# NRPB Consultation Document

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## Proposals for Limiting Exposure to Electromagnetic Fields (0 – 300 GHz)

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## Summary

**The review of health effects in the Consultation Document of exposure to power frequency EMFs needs to be improved in a number of ways. It is essential to give due mention to the findings of the 2002 California Health Department EMF Report which, in addition to childhood leukaemia, associates a number of cancer and non-cancer illnesses with exposure to magnetic fields, including adult brain cancer, Amyotrophic Lateral Sclerosis or ALS and miscarriage. Reference should also be made to further recent studies which continue to report adverse health effects such as neurodegenerative diseases associated with magnetic field exposures.**

**The evidence for an association between childhood leukaemia and magnetic field exposures greater than 0.2 μT should be acknowledged.**

**There is now a strong body of evidence that chronic exposure to magnetic fields as low as 0.2 μT or lower disrupts the production of melatonin in the pineal gland. Further evidence suggests that the *disruption* as well as *reduction* in pineal melatonin production may act to increase the risk of cancer and other adverse health outcomes. There is also a body of evidence that the oncostatic action of melatonin is impeded by magnetic fields as low as 1.2 μT.**

**Recent research into the role of melatonin as a potent radical scavenger shows that the hormone is highly protective of oxidative damage to the human haemopoietic system and to the fetus. Overall, the evidence supports the hypothesis of a causal chain of events in which exposure to magnetic fields affects the efficacy of melatonin in protecting the haemopoietic system either *in utero* or in childhood, increasing the risk of leukaemia. This hypothesis could also apply to other cancer and non-cancer adverse health outcomes associated with magnetic field exposures.**

**The health effects of exposure to time-weighted average power frequency magnetic fields above normal neighbourhood levels, in the range 0.2 to 1.6 μT, are potentially large and may therefore be significant in terms of public health policy. In the case of new fixed installations, some countries have already introduced strict limits on exposure, based on considerably less evidence of adverse health effects than is now apparent. Similar measures should be adopted as a matter of urgency if the UK is not to be seen as insensitive to the health effects of those involuntarily exposed to elevated levels of magnetic fields. Ideally, the aim should be to restrict exposures to typical neighbourhood levels, around 0.05 μT.**

**Furthermore, in the case of existing installations, notably high voltage powerlines in the vicinity of houses, hospitals, schools, nurseries and children's play areas, a timetable of remedial measures should be introduced.**

## Detailed comments

### Introduction

I will be confining my comments to power frequency electric and magnetic fields, so they will mainly refer to the section of the Consultation Document < 100 kHz.

**1.** As a general point, I was surprised that there appears to be no reference to the California Health Department Report of June 2002: "*An evaluation of the possible risks from electric and magnetic fields (EMFs) from power lines, internal wiring, electrical occupations and appliances*". Prepared by R R Neutra, V DelPizzo and G M Lee. Available online at http://www.dhs.ca.gov/ehib/emf/RiskEvaluation/riskeval.html. I believe it essential that this report be acknowledged. It reaches a number of conclusions:

- EMFs (electric and magnetic fields) can cause some degree of increased risk of childhood leukaemia, adult brain cancer, Lou Gehrig's Disease (Amyotrophic Lateral Sclerosis or ALS) and miscarriage:

- The reviewers strongly believe that EMFs do not increase the risk of birth defects or low birth weight;

- The reviewers strongly believe that EMFs are not universal carcinogens, since there are a number of cancer types that are not associated with EMF exposure;

- To one degree or another, the Reviewers are inclined to believe that EMFs do not cause an increased risk of breast cancer, heart disease, Alzheimer's Disease, depression, or symptoms attributed by some to a sensitivity to EMFs. However,

- All three scientific reviewers had judgements that were "close to the dividing line between believing and not believing" that EMFs cause some degree of increased risk of suicide, or

- For adult leukaemia two of the scientific reviewers are "close to the dividing line between believing and not believing" and one was "prone to believe" that EMFs cause some degree of increased risk.

I should emphasise that in the light of the continuing evidence that is being published and the new evidence on mechanistic considerations involving melatonin, I would go further than the findings in the California Health Department Report. Further explanation of the conclusions I now draw are given in this reply document.

