Cancer in Children and Young People

The Cancer in Children and Young People set of articles is separated into 12 sections, each of which can be individually downloaded. It is a 'work in progress' incorporating new information whenever time permits.

Section 4

Non-Ionising Radiation – electromagnetic fields (EMFs)

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Childhood cancer and EMFs

As we saw in section 2, only about 10% of childhood cancers are inherited. Mostly are multi-factorial, involving an initiatory event and at least one promotional event. Precisely how many sequential co-operating mutations are required to produce overt, clinical cancer is not entirely clear, but the relatively short latency, especially in infancy and childhood suggests that only a few are needed in comparison with most adult carcinomas that are thought to evolve over decades.

The increase in incidence of childhood leukaemia during the 20th century suggests that changes in environmental factors, including lifestyle, are at least partly responsible.

Excessive exposure to non-ionising radiation has been linked to an increased risk of developing cancer. SCENHIR (the Scientific Committee on Emerging and Newly Identified Health Risks) in 2009, concluded that their previous assessment that ELF magnetic fields were a possible carcinogen and might contribute to an increase in childhood leukaemia was still valid, taking into consideration the subsequent epidemiological and animal studies. Environmental agents can also contribute to cancer by increasing the genotoxic potential of other agents, interfering with the DNA repair processes, allowing a cell with DNA damage to survive and stimulating the cell division, resulting in alteration of the normal functions of the cell.

Eden's summary of the aetiology of childhood leukaemia (2010) said "*environmental factors for which some evidence exists include non-ionising electromagnetic radiation and electric fields.*"

Here we look at non-ionising radiation (electromagnetic fields or EMFs) which has been implicated by a significant amount of scientific research in the development of childhood cancer, either as cancer initiator or promoter.

Belyaev (2015) says the survival rate of children with leukaemia depends on ELF magnetic field exposure at home.

ELF (powerfrequency or PF) magnetic field exposure

Schüz, a very cautious scientist, in a 2011 review, concluded that the assessment that ELF-MF are a possible carcinogen and may cause childhood leukaemia remains valid. He confirmed this in 2016.

Röösli (2013) suggests that, if causal, 1-4% of all childhood leukaemia cases could be attributed to low-frequency magnetic fields.

In a meta-analysis of 11,699 cases of childhood leukaemia, magnetic field levels equal to, or higher than 0.2µT was associated with childhood leukaemia (Zhao 2014). Thomas (1999) and Pedersen (2015) found links between childhood leukaemia and residential magnetic field exposure, showing risk factors of between 1.5 and 2.2. Valera's editorial (2014) referring to 4 other meta-analyses between 1998 and 2001, comments "*Undoubtedly, the evidence reinforced by this new meta-analysis searching for the involvement of EMF exposure and childhood leukemia is far from being considered definitive. Nevertheless, the work by Zhao et al may help us to consider that, besides the well known environmental factors leading to childhood leukemia, children living in highly exposed areas of extremely-low frequencies of EMF may also deserve our attention.*"

Prenatal and childhood exposure to high voltage power lines was considered as the most important environmental risk factor for childhood ALL in a study by Tabrizi & Hosseini (2015).

A study by Bunch (2014) reported no increased risks from overhead powerlines, but this was a seriously flawed study.

Kheifets & Oksuzyan (2008) outlined some of the difficulties in studying the link between EMFs and childhood leukaemia. She suggested that more revealing studies might include those of highly exposed children living in flats next to built-in transformers or electrical equipment rooms (that is based on an assumption that the higher the exposure, the greater the risk, a viewpoint not shared by everybody) or, an investigation of possible joint effects of environmental exposures and genetic cofactors.

Sidaway (2013) suggested that airborne electroactivity may provide the basis for a plausible outline model of a mechanism to explain the adverse health impact of overhead powerline residential proximity. Swanson (2014) accepted the association between childhood leukaemia, distance from power lines and corona ions, but did not conclude that there was a causative factor involved.

ELF (powerfrequency or PF) electric field exposure

Fiocchi (2015) suggests that the main contribution in terms of induced electric fields from power lines to foetal exposure is given by the fundamental frequency component, though the harmonic components add some contributions to the overall level of electric fields.

Parental occupational exposure to EMFs

In a study of children whose mothers were occupationally exposed to low levels of powerfrequency magnetic fields during pregnancy, Infante-Rivard & Deadman (2003) found a slightly increased risk of developing ALL between 0-9 years. Pearce (2007) found that paternal occupational exposure to EMFs prior to the child's conception resulted in a significant increased risk of acute lymphoblastic leukaemia (ALL) for boys aged less than 6, though the strength of this association is weakened as the research team looked at ionising radiation exposure as well, which has been linked to male susceptibility to cancer. Criticisms have been made of studies that rely on estimated field levels, as being unreliable due to the variation in exposure of different jobs, and neither was home exposure assessed.

