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SCIENTIFIC COMMITTEE ON EMERGING AND NEWLY IDENTIFIED HEALTH RISKS
(SCENIHR)

Opinion on Possible Effects of Electromagnetic Fields (EMF) on Human Health

Response from
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Note: These comments apply to the sections concerning ELF (power frequency) electric and magnetic fields

1. General Comments

As it stands, this document presents only a partial discussion of health effects associated with exposure to power frequency electric and magnetic fields (EMFs), since whole areas concerning health endpoints, possible mechanisms and the findings from analogous research fields are not discussed.

A number of statements are made which we would regard as unsupportable given the information available in the peer-reviewed literature on EMF health effects.

We are surprised that the California Department of Health Services EMF Report (CDHS 2002) is not cited. This report, after a ten year California EMF program, drew on the experience of the US NIEHS 1999 Report and the (unpublished) US NCRP Report of 1995, as well as IARC 2002, gave a 2B IARC classification to five health endpoints; childhood leukaemia, adult leukaemia, adult brain cancer, amyotrophic lateral sclerosis (ALS) and miscarriage.

At present a number of key studies, both epidemiological and laboratory, are not cited in the references.

The discussion of scientific mechanisms appears very limited. Further, the conclusions on page 43 state "*There is no known mechanism to explain how electromagnetic field exposure may induce leukaemia*". This gives an impression of a sweeping absolute assertion which we feel goes beyond the reasonable interpretation of the evidence. Of course, definitions of

"*explain*" and "*induce*" might be stretched to accommodate such an assertion, but we hope this is not what SCENIHR would wish to do. A better approach might be to note that candidate causal mechanisms have been put forward, with some evidence, for example those involving melatonin, which might explain an increased risk (importantly different and more appropriate a term than "induce" in this context), but that the evidence so far falls well short of establishing proof.

In recent years substantial progress has been made in the areas of the melatonin hypothesis and the radical pair mechanism. Findings from two research fields, beyond the terms of reference of current EMF health effects assessment committees, have yielded important relevant findings, namely (i) a somewhat similar range of adverse health effects to those reportedly associated with ELF EMF exposure have also been associated with fluctuations in solar and geomagnetic fields and (ii) the mechanisms by which some animal species detect small changes in the Earth's static magnetic field for the purposes of navigation are starting to be elucidated. Strong evidence in support of a radical pair mechanism as one navigational tool, suggests that in birds magneto-receptors, together with the necessary amplification mechanisms, exist in the eye. Findings in these areas add to the plausibility of ELF EMF health effects and the mechanisms by which they may occur.

Overall, considerably more work in developing this SCENIHR document would be of fundamental benefit before the document is published in final form.

Alternatively, an awareness of such areas of work, without a review of them, might be briefly stated and the conclusions moderated, if an early publication is desired.

2. Specific Comments

1. Statement, page 5 under ELF fields: "*There is no known mechanism to explain how electromagnetic field exposure may induce leukaemia*".

Response: (i) For ELF the correct term for the acronym EMF or EMFs should be "*electric and magnetic fields*" because at power frequencies (50/60 Hz) technically we are in the "near field", where the electric and magnetic field need to be considered separately. Note that at ELF frequencies there is essentially no associated electromagnetic radiation.

(ii) The assertion "*there is no known mechanism…*" is a theme repeated throughout the document. Not known to whom? This statement misrepresents the actual debate relating to how magnetic field exposure may affect cancer risk. As will be discussed below, some people would consider the melatonin hypothesis as a viable working hypothesis to explain the otherwise disparate range of adverse health outcomes associated with ELF EMF exposures. Also, advances in our understanding of the effect of low intensity magnetic fields on radical pairs, both in the laboratory and animal navigation, are particularly relevant to ELF EMF health effects. Note that the melatonin hypothesis and the radical pair mechanism should not be considered as competing or separate hypotheses, indeed the two mechanisms could be taking place hand-in-hand. The report's sweeping assertion, as stated, gives the impression of no evidence whatsoever, and total ignorance (and scepticism) of any potential mechanism at all, which is far from a balanced reflection of the actual evidence.

2. Statement, page 5 under ELF fields: "*The effects have not been replicated in animal studies*".

Response: Taken out of context, this statement misrepresents the actual situation. The real issue is that there is no animal model for acute lymphoblastic leukaemia, the common leukaemia sub-type in children.