**2.** Under paragraph 117, the prospective study on magnetic fields and miscarriage by Lee *et al*. (2002) should be included alongside that of Li *et al*. (2002). Note that these two studies were published concurrently in Volume 13 of *Epidemiology*.

**Section 4: Electromagnetic fields of frequencies < 100 kHz**

Paragraphs 105 and 106

I believe the above California Health Department EMF Report should also be mentioned here.

Paragraph 108 - concerning childhood leukaemia

In addition to the pooled analysis of childhood leukaemia studies by Ahlbom *et al*. (2000) mention should also be made of the pooled analysis by Greenland *et al*. (2000) which suggests a 1.7-fold increase in risk for magnetic field exposures above 0.3 μT.

It should be mentioned that both these pooled analyses concerned studies of exposure in childhood. Greaves (2002) provides evidence that the initiating step in childhood acute lymphoblastic leukaemia occurs *in utero* (or is at least present at birth). Two studies have looked at childhood acute lymphoblastic leukaemia risk in relation to exposure during pregnancy. Infante-Rivard (1995) found increased childhood leukaemia risk in relation to mothers exposed to magnetic fields from sewing machines (odds ratio 5.78; 95% CI: 1.27 – 6.25). Infant-Rivard and Deadman (2003) carried out a population-based case-control study of 491 incident cases of acute lymphoblastic leukaemia in children in Québec, in which occupational magnetic field exposure during the mother's pregnancy was assessed. Increased risk of childhood leukaemia in relation to magnetic field exposure was found for exposures greater than 0.2 μT. The highest odds ratio of 2.5 (95% CI = 1.2 - 5.0) was found for maximum exposure attained in an occupation (> 0.4 μT).

The findings of Greenland *et al*. (2000) and Infante-Rivard and Deadman (2003) mean that the possibility of increased risk of childhood leukaemia below 0.4 μT cannot be excluded.

Paragraphs 109, 110 & 111 - concerning brain tumours and leukaemia in adults

*(i) Brain Tumours*

Notwithstanding the statements in paragraphs 109 & 110, there does appear to be a clear association between magnetic field exposure and increased risk of brain tumours in adults.

Chapter 9 of the California Health Department Report reviews thirty-two studies of adult brain cancer (see page 166 of the California Report attached as Appendix 1). Of these, twenty-four give an odds ratio greater than 1.00, two give an odds ratio of 1.00 and six give an odds ratio less than 1.00. Furthermore, of the twenty-four studies with an odds ratio greater than 1.00, six are statistically significant.

On a simple binomial distribution we could ask what is the probability of obtaining this set of odds ratios by chance if there were no association between magnetic fields and adult brain cancer? Whichever way one looks at the figures, the probability of a chance finding is extremely small ($< 10^{-2}$). Furthermore, if we separate out the six studies where the odds ratios are statistically significant, for the remaining twenty-six studies, it is still the case that the probability of observing eight studies with an odds ratio of 1.00 or less remains small.

This means that taken as a whole, both the set of studies with odds ratios that are statistically significant and the remaining set independently provide evidence of an association between adult brain tumours and magnetic fields.

Two further papers have been published on adult brain tumours since publication of the California Report. Villeneuve *et al*. (2002) reported an increased risk among men diagnosed with glioblastoma multiforme (OR = 5.36; 95% CI: 1.16-24.78) for average occupational exposures greater than 0.6 μT relative to those with exposures < 0.3 μT. Navas-Acién *et al*. (2002) found evidence that ELF magnetic fields seemed to enhance the effect of specific chemicals in the causation of gliomas.

There is mechanistic support to suggest that the association between magnetic fields and brain tumours is causal. Wei *et al*. (2000) found that magnetic fields can increase the proliferation of human astrocytoma cells and strongly potentiate the effects of two agonists. As discussed in more detail later, there is now strong evidence that chronic exposure to magnetic fields as low as 0.2 μT or lower can suppress and otherwise disrupt the nocturnal production of melatonin in the pineal gland. There is further evidence that melatonin is highly protective of oxidative damage to the brain *in utero*.

**Taking the above findings, I conclude that there is strong evidence for a causal association between adult brain cancer and magnetic field exposures**.