A small increase in risk of ALL (Reid 2011) and a larger one with childhood cancer (Smulevich 1999, Keegan 2012) with maternal or paternal exposure any time before the birth, was linked to extremely low frequency electromagnetic fields (ELF EMFs). In a study in Iran by Tabrizi & Bidgoli (2015), prenatal and childhood exposure to high voltage power lines was considered as the most important environmental risk factor for ALL.

Children under 5 had an increased risk of brain tumours if their mothers or fathers were employed as electrical workers (Cordier 2001) or electric power installers (Olshan 1999). Li (2009) suggests a possible association between maternal occupational ELF-EMF exposure shortly before and during pregnancy (including among sewing machine operators), and astroglial tumours in their children.

The evidence is mixed as to whether EMFs directly damage DNA, although indirect effects such as from the bystander effect (in which unirradiated cells exhibit irradiated effects as a result of signals received from nearby irradiated cells), may be responsible. It is possible that the way EMF exposure has been measured may be responsible for the mixed results obtained experimentally. Kavet (2011) suggests that contact current could be responsible for the association of childhood leukaemia with magnetic fields.

Though experiments may be contradictory or inconclusive, nevertheless, it is suggested that EMFs could act by:

- Directly increasing the level of harmful **free radicals** within the body

- Affecting **other cellular processes** (including direct, or indirect tumour promotion), some of which may not even have been investigated as yet
- Decreasing the level of the protective hormone **melatonin**
    - Acting in a synergistic way with respect to **other pollutants**, making them more harmful

Free radical effects

In body tissue free radicals are dangerous high-energy particles that damage cells and can both cause and accelerate the progression of cancer. Timmel & Henbest (2004) were the first to show that exposure to EMFs can increase the yield of free radicals by more than 60%. The theory was reviewed by Simkó & Mattson (2004), who concluded that EMFs cause a general increase in the levels of free radicals, which could explain the diverse and often inconsistent nature of observed effects of EMFs, free radicals being intermediaries in many processes. DNA damage could arise as a result of persistently elevated free radical concentrations, caused by long-term EMF exposure, or via the radical pair mechanism by which magnetic fields increase the lifetime of free radicals, allowing more DNA damage to occur (Rollwitz 2004, Henshaw 2008).

Melatonin effects

Denis Henshaw, a long-time investigator into powerfrequency magnetic fields and childhood leukaemia suggests that melatonin may underpin the mechanism of the connection. He suggests that magnetic fields disrupt the production and action of melatonin and associated neurotransmitters and enzymes; that melatonin acts as a natural anti-cancer agent; there are many studies showing that magnetic fields reduce the production of melatonin, especially at night; magnetic fields inhibit the anti-proliferative action of melatonin on breast cancer cells and suppress the action of the anti-cancer drug Tamoxifen; melatonin is highly protective of oxidative damage to the haemopoietic system; melatonin crosses the placenta in women and in animals it has shown to be highly protective of oxidative damage to the foetus.

The hormone melatonin, is thought to protect the body from cancer

- by neutralising free radicals
- by inhibiting the uptake of growth factors by cancer cells
- by increasing the likelihood of cancer cells undergoing apoptosis (cell death), and
- by inhibiting the growth of blood vessels in tumours.

The production of melatonin at night (when the majority of melatonin is produced by the body's pineal gland) has been found to be reduced significantly by light at night and magnetic fields associated with the electricity supply (Henshaw & Reiter 2005, Erren 2005). Lupke (2004, 2006) suggested that EMFs reduced the anti-oxidative protection from melatonin.

Badr (1999) found that melatonin protects cells from genetic damage. Melatonin helped prevent oxidative damage to the human haemopoietic system (Vijayalaxmi 1996, 1999) and in animal foetuses (Wakatsuki 1999, Okatani 2001). Melatonin levels are particularly high during pregnancy (Nakamura 2001), so any change in these levels may result in some of the *in utero* damage which cause the 'first hit' which ultimately leads to cancer.

A study by Luukkonen (2014) suggests that MF exposure disturbs oxidative balance immediately after the exposure, which might explain their previous findings on MF altered cellular responses to menadione-induced DNA damage. Persistently elevated levels of micronuclei were found in the progeny of MF-exposed cells, indicating induction of genomic instability. However, the MF levels were significantly higher than those that would normally be found in areas of public exposure, so it is uncertain whether the findings would apply to genetic changes at lower levels.