3. Statement, under 3.2 Terms and Definitions: The definition of EMF, ELF and electromagnetic fields.

Response: As stated under (1) above, the term 'electromagnetic fields' should not be used to describe ELF fields, rather "electric and magnetic fields".

4. Statement, page 30, c: "*Medical Applications*"

Response: There are interesting parallels between the use of ELF EMFs for bone healing and radiotherapy in cancer treatment. In the case of radiotherapy, radiation doses in the regime of tens of sieverts, which are otherwise lethal, are routinely employed. The aim is, of course, to kill the cancer in question, be it a solid tumour or leukaemia. However, there remains a probability of the patient subsequently contracting secondary cancer from the treatment itself. At the same time, for ionising radiation, the International Committee on Radiological Protection (ICRP) imposes restrictions on public exposure in the milli-sievert regime. The ELF magnetic field analogue is the ICNIRP guideline exposure of 100 μT, which is 250 times higher than 0.4 μT where an associated doubling of the risk of childhood leukaemia has been acknowledged.

5. Statement, page 30, section 3.5.2.1: "*Furthermore, the IARC monograph concluded, there was no evidence for an association of ELF magnetic fields with any other type of cancer…*"

Response: What does the term '*no evidence*' mean and is this really what the IARC Report shows? In Appendix 1, below, we provide the results of a p-value analysis of the odds ratios of the epidemiological studies listed in tables 25, 26, 29 & 30 of the IARC Report (2002), in terms of the number of odds ratios with positive values and those which are statistically significant. We know very well the dangers of multiplying probabilities for non-independent events, and take this into account, and also have analysed sets of one OR per separate study; in all cases the calculations are remarkably significant. For adult leukaemia for example, from a total of 174 odds ratios the p-value for the 111 positive odds ratios occurring by chance is 0.0002 and for the 16 statistically significant positive odds ratios $p = 4 \times 10^{-15}$. A restricted analysis, avoiding any "double counting" yields respective p-values of 0.011 and 2×10^{-9}. A similar result is found for adult brain tumours.

These features were not brought out by the IARC authors, who showed no sign of awareness of them. By complementing IARC's essentially subjective assessment of the data with a more objective analysis of the aggregated cited studies, we see the statistical value of the information rejected by IARC. The adult leukaemia and adult brain cancer data cited by IARC are seen to be broadly in line with the data presented in CDHS (2002).

6. Statement Page 31 line 4: "*None of them* [possible mechanisms in Kheifets 2005 for the childhood leukaemia findings] *reaches a level beyond speculation*"

Response: This is an assertion and lacks specifics. In the English language the word "*speculation*" can carry strong overtones of disparagement. It is not clear how "speculation" is defined here, but science advances by forming and testing hypotheses. If the word is to be used, SCENIHR might consider defining "speculation" to mean a hypothesis which has not been tested at all and the plausibility of which is not supported by any evidence at all. We would counsel against using such emotive words. It would be better to provide specific examples of what was discussed at the WHO 2004 Istanbul meeting and then provide quantitative justification for a more measured statement.

7. Statement, page 31 para 1, in relation to breast cancer: "*However, later, big and well controlled studies have been entirely negative and the hypothesis of a link between ELF field exposure and breast cancer risk is essentially written off (Forssen et al. 2005)*".

Response: The study by Forssen *et al.* is indeed a large one. 20,400 cases of breast cancer were involved and the overall odds ratio for women exposed to 0.3 μT or more was 1.01 (95% CI: 0.93 – 1.10). However, the study could be considered to have three weaknesses: (i) the exposure assessments were based on job title which is a very crude method of assessing exposure and Forssen *et al.* acknowledge the possibility of exposure misclassification; (ii) this study concerns daytime exposure only, and so would not test the hypothesis that nocturnal melatonin disruption by EMFs may affect breast cancer risk (data on exposure to light-at-night, which suppresses nocturnal melatonin production, in night shift workers show increased risk of breast cancer) and (iii) the study by Forssen *et al.* is in a single Swedish population who enjoy good dark winter nights where nocturnal melatonin production might be less disrupted compared with populations in other developed countries. In the meta-analysis of EMF breast cancer studies by Erren (2001), it is interesting to observe that for all studies at higher latitudes (52º – 59º) the odds ratios obtained are close to the null, but for those at moderate latitudes (38º - 46º) positive odds ratios are observed, the average in this latitude band being 1.26. This limited evidence might be indicative of a latitude effect due to day length or due to interactions with the Earth's geomagnetic field.