*(ii) Adult leukaemia*

Concerning adult leukaemia, chapter 8 of the California Report cites forty-three independent odds ratios from thirty-nine studies (see pages 121 & 122 of the California Report attached as Appendix 2). Of the forty-three odds ratios, thirty are > 1.00, five are 1.00 and eight are < 1.00. Of the thirty-five studies with odds ratio > 1.00, nine of these are statistically significant.

As with brain tumours, the probability of obtaining the above set of odds ratios by chance if there were no risk with magnetic field exposures, is extremely small ($< 10^{-2}$).

As will be discussed in more detail later, melatonin is highly protective of oxidative damage to the haemopoietic system. This suggests that suppression of the production and disruption of the action of melatonin by magnetic fields could act to increase leukaemia risk.

**I therefore conclude that there is strong evidence for a causal association between magnetic field exposures and adult leukaemia.**

Paragraph 111 – concerning breast cancer.

Erren (2001) has provided a particularly valuable meta-analysis of forty-three epidemiological studies in relation to breast cancer in women and men. Of twenty-four studies among women, the pooled relative risk was 1.12 (95% CI: 1.09 - 1.15). Of the fifteen studies among men, the pooled relative risk was 1.37 (95% CI: 1.11 – 1.71).

### 4.2.3 Neurodegenerative diseases

Paragraph 112

Two papers have appeared in the July 2003 issue of *Epidemiology*, Vol 14 (No. 4). Feychting *et al*. (2003a) report increased risk of Alzheimer's disease mortality (RR = 2.3; 95% CI = 1.6 – 3.3 for exposures > 0.5 μT). ALS was not associated with EMF exposure but the risk estimate with "electrical and electronics work" was 1.4 (95% CI = 1.1 -1.9). Håkansson *et al*. (2003a) report increased risk of both Alzheimer's disease mortality (RR = 4.0; 95% CI = 1.4 – 11.7) in the highest exposure group for both sectors combined and ALS (RR = 2.2; 95% CI = 1.0 – 4.7) in the highest exposure group.

The journal has also published an authors' commentary by Feychting and colleagues (2003b) and Håkansson and colleagues (2003b) on the similarities and differences between these studies and their findings.

### 4.2.4 Suicide and depression

Paragraph 113

In my opinion, the evidence associating magnetic field exposures with increased risk of both depression and suicide is much stronger than that acknowledged in any of the recent international reports.

I have published my own review on this subject (Henshaw, 2002). In the case of depression, although there are variations in the type of depressive symptoms being reported, there is otherwise consistency in the trend towards an association with magnetic field exposures. Here, I find the data for the UK carried out in the Midlands by the Wolverhampton GP, the late Dr Stephen Perry (Perry *et al*. 1989) to be particularly relevant. Similar comments apply to the reported increased risk of suicide associated with magnetic field exposures (Reichmanis *et al*. 1979; Perry *et al*. 1981).

There are mechanistic reasons for supposing that increased risk of depression and suicide might be associated with magnetic field exposures. As discussed in more detail later, there is now strong evidence that chronic exposure to magnetic fields as low as 0.2 μT or lower can suppress and otherwise disrupt the nocturnal production of melatonin in the pineal gland. Depression is known to be associated with reduced melatonin (Nair *et al*. 1984, 1985 and papers in Wilson, 1988) and severe depression is known to be a strong risk factor for suicide.

### 4.2.7 Reproductive outcome

Paragraph 116

The California Health Department EMF Report reviews eleven studies of spontaneous abortion in relation to high magnetic field VDU exposure (see page 248 of the California Report attached as Appendix 3). Nine of these have an odds ratio > 1.00, one has an odds ratio of 1.00 and one has an odds ratio < 1.00. For three of the studies with an odds ratio > 1.00, the association is statistically significant.

Modern VDUs have much lower magnetic fields than earlier models. It would appear from the above that exposure near older types of VDUs with high magnetic fields is associated with increased risk of spontaneous abortion.

