1109/TBME.2003.812165.

There is a recent body of research that suggests the association between residential magnetic field and childhood leukemia may be explained by contact currents. Contact current flows through the body whenever it touches two conductive surfaces that are at different electrical potentials.… For a child-size model, the electric field averaged across the lower arm marrow was about 5 millivolts per meter (mV/m) per microampere of current. The upper 5% of this tissue had an estimated field of 13. For adults, these values were about 60% less. Measurements of contact voltages in residences suggest that a child could experience contact currents of up to tens of microamperes which would result in a dose of hundreds of millivolts per meter to the lower arm bone marrow.

[1uA = 5 to 13 mV/m or 1:5-13]

2004:

A Portable Meter for Measuring Low Frequency Currents in the Human Body. J.C. Niple,[1]* J.P. Daigle,[2] L.E. Zaffanella,[2] T. Sullivan,[3] and R. Kavet[4] Bioelectromagnetics 25:369 ^ 373 (2004)

•For example, if the body in Figure 1 were to touch an object at a voltage of 1 V_{RMS} with the right hand while standing on the ground (at 0 V_{RMS}), a contact current will flow through the body.
•For our example, if the two skin resistances total 1 x 10^6 Ω [1,000,000 Ohms] , the contact current will be approximately 1 μA and will be almost entirely determined by the skin resistances.
•This compares to typical hand to foot bulk body resistances of from hundreds of ohms to 1000 or 2000 Ω.
[1,000,000 Ω = 1 μA at 1V, 1000 Ω = 1000 μA at 1,000 mV or 1:1]

Association of Residential Magnetic Fields With Contact Voltage. Robert Kavet,1* Luciano E. Zaffanella,2 Robert L. Pearson,3 and John Dallapiazza3. 1Electric Power Research Institute, Palo Alto, California 2Enertech Consultants, Lee, Massachusetts 3CH2MHill, Englewood, Colorado Bioelectromagnetics 25:530 ^ 536 (2004)

•imperceptible current (tens of microamperes, μA) is on the order of hundreds of millivolts per meter (mV/m) [Dawson et al., 2001; Kavet and Zaffanella, 2002].
•Nonetheless, the results of this study encourage us to believe that, if a physical factor is responsible for the association of magnetic fields with childhood leukemia, contact current is a plausible prime candidate.

[10 μA = 100 mV/m or 1:10]

2005

•Contact Current Hypothesis: Summary of Results to Date Robert Kavet* Electric Power Research Institute (EPRI), Palo Alto, California Bioelectromagnetics Supplement 7:S75 ^ S85

Dose computations using anatomically correct models of children [Dawson et al., 2001] reveal that a modest, imperceptible current into the hand (10 or a few 10s of μA) produces electric fields in the bone marrow of the arm that far exceed those due to typical ambient residential magnetic fields, but, more importantly, are of a magnitude that overcomes challenges based on biophysical plausibility. For example, the model estimates that 10 μA of current produces about 50 mV/m averaged across the marrow in the lower arm of a small child, and about 130 mV/m or above in 5% of that tissue. Table 6 compares the electric fields in

[10 μA = 50 to 130 mV/m or 1 : 5-13]

2009

RESIDENTIAL MAGNETIC FIELDS AND MEASURES OF NEUTRAL-TO-EARTH VOLTAGE: VARIABILITY WITHIN AND BETWEEN RESIDENCES. Robert Kavet* and H. Christopher Hooper† Kavet, Robert; Hooper, H Christopher. Health Physics. 97(4):332-342, The Radiation Safety Journal. October 2009.

•…effects of contact current, it is instructive to examine dose to bone marrow from expected levels of exposure as an indication of potential biophysical plausibility. If one estimates wet body resistance to be 1 kΩ [1,000 ohms], as represented by the resistor used to measure V_{bath}, then contact current exposure would be 1 μA per mV of V.

[At 1 kΩ, 1 μA = 1 mV or 1:1]

(2009 cont.)
RESIDENTIAL MAGNETIC FIELDS AND MEASURES OF NEUTRAL-TO-EARTH VOLTAGE: VARIABILITY WITHIN AND BETWEEN RESIDENCES Robert Kavet* and H. Christopher Hooper. © 2009 Health Physics Society

Finally, given the strong possibility that control-selection bias may partially explain the associations of magnetic fields with childhood leukemia reported … then the associations of B_{avg} with V_{bath} of the magnitude reported here would support contact current as a potential explanatory factor. If one estimates wet body resistance to be 1 kΩ, as represented by the resistor used to measure V_{bath}, then contact current exposure would be 1 μA per mV of V_{bath}. …For example, the average electric field in the lower arm's bone marrow of a "typical" 5-y-old child (~18 kg) exposed to 100 μA would be about 0.5 V m^{-1} [500 mV/m] with 5% of the tissue estimated with at least 1.3 V m-1 [1,300 mV/m] Dawson et al. 2001).
100 μA = 500 or 1,300 mV/m or 1:13

2011

The Relationship between Residential Magnetic Fields and Contact Voltage: A Pooled Analysis. R. Kavet, C. Hooper, P. Buffler and M. Does. RADIATION RESEARCH 176, 807–815 (2011) 0033-7587/11 ©2011 by Radiation Research Society. DOI: 10.1667/RR2719.1

•the dose to portions of a child's bone marrow of the order of about 1 V/m from 60 mV contact voltage (~60 μA assuming ~1,000 Ω body resistance) exceeds background activity of endogenous fluctuating fields and the presumed thresholds at which biological effects are plausible.
•we believe that exposure to contact current in the bathing scenario has the characteristics to explain the association of magnetic fields with childhood leukemia.
[At 1 kΩ, 60 mV = 60 μA or 1:1]

(2011 cont.)

NIH: Exposure to Electrical Contact Currents and the Risk of Childhood Leukemia. Monique Does, Ghislaine Scélo, Catherine Metayer, Steve Selvin, Robert Kavet, and Patricia Buffler. Radiat Res. 2011 March ; 175(3): 390–396. doi:10.1667/RR2357.1. NIH Public Access

•Contact currents occur when a person touches conductive surfaces at different potentials and completes a path through which electric current flows within the body. The voltage on a residential water line can produce contact currents in young children while they are bathing provided that they are in contact with a metallic fixture contiguous with conductive and grounded water pipes and that the drain is made of conductive material. In the only data set from a large-scale exposure assessment of residential contact voltage (10), about 4% of the residences had a contact voltage measurement of 100 mV or greater in the bathtub (data not shown). Assuming that a child's wet body resistance is 1,000 ohms (11), dosimetry modeling estimates that for an 18-kg child, the resulting current (100 μA) would produce a 99th percentile electric field in the lower arm of 1.5 V/m (12).

[100 μA = 1,500 mV/m or 1:15]

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