The study by Forssen *et al.* has been commented upon by Erren (*Am J Epidem*. 2005; 162: 389-395), who also discusses melatonin, commenting on the problems of confounding with exposure to light-at-night as well as other methodological issues.

In summary, the study by Forssen *et al.* (2005), while indicating a low breast cancer risk from EMF exposure in the more northerly latitude of Sweden, does not justify that a link between EMFs and breast cancer can essentially be written off.

8. Statement, page 31 under '*Discussion*', where it is asserted that the association between CL and MF have little support from known mechanisms or experimental studies.

Response: This issue has already been discussed in (1) above. First, it needs to be acknowledged that there is no animal model for acute lymphoblastic leukaemia (ALL), the common form of leukaemia in childhood. The above statement depends on what is meant by a 'known' mechanism – known to whom? The implication would be known to science, by

publication in the peer-reviewed literature. A paper presented at the WHO Istanbul meeting in June 2004 and subsequently published in Henshaw & Reiter (2005) seeks to develop the melatonin hypothesis with respect to magnetic fields and childhood leukaemia. In that paper it is pointed out that whereas volunteer experiments have yielded equivocal evidence for melatonin disruption following acute exposure to magnetic fields, longer term exposures and populations chronically exposed to neighbourhood fields show a degree of consistency of melatonin disruption. The additional presence of magnetic field switching and/or electric fields also appears to be important. In recent experiments *in vivo*, melatonin has been shown to be highly protective of oxidative damage to human lymphocytes and in animals highly protective of oxidative damage to the fetus. The latter may be important given that the initiating step in childhood leukaemia is believed to occur *in utero*.

This is just one example of a working hypothesis. In summary, we would regard the statement on page 31 as constituting an unsupported assertion concerning the current state of scientific knowledge.

9. Statement, page 34 section titled "*Discussion*"

Response: This section while valuable could usefully be extended. Once more, for example, there is no mention of the melatonin hypothesis which would unite the otherwise disparate health end points associated with magnetic field exposure, ranging from childhood and adult leukaemia, brain tumours, depression and miscarriage. The following points are emphasised:

(i) Henshaw & Reiter (2005) show there is a degree of consistency that populations exposed to neighbourhood EMFs, show melatonin disruption, especially when MF switching and/or EFs are also involved.

(ii) A recently published volunteer study involving 115 women demonstrated melatonin suppression following exposure 5 nights per week for one month to a 0.8 μT magnetic field source placed under the bed while sleeping (Davis *et al.* 2006).