Paragraph 117

The study by Lee *et al*. (2002) should be included in this paragraph. It was published alongside the study by Li *et al*. (2002) in Volume 13 of *Epidemiology*. Lee *et al*. (2002) found clear evidence of increased risk with magnetic field exposures. The evidence was greater for maximum level exposure compared with the time-weighted average exposure. Starting with the highest quartile exposure, adjusted odds ratios and 95% confidence

intervals were 3.1 (95% CI = 1.6 -6.0), 2.3 (95% CI = 1.2 - 4.4) and 1.5 (95% CI = 0.8 – 3.1) for the rate-of-change metric; 2.3 (95% CI = 1.2 – 4.4), 1.9 (95% CI = 1.0 – 3.5) and 1.4 (95% CI = 0.7 – 2.8) for the maximum value; and 1.7 (95% CI = 0.9 – 3.3. ), 1.7 (95% CI = 0.9 – 3.3) and 1.7 (95% CI = 0.9 – 3.3) for time-weighted average.

There is disagreement about the merits of the above two studies. With regard to the comment in AGNIR 2002, I wrote to the then Chairman of the AGNIR, Sir Richard Doll, to express the view that I thought that the points made in AGNIR 2002 were of relatively minor nature which did not affect the positive associations referred to in the studies. I understand that Dr Raymond Neutra, lead author of the California Health Department Report and co-author with Lee *et al*. (2002), also wrote to Sir Richard Doll to express similar sentiments (Neutra, 2002, personal communication).

### 4.2.8 Epidemiological uncertainties

Paragraphs 119 & 120 – concerning bias and confounding

The California Health Department EMF Report repeatedly emphasises that biases and confounding may act either to increase or to decrease an association. It should not therefore be automatically assumed that positive associations can be "explained away" by bias and confounding.

Paragraph 121 – concerning inconsistencies in results, for example, concerning depressive illnesses.

There are still gaps in our knowledge of how best to characterise exposure to power frequency magnetic fields. Kato and Shigemitsu (1997) showed that circularly polarised fields were far more efficient at suppressing pineal melatonin production in Wistar-King rats compared with linearly polarised fields. Polarised fields occur principally near high voltage powerlines, although they can occur near houses from underground cables with poor phase imbalance. Thus, there may be sound reasons of metric for the apparent inconsistencies in findings concerning depressive illness. As stated above, my view is that there is consistency in the overall findings of an association between magnetic field exposure and depressive illness.

(The literature on reduced nocturnal production of pineal melatonin in human population groups (see below) contains a number of examples of occupational exposures near powerlines and their associated polarised fields).

### 4.2.9 Summary

Paragraph 123

It is incorrect and misleading to say that prolonged exposure to higher levels of ELF magnetic fields is associated with a *small* raised risk of leukaemia in children. At 0.4 μT the risk is actually doubled. Current studies have tended to look at exposure in childhood. Two studies that have addressed exposure in pregnancy give higher risk factors and such exposures are by their nature relatively short term.

The pooled analyses of Greenland *et al*. (2000) and the findings of Infante-Rivard and Deadman (2003), mean that the possibility of increased risk of childhood leukaemia below 0.4 μT cannot be excluded.

I regard the statement that IARC (2001) "*considered the evidence for excess cancer risks of all other kinds in adults and children as inadequate*" to be outdated. We now have the benefit of more recently published information, the California Health Department Report cited above suggesting links between magnetic field exposures and brain cancer and leukaemia in adults, as well as the recent reports below, in relation to prostate cancer and melanoma.

As explained below, I regard the evidence of reduced melatonin secretion by magnetic fields as low as 0.2 μT or lower, and the recent findings that melatonin is highly protective of oxidative damage to the human haemopoietic system, as powerful evidence of a causal association between magnetic fields exposure and increased childhood leukaemia risk.

Paragraph 124

The statements in this paragraph should be revised to take account of the recently published studies on Alzheimer's disease and ALS discussed under paragraph 112 above (Feychting et al. 2003a, b; Håkansson *et al*. 2003a, b).