Professor Henshaw, Scientific Director of CHILDREN with CANCER UK, said *"Low-frequency magnetic fields can suppress production of melatonin, which, in pregnant women, will deprive the foetal brain of the protective hormone."*

A variety of bone marrow cells have been shown to produce melatonin (Tan 1999, Conti 2000, Carrillo-Vico 2004). Whilst the specific function of melatonin in these cells remains unknown, its suppression could have clear implications for cancer initiation and/or progression. A reduction in melatonin in the leukocyte precursor cells would be expected to enhance free radical-mediated DNA damage, thereby increasing the likelihood of these cells becoming carcinogenic.

Melatonin reduces the growth of HL-60 myeloid leukaemia cells *in vitro* (Henshaw 2008).

Light at Night

Evidence suggests that increasing exposure to light at night (LAN) and the consequent disruption of circadian rhythms, especially via reduction in nocturnal pineal melatonin, is a significant factor in the increasing incidence of breast cancer in recent decades in industrialised countries (Blask 2005). Whether LAN features in childhood cancer risk is not known. Electric light exposure at night can disrupt the circadian rhythm and many other physiological processes that are under circadian control. Because of this, Stevens (2012) suggests that ill-timed electric light exposure to pregnant women, to neonates, infants, and small children may increase cancer risk in those children.

Synergistic effects

Airborne pollutant particles are known to have a significant effect on health and a number of studies have reported an association between childhood cancer and exposure to traffic pollution, or particularly benzene (Lagorio 2013). The strong electric fields associated with high voltage power lines may affect the charge on the chemicals found in traffic pollution, making them more likely to be absorbed by the body. This effect can be observed up to 7 kilometres downwind of a high voltage powerline (Fews 1999a). The older the cable and the wetter the weather the more charged ions are emitted (Fews 1999b). The report by Draper (2005) found increased risk of leukaemia in children born within 600 metres of National Grid 400 and 275 kilovolt power lines. This distance is clearly too far away to be a direct EMF effect, but could validate the ion polarisation theory. However, as Coghill (2005) points out the study did not take into consideration the 20,000 km of 132 kV power lines (the high voltage ones that tend to be closest to residential homes) and the more than 260,000 pole mounted transformers. So the increased risk that WAS found is likely to be an underestimate of the number of families affected by this serious childhood cancer.

Maternal use of a sauna close to conception or in the first trimester, and paternal use in the 3 months before the pregnancy, use of an electric blanket, or any heat source have been linked to an increased risk of medulloblastoma. Heat and magnetic field exposure would both have been involved (Bunin 2006), and both may have contributed.

Mair (2008) also suggested that EMFs could be mutagenic on their own, or could potentiate ionizing radiation mutations.

Brain and CNS tumours

Women who worked in low-frequency magnetic environments when pregnant, such as machinists, hairdressers, nurses and dry cleaners were twice as likely to have babies that developed brain tumours (Li 2009).

In a meta-analysis of 13 studies (Mezei 2008), there was a very slightly elevated risk of brain tumours with exposure to magnetic field levels in the home over 0.2 microtesla (µT), with a greater risk at levels of 0.3 or 0.4 µT. A more recent study not included in the meta-analysis found a positive association between exposure to residential magnetic fields above 0.4 microtesla and the risk of brain tumours (Saito 2010).

Preston-Martin (1996) found no association, but she concluded that the prevalence of high fields in Los Angeles homes was too low even to detect a **moderate** effect. Gurney & van Wijngaarden (1999) concluded that electromagnetic fields (EMFs) played no causal role in brain cancer development, and Kheifets (who has been repeatedly funded by the power industry), in a pooled analysis of 10 studies, found no association (2010).

Leukaemia

There is disagreement as to whether the relationship between EMF exposure and an increased risk of childhood leukaemia is a causal one, or whether there is a coincidental association with some other, as yet undiscovered, factor. However, the relative risk is surprisingly consistent, even though epidemiology is a bit of a blunt instrument to detect causal factors in a multi-factorial illness. Even Public Health England (former HPA-RPD), the International Agency for Research on Cancer (IARC, 2001) and the World Health organisation (WHO) have all agreed that EMFs are a potential carcinogen (Class 2B) and that precaution is warranted.

The California EMF Programme report (Neutra 2002), has been recognised as one of the more definitive documents of recent times. The authors concluded that EMFs increased the risk of childhood leukaemia. The International Agency for research on Cancer (IARC) classified magnetic fields as a "possible human carcinogen", though this was not sufficient to influence public health policy according to Kheifets (2006). The results of one Canadian study by Green (1999), based on personal measured fields rather than spot measurements found a significant increase in risk of childhood leukaemia at 0.14 microtesla (even lower than most of the published literature, which seems to show a consensus at 0.3 – 0.4 microtesla), though there was no association with living near high voltage powerlines. Teepen