(iii) The properties of melatonin have been extensively researched. The multiple actions of melatonin, some of which are receptor mediated, make melatonin a broad-spectrum and ubiquitously-acting antioxidant. Its concentration in some tissues and organs can be orders of magnitude higher than in blood making it more effective that vitamins A, C or E or glutathione (see Editorial: Reiter & Tan 2003).
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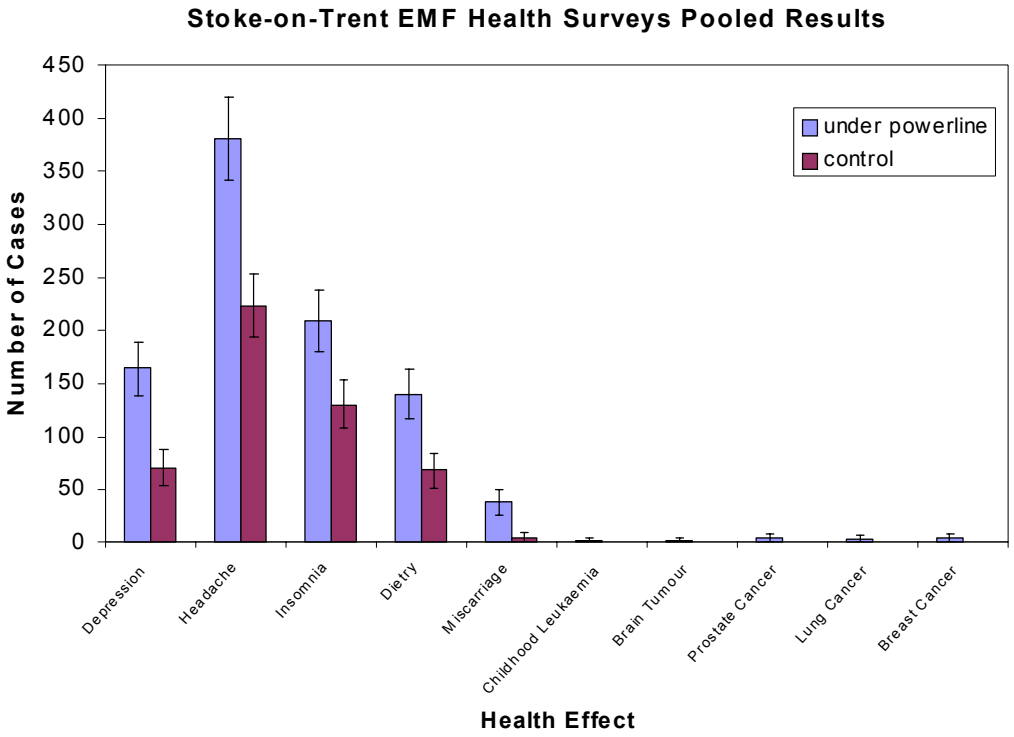
(iv) Blask *et al.* (2005) found that blood taken from women, containing the normal nocturnal burden of melatonin suppressed the growth of MCF-7 breast cancers transplanted into rats.

(v) A recent report by the UK HPA AGNIR on melatonin has been the subject of a critique which may be accessed at:
http://www.electric-fields.bris.ac.uk/CritAGNIR.htm

10. Statement, page 34, under section titled "*Symptoms*"

Response: This is probably the appropriate section to discuss depression and depressive symptoms. The peer-reviewed literature contains a number of reports of depression associated with EMF exposures (see references list below).

The difficulty with blind provocation studies is that rarely is there an opportunity to mimic chronic exposure to EMF, such as in individuals living near high voltage powerlines. Our own anecdotal experience is that most individuals report no symptoms as a result of living close or under high voltage powerlines. Conversely, given that some people do display symptoms this may suggest a sensitivity effect in some individuals. We have been given the results of three surveys of symptoms in individuals living within 25 metres of high voltage powerlines in Stoke-on-Trent, Staffordshire, UK. While these are not peer-reviewed studies, and they were made following widespread local concern, care was taken to establish a matched control population. The pooled results for various reported health effects are given in the figure below:



Data such as these, together with the body of peer-reviewed literature, suggest that the possibility of increased risk of depression and depressive symptoms, suicide and miscarriage (see also next section) in relation to chronic neighbourhood EMF exposures cannot be dismissed.

11. Statement, page 35, section 3.5.4.1 "*Epidemiology*"

Response: (i) Currently missing from this section is a discussion of miscarriage. The California Department of Health Services EMF Report (2002) reviewed various studies of

spontaneous abortion: (i) women working with VDTs; (ii) use of electric bed or blankets; (iii) studies using residential spot or wire code exposure metrics and (iv) two recent studies by Li *et al.* (2000) and Lee *et al.* (2000) which found an association with peak fields and a rate of change parameter. CDHS (2002) assigned an IARC Class 2B classification to miscarriage.

(ii) Also missing is a discussion of suicide risk. A number of studies have suggested an increased risk of suicide with EMF exposures (e.g. Wijngaarden *et al.* 2000 and the references list below). A plausible mechanism related to melatonin and depression has been suggested.

(iii) The statement "*However, later well controlled studies have dismissed this hypothesis*" for cardiovascular disease seems both hasty and extreme. Firstly, the hypothesis was prompted by an "*effect of heart rate variability seen in laboratory studies*" which presumably remains valid and which might plausibly affect cardiovascular disease in some susceptible subsets of the population. Secondly, the new general evidence itself is specifically limited (as discussed above) and does not support a universal conclusion (as distinct from a general Swedish population conclusion). Thirdly, by way of analogy, unusually high values of fluctuations in the geomagnetic field are reported to have an effect on cardiovascular health (Palmer *et al.* 2006). Fourthly, effects on heart pacemakers are accepted. The hypothesis itself, "*that ELF exposure might affect the risk of cardiovascular disease*", is quite open and unrestricted, and hence less easily dismissed. The assertion of dismissal of such a broad hypothesis seems therefore scientifically unsound.