**Paragraph 125**

**I strongly disagree with the statement that the results of epidemiological studies cannot be used as a basis for the derivation of quantitative limits on exposure to EMFs. In fact, for new fixed installations, I think the statement cannot be defended.**

**We now have a substantial body of human epidemiological data indicating a range of both cancer and non-cancer adverse health outcomes associated with power frequency exposures to magnetic fields in the range 0.2 – 1.6 μT. Such evidence would justify the imposition of exposure limits well below 0.2 μT and certainly not at the level of 100 μT proposed in the NRPB Consultation Document.**

**contd..**

**Paragraph 125 continued**

**Already, in the case of fixed electrical installations, such as powerlines and substations, some countries have acted to reduce exposures on the basis of considerably less evidence than that now presented by NRPB, itself in need of further update. Thus, in 1998, Sweden introduced an advisory limit of 0.2 μT. Similarly, in 1999, Switzerland introduced a regulatory 1 μT limit. In 2000, three Italian regions: Veneto, Emiglia-Romagno and Tuscany introduced a 0.2 μT limit[1].**

**The Consultation Document should be updated in a number of areas to include discussion of the California Health Department EMF Report of 2002 and further recently published papers on adverse health outcomes from magnetic field exposures.**

**There is evidence to suggest increased risk of childhood leukaemia by exposure to time-weighted average flux densities above 0.2 μT. There is also evidence of increased risk of certain adult cancers, especially brain tumours and leukaemia in relation to magnetic field exposures.**

**At 0.4 μT the increased risk in childhood leukaemia indicated by epidemiological studies is not small, rather a doubling of risk is observed. The evidence of reduced melatonin secretion by magnetic fields as low as 0.2 μT or lower, and the recent findings that melatonin is highly protective of oxidative damage to the human haemopoietic system, constitute powerful evidence of a causal association between magnetic fields exposure and increased childhood leukaemia risk.**

**I disagree with the statement that studies of health outcomes other than cancer have generally been difficult to interpret.**

**4.3 Biology**

**4.3.3.1.1 Human studies**

Paragraphs 150 – 153

*Melatonin, its properties and disruption by magnetic fields*

Compared with other antioxidants, melatonin is a potent endogenous free radical scavenger (López-Burillo *et al*. 2003). The hormone has been widely discussed in this regard.

[1] Note that the Italian Constitutional Court has judged that these regulations are constitutional, meaning that they are legally in force in these regions.

As paragraphs 150 - 153 acknowledge, it has been suggested that chronic exposure to EMFs may disrupt pineal physiology and decrease circulating levels of melatonin and thereby increase the risk of breast and certain other cancers. Allied to this hypothesis is the suggestion that increased exposure to light-at-night similarly disrupts pineal melatonin leading to increased cancer risk. It is generally acknowledged that the effects of light-at-night on pineal physiology are considerably more researched and understood than are effects from magnetic fields. Nevertheless, support for the melatonin-magnetic field hypothesis may be sought in recent findings in relation to exposure to light-at-night. Thus, a number of recent papers have reported decreased incidence of breast and certain other cancers in the blind and partially sighted (Hahn 1991; Feychting *et al*. 1998; Verkasalo *et al*. 1999). A recent paper by Hansen (2001) reported increased breast cancer risk in nightshift workers. This paper supports the hypothesis that the *disruption* as well as *reduction* of pineal melatonin production may result in increased cancer risk.

While short-term laboratory studies of melatonin secretion in small numbers of humans have provided little or mixed evidence of suppression by power frequency magnetic fields, studies in chronically exposured general population or occupational groups now show a consistent pattern in the suppression of the nocturnal production of pineal melatonin by magnetic fields as low as 0.2 μT or lower.

The following ten studies fall into the above category, the numbers in square brackets represent the number of cases/controls that were employed: Wilson *et al*. 1990 [42]; Pfluger & Minder, 1996 [108]; Burch *et al*. 1998 [142], 1999 [142], 2000 [149], 2002 [study 1: 149; study 2: 77]; Davis *et al*. 2001 [203]; Levallois *et al*. 2001 [221/195]; Juutilainen *et al*. 2000 [39/21] and Graham *et al*. 2000 [30]. Some of these studies are in the general population near powerlines, while others are in occupationally exposed groups. All studies have suitable control groups and some show a dose-response between exposure level and decreased nocturnal melatonin production. Furthermore, the study groups were invariably exposed to three-phase magnetic field sources indicating exposure to elliptically or circularly polarised fields. As pointed out earlier, studies in rats have suggested that circularly polarised fields, which induce higher currents in the body compared with linearly polarised fields, are more effective in reducing pineal melatonin secretion.

A recent study by Touitou *et al*. (2003) in 15 men occupationally exposed to magnetic fields for 1 to 20 years showed no decrease in nocturnal melatonin secretion compared with 15 unexposed men. This result is in a comparatively small number of subjects (15) and does not detract from the ten studies cited above, involving much larger numbers of subjects.

Paragraphs 150 – 153 - continued

There is also evidence that the oncostatic properties of melatonin are themselves disrupted by magnetic fields. This issue is mentioned here as well as below in response to paragraph 172. Ishido *et al*. (2001) has shown that 1.2 μT magnetic fields suppresses the anti-proliferative action of melatonin on MCF-7 breast cancer cells *in vitro*, at

physiologically relevant melatonin concentrations of between $10^{-11}$ and $10^{-9}$ M. This is the fifth laboratory independently to report this finding and the observation now appears robust.

It should also be noted that in a series of detailed experiments, 1.2 μT magnetic fields have also been shown to inhibit the action of the drug Tamoxifen widely used in the treatment of breast cancer (Harland & Liburdy 1997; Liburdy & Harland 1997; Harland *et al*. 1999 and Blackman *et al*. 2001).

Below, in response to paragraph 172 under Cellular studies, I will discuss the recent work demonstrating that melatonin is highly protective of oxidative damage to the human haemopoietic system and of oxidative damage to the fetus in animals. Together with the evidence of melatonin disruption by magnetic fields, I suggest that we now have a plausible mechanism by which exposure to power frequency magnetic fields increases the risk of childhood leukaemia and indeed of certain other cancers.

#### 4.3.3.1.3 Cellular studies

Paragraph 170

A number of experiments have suggested that magnetic fields may act as a co-initiator of chromosome damage. Cho & Chung (2003) looked at micronuclei (MN) and sister chromatid exchange (SCE) in human lymphocytes induced by the chemical carcinogen benzo[α]pyrene (BaP) and how these are affected in the presence of 0.8 mT 60 Hz magnetic fields. The authors report a significant dose-dependant increase in the frequency of MN and SCE induced by BaP by magnetic fields. The authors cite similar conclusions found in other work.

Paragraph 172

I have discussed above the work by Ishido *et al*. (2001) demonstrating the ability of 1.2 μT magnetic fields to suppress the oncostatic action of melatonin *in vitro* and that this finding has now been independently reported in five laboratories worldwide. The final sentence in paragraph 172: "*However, the robustness of this effect has been queried (NIEHS 1998)*" is out of place since Ishido *et al*. (2001) postdates the NIEHS 1998 report. Therefore this sentence should be removed.

*Melatonin protects the haemopoietic system and the fetus against oxidative damage*

As indicated above, there are now a number of studies which have demonstrated that melatonin is highly protective of oxidative damage to the haemopoietic system in humans and of similar damage to the fetus in animals.

Melatonin has been shown to protect the human haemopoietic system against oxidative damage from both chemical carcinogens and radiation (for example, Reiter *et al*. 1997). Vijayalaxmi *et al*. (1996) demonstrated the protectiveness against gamma

radiation. Human volunteers were given 300 mg of melatonin. Blood samples were taken immediately and one and two hours later. Blood lymphocytes were irradiated with 1.5 Gy of gamma radiation. Compared with controls, a 50 – 70% decrease in DNA damage was found in blood samples taken two hours after administration of melatonin. The authors concluded "*The data may have important implications for the protection of human lymphocytes from the genetic damage induced by free radical producing mutagens and carcinogens*". In another experiment Vijayalaxmi *et al*. (1999) pre-treated mice with zero, 125 and 250 mg of melatonin. The mice were then irradiated with 8.15 Gy of gamma radiation. After 30 days 45% survival was observed in mice untreated with melatonin, but 85% survival was observed in those treated with 250 mg melatonin.