12. Statement, page 36 under 'Endocrine system', concerning melatonin disruption by magnetic fields it is said: "*No effects have been seen on human volunteers under controlled laboratory conditions*".

Response: (i) This statement is not correct. Some official reports have classified studies as showing 'no effect' when effects are evident but not at the 95% confidence level. Such practice is flawed as explained in epidemiology text books (e.g. Rothman and Greenland 1998, Ch. 12), and should be avoided since it constitutes misrepresentation of the data.

(ii) Whereas it is true that human volunteer experiments involving acute exposures to magnetic fields under laboratory conditions have provided equivocal evidence of melatonin disruption, volunteer experiments with non-acute exposures and studies of populations exposed to neighbourhood fields do show evidence of melatonin disruption. In the case of neighbourhood fields, the effect of magnetic field switching and/or the presence of electric fields appears of additional importance (see Henshaw & Reiter – paper presented at the WHO Istanbul Workshop, June 2004 and published in *Bioelectromagnetics* 2005). A recently published volunteer study involving 115 women demonstrated melatonin suppression following exposure 5 nights per week for one month to a 0.8 μT magnetic field source placed under the bed while sleeping (Davis *et al.* 2006).

13. Statement, page 37 under "*Conclusions about ELF fields*"

Response: (i) As stated above, we question whether the IARC judgement on the data actually presented in its 2002 report is properly informed and reasonable. As illustrated in (5) above and in Appendix 1, by complementing IARC's essentially subjective assessment of the data with a more objective analysis of the aggregated cited studies, we see the statistical value of

the information rejected by IARC and the similar information considered (in part at least) in the California Department of Health Services EMF Report (CDHS 2002). The latter report classified both adult leukaemia and adult brain cancer as a Class 2B possible carcinogen, as well as three other health outcomes of EMF exposure.

(ii) We also question the statement that the epidemiological results for childhood leukaemia have little support from known mechanisms and experimental studies, since this gives little credit for recent advances in understanding.

14. Statements; page 42 in the ELF conclusions.

Response: (i) Some statements seem to be too hasty or prejudiced an interpretation of the scientific evidence and carry unwarranted overtones, for example: "*The effect, if any, seems to be limited to exposures above 0.4 μT*" and "*There is no convincing suggestion of any other carcinogenic effect of ELF on either children or adults."* In the latter, we recognise that the use of "*convincing*" provides an escape, but hope that SCENIHR would not wish to create an impression, such as the phrase "*no convincing suggestion*" does, of nothing to consider. This latter sentence seems to have the effect of diminishing hypotheses for end points beyond childhood leukaemia, yet the same might be said of childhood leukaemia, so the sentence seems rather gratuitous.

(ii) Also, phrases such as "*speculation*", "*no convincing suggestion*", "*no known mechanism*" and "*no evidence*" are in some cases simply wrong. For example, the attribution to IARC of the conclusion that "*there was no evidence for an association of ELF magnetic fields with any other type of cancer*", does not actually follow from an objective analysis of the data in the IARC report.

IARC, for all its shortcomings, takes care to put its conclusions into an explained format of definitions, and classed the relevant evidence in this case as "*inadequate*". It would be better if SCENIHR had a set of defined terms in order to reduce the appearance of prejudice.

15. Statement, page 43 top paragraph: "*There is no known mechanism to explain how electromagnetic field exposure* [the authors mean electric and magnetic field] *may induce leukaemia*".

Response: As already stated, this statement fails to point to the progress in understanding how EMFs may cause increased risk of childhood leukaemia. The term '*induce leukaemia*' implies primary (1st hit) cause and says nothing about promotional factors in childhood leukaemia.

16. Statement, page 43 top paragraph: "*The effects have not been replicated in animal studies*".

Response: As already stated, the sentence is not meaningful because the real issue here is that there is no animal model for acute lymphoblastic leukaemia, the most common form of leukaemia in children.

The following two sections concern areas of science which would normally fall outside the terms of reference of committees investigating the health effects of exposure to power frequency electric and magnetic fields.