In humans, melatonin is rapidly transferred from the maternal to the fetal circulation (Okatani *et al*. 1998). There is an extensive and growing literature on the ability of melatonin to protect against oxidative damage to the fetus both in animals and in humans. The following papers are cited by way of example: Okatani *et al*. (1997), (2000), (2001a), (2001b), (2001c); Wakatsuki *et al*. (1999a), (1999b), (2001).

#### 4.3.3.3.2.3 Magnetic field detection in animals

Paragraph 210

In the search for specific mechanisms by which the human pineal gland and/or the visual system linked to the pineal gland detect magnetic fields, recent research in homing pigeons may be of interest. Hanzlik *et al*. (2000) have shown the presence of $Fe^{3+}$ concentrations in the beak/skull of homing pigeons. These take the form of 1 - 5 nm aggregates of magnetite crystals which form clusters 1 - 3 μm in diameter, arranged in distinct coherent elongated structures associated with nervous tissue and located between fat cells. Birds can detect a change in geomagnetic field of only 70 nanotesla (nT). The observations confirm the principle of animal detection of magnetic fields well below those where adverse health effects of power frequency magnetic fields are reported in humans.

## 7. Proposals

Paragraph 530

As I have already indicated, I strongly disagree with the view that the current body of evidence of adverse health effects associated with magnetic field exposure is insufficient to derive quantitative restrictions on exposure to EMFs. In the case of new fixed installations, I would advocate the immediate introduction of strict regulations on exposure, in line with those already adopted in some countries. Ideally, the aim should be to restrict exposures to typical neighbourhood levels, around 0.05 μT. In the case of existing installations, notably powerlines near houses, hospitals, schools, nurseries and

children's play areas, a timetable of remedial measures should be introduced. The argument for such regulations is as follows:

*(i) On the evidence alone*

It is clear from the body of evidence now available that the association between power frequency magnetic field exposure and ill-health goes far beyond an association with childhood leukaemia, embracing outcomes such as miscarriage. The evidence has already reached a level of serious public health significance.

*(ii) The rate of growing evidence*

Furthermore, the evidence of adverse health effects continues to increase and is doing so at an accelerating rate. Although scientists are reticent, even for childhood leukaemia, to regard the existing associations with ill-health conditions as causal, I argue here that is extremely difficult to see how future research will overturn the current body of knowledge. I therefore concur with the view expressed in the California Health Department Report that it is more likely than not that magnetic fields cause increased risk of a number of adverse health outcomes.

*(iii) Action by other countries*

As already stated, in the case of new fixed installations, Sweden, Switzerland and certain Italian regions have already acted to restrict exposure to magnetic fields based on considerably less evidence of adverse health effects than that presented in the NRPB Consultation Document. Furthermore, these restrictions are in the range 0.2 to 1.0 μT which is still in the range where for example an associated doubling of childhood leukaemia risk is acknowledged. Ideally, therefore, the aim should be to restrict exposures to typical neighbourhood levels, around 0.05 μT.

**Summary of other recent published studies**

There are a number of recent published studies adding to the evidence of adverse health effects associated with exposure to power frequency magnetic fields.

Prostate Cancer

Charles *et al*. (2003) studied exposure to electromagnetic fields, polychlorinated biphenyls and prostate cancer mortality in electric utility workers in five large US electric utility companies. After adjustment for PCB exposure, race and active work status within the past two years, workers categorised in the highest 10% of EMF exposures were twice as likely to die from prostate cancer as those exposed to EMFs at lower levels; (odds ratio = 2.02; 95% CI: 1.34 – 3.04).

Melanoma

Tynes *et al*. (2003) studied the incidence of malignant melanoma in populations living near high voltage powerlines in Norway. Time-weighted average magnetic field exposures to residential magnetic fields generated by powerlines were calculated. Exposures were analysed using cut-off points of 0.05 and 0.2 μT. Analysis of the two upper magnetic field categories (0.05-0.2 μT and >0.2 μT) showed an odds ratio of 2.01 (95% CI: 1.09 – 3.69) and 2.68 (95% CI: 1.43 – 5.04) for women and an odds ratio of 1.70 (95% CI: 0.96 – 3.01) and 1.37 (95% CI: 0.77 – 2.44) for men respectively. Occupational exposures were also estimated but these showed no significant association with malignant melanoma.

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