3. Adverse health effects associated with fluctuations in solar and geomagnetic fields

The natural geomagnetic field of the Earth is far from static. Superimposed on the quasi-static, latitude dependent field, ranging from approximately 20 to 60 μT, are fluctuations on short-term time-scales. The so-called Schumann resonances, with principal ELF frequencies 7.8, 14.2, 19.6, 25.9, 32 and 41 Hz arise from cavity oscillations in the ionosphere induced by solar and global lightning activity. Some of these frequencies coincide with the frequency of certain brain rhythms. Other fluctuations, varying between 5 and 500 nT occur as a result of geomagnetic storms and are described over three hour periods by K-indices. This is in addition to nano-tesla changes resulting from the natural diurnal variations due to solar activity.

A range of adverse health effects not dissimilar to those associated with ELF EMFs have been reported as associated with fluctuations in the Earth's geomagnetic field. These have been partially reviewed by Ward (2006):
http://www.electric-fields.bris.ac.uk/Volume2%20Appendix1&2.pdf

A more comprehensive review has been made by Palmer *et al.* (2006).

This body of data provides information on adverse health effects of ELF EMF exposure by way of analogy and plausibility.

4. Animal navigation in the Earth's geomagnetic field

Many animal species are known to navigate by sensing small changes in the Earth's magnetic field. Birds have been identified as having compass and magnetic intensity information, the latter, attributed to magnetite in their breaks, enabling changes as low as 10 nT to be detected. Ritz *et al.* (2004) identified robins as possessing compass information by means of a radical pair mechanism involving detection of field changes as low as 84 nT. In a recent review, Wiltschko and Wiltschko (2006) described this mechanism in birds as due to an array of magneto-receptors, consisting of photopigments, postulated to be cryptochromes, situated in the right eye. For magneto-reception to occur, visible light of a particular wavelength initiates radical pair production from which magneto-reception occurs from the detection of the ratio of singlet to triplet spin states. It would appear that in birds these photopigment arrays constitute the necessary mechanism for amplifying magnetic field interaction with a single pair spin state to a signal of sufficient amplitude to be interpreted and registered by the brain.

How do these finding relate to adverse health effects of ELF EMFs in humans? They demonstrate a biological mechanism for the detection of low intensity magnetic fields (in the tens of nT regime), and one which involves one of the candidate mechanisms for adverse health effects of ELF field exposure. The finding that in birds magneto-reception occurs in the eye, at the site of the newly discovered ganglion cells which signal the pineal gland to

produce nocturnal melatonin, is intriguing (Berson *et al.* 2002, Hattar *et al.* 2002). Equally intriguing, in salamanders the magneto-receptors have been found to be located in the pineal gland itself (Deutschlander *et al*. 1999, Adler & Taylor 1980).

With time-scales of microseconds, the radical pair mechanism will not discriminate between static or power frequency fields, thus extending the mechanism, to the existing body of work on the adverse effects of power-frequency magnetic fields.

An important principle for ELF and RF fields is that if a signal or exposure can be detected, in principle it can have an effect. This is an '*information effect*' – one which needs only the energy necessary to transmit the information, not the energy to create an energetic effect directly. Such information effects might be suspected where there are intricate control systems and in-built amplification mechanisms. It sometimes seems as though the established review bodies have been unable to consider such information effects and have been prejudiced by a supposed implausibility of energetic effects.

Appendix 1

Statistical comparison of the reviews of epidemiological studies of adult leukaemia from the California Department of Health Services (CDHS) EMF Report (2002) and the International Agency for Research on Cancer, IARC Report (2002).

A1.1 California Report

Table 1 presents a p-value analysis of the odds ratios from studies considered in the California Department of Health Services EMF 2002 report (CDHS 2002). We know very well the dangers of multiplying probabilities for non-independent events, and take this into account. Representative results were used in the California report, one from each study, to avoid this problem. Here we have used the cumulative binomial distribution for p-values for the observed numbers of positive or positive-significant results. Apart from childhood leukaemia, low p-values (<0.05) are found for a number of end points. For purposes of comparison with IARC (2002), these include both adult leukaemia and adult brain tumours.

Table 1. Epidemiological studies reviewed by CDHS (2002) and the corresponding number of odds ratios > 1.0, number which were statistically significant and p value for each set.

Disease	Number of studies	Positive studies: number, p value*		Significant positives: number, p value*	
1. Childhood leukaemia	19	16	0.0014	3	0.01
2. Adult leukaemia	43	32	0.0007	11.5	<<0.00001
3. Adult brain cancer	32	25	0.0007	6	0.0001
4. Miscarriage	37	27.5	0.0015	9	<<.00001
5. ALS	7	6,	0.06	3	0.0004
6. Childhood brain cancer	12	6	>0.5	2	0.04
7. Female breast cancer	24	17.5	0.012	5.5	0.0001
8. Male breast cancer	16	11.5	0.04	-	
9. Alzheimer's disease	6	4	0.34	2.5	0.001
10. Suicide	8	6.5	0.02	3	0.0007
11. Heart disease	8	6.5	0.02	5.5	<<0.00001

*Null hypothesis, result occurs by chance

For the CDHS set of adult leukaemia studies, there are similar relative risks for the residential and the occupational studies. Taking all 43 studies together, based on the externality of Kheifets *et al.* (1997) selected representative odds ratios, the meta-analytic summary cited from Kheifets *et al.* was OR = 1.2 with CI 1.12 - 1.14. The CI values were given in the draft 3 CDHS report.

Of the 43 studies, the CDHS report, page 121, notes that 29 had OR > 1 with $p \leq 0.01$. That is, in aggregate the occurrence of positive results is statistically significant. Counting results with OR = 1.0 as half positive and half negative gives 32 positive results with $p < 0.001$, highly significant.

A much stronger statistical observation, not made by CDHS, is the number of significant positive results. These are results with 95% confidence intervals wholly above 1. For the one-sided test (that has p = 0.025 for each occurrence) there are 14 occurrences, that is, significant positive results from the 43 listed results, and no significant negatives. This combination has a p-value of approximately 10^{-12}, which is extremely significant. The significance boundary is different from the 50-50 split for simple positives, so that a marginal occurrence with lower confidence limit equal to 1.0 might still be counted as with p = 0.025 for the occurrence, but even if these marginal occurrences were only counted as halves there would still be 11.5 occurrences with aggregate p-value approximately 10^{-8}, which is still extremely significant.

Although CDHS did not note the number of significant positives, they did note the meta-analytic summary and the number of positives, and formed a view about the strength of these findings which led them to give them greater weight than, seemingly, did the IARC Report.

A1.2 IARC Report

Now consider the statistical aggregation of the adult leukaemia results chosen by IARC.

Firstly, they include ranges of exposures from the same studies, both high and low exposure categories. It is surprising therefore that simply combining all the IARC-reported results together (omitting only base or reference levels) gives a statistically strong aggregation, as shown in table 2, taken from tables 25, 26, 29 & 30 of the IARC Report. Note that not all the results are independent; e.g. some are totals of other results for sub-types of leukaemia.

Table 2. Adult leukaemia studies reviewed by IARC (2002) and the corresponding number of odds ratios > 1.0, number which were statistically significant and p value for each set.

Description (all results)	No. of RRs	Positives	p-value for Positives	Significant Positives	p-value for Sig-Pos
Residential	33	21.5	0.0814	5	0.0013
Cohort occupational	72	40	0.2048	12	2×10^{-7}
Case-control occupational	69	49.5	0.0003	16	1×10^{-11}
Total	174	111	0.0002	33	4×10^{-15}

Now consider the results (as tabled by IARC) after (our) selection for relevance. First, where there are multiple results for sub-types of leukaemia, select only the total or "all leukaemias" results, so that sub-type results are not repeated and individual studies are not over-represented. Likewise, take Theriault's combined cohort results [as cited in IARC], not the separate ones. Second, where there are separate results tabled for different exposure bands from the same study, select only the highest band, so that the most relevant test to detect an effect is used. That will mainly be with a cut point at 0.2 μT, which is lower than the principal categories of Ahlbom *et al*. (2000) and Greenland *et al.* (2000). Third, omit results which give low cumulative exposures in μT-years, typically below an average of 0.2 μT. Fourth, omit occupational studies which give no estimate of exposure. This gives the results in Table 3.

Table 3. Adult leukaemia studies reviewed by IARC (2001) and the corresponding number of odds ratios > 1.0, number which were statistically significant and p value for each set – selected as described in the text.

Description (select results)	No. of RRs	Positives	p-value for Positives	Significant Positives	p-value for Sig-Pos
Residential	5	4	0.1875	2	0.0059
Cohort occupational	6	5	0.1094	4	6×10^{-6}
Case-control occupational	5	4	0.1875	2	0.0059
Total	16	13	0.0106	8	2×10^{-9}

As would be expected, the effect of selection is to reduce numbers of results admitted, and thereby to reduce p-values, while increasing the percentage both of positive results and of significant-positive results.

In conclusion on this statistical comparison, the results considered by IARC, although different from those considered by CDHS, carried at least as strong an aggregate statistical message. That message remains after further selection of results for relevance. CDHS identified part of the message, but not the strongest part. IARC did not identify the message.

Appendix 2

DRAFT – Version 1 29/6/06: Adverse health effects associated with exposure to ELF electric and magnetic fields – assembly of scientific evidence and discussion of possible public health impact - Summary

M. J. O'Carroll[1] & D. L. Henshaw[2] with help from J. Close, J. Ward, S. Limb, E. Ainsbury, A. Buckley, P. Keitch, J. Matthews and M. Wright. [1]University of Sunderland, Garden House, Welbury, Northallerton, DL6 2SE, UK. [2]H H Wills Physics Laboratory, University of Bristol, Tyndall Avenue, Bristol, BS8 1TL, UK

The summary below is taken from a 160-page draft document which assesses the scientific evidence for the range of adverse health effects which have been associated with exposure to power frequency electric and magnetic fields. The document also carries out cost impact analysis for the UK population on the basis of a number of "*what if*" scenarios. The main conclusion, given in the first table, shows that when illnesses other than childhood leukaemia are considered, it becomes cost-beneficial to consider active remedial measures to reduce exposure to power frequency electric and magnetic fields.

The full document (in three volumes) may be accessed at:
http://www.electric-fields.bris.ac.uk/ocarroll.html

Summary

The following table gives the total impact on society, in thousands of pounds per year per 1,000 exposed population, from EMF exposure for five '*what-if*' scenarios, as calculated in a moderate and transparent way in section 2.3 of the main document. The impact of other diseases is of the order of 100 times greater than that of childhood leukaemia alone.

	CL alone[1]	NIEHS 2[2]	CDHS 5[3]	CDHS 11[4]	12 diseases[5]
With credibility factors	4	70	146	679	716
With definite causation	5	122	246	1899	2629

[1]Childhood leukaemia; [2]Childhood and adult leukaemia; [3]as 2 plus adult brain cancer, ALS and miscarriage; [4]full list in CDHS 2002; [5]as 4 plus depression.

We do not think it is rational to base an assessment of cost impact on childhood leukaemia alone, when most of the hypothesised mechanisms and their supporting evidence relates to biological systems involved in many diseases, rather than exclusively to childhood leukaemia. The decreasing 'Degree of Certainty' [as described in CDHS 2002] with greater numbers of diseases is however reflected in the credibility factors. Therefore, while there remains considerable uncertainty and imprecision in such assessments, it seems sensible to give consideration to the above scenarios and multiple outcomes, without adopting any one as definitive.

The next table shows the numbers of ELF-EMF epidemiological studies covered in major reviews to 2002, as explained in section 2.2. This shows that, on the basis of numbers of

studies and their statistical strength, there is stronger evidence for some other diseases than for childhood leukaemia.

Disease	Studies	Positives	Significant positives	Significant negatives
Childhood leukaemia	19	16	3	0
Adult leukaemia	43	32	11	0
9 other diseases	150	110	36	1

Since 2002 there have been many new studies increasing knowledge of potential mechanisms. Important earlier studies have been overlooked in the major reviews, for example the results of Schuz *et al.* (2001) showing stronger associations of childhood leukaemia with nocturnal exposure, with its implications for the melatonin hypothesis.

In addition, we note two substantial areas of established and relevant research which have also been largely overlooked: solar and geomagnetic activity (S-GMA), which includes ELF exposure and bio-detection of magnetic fields by migrating birds and other animals. Both give firm implications for biological effects of very low fields. The first reinforces implications of ELF EMFs for various diseases. The second reinforces implications for biological mechanisms by which this may be possible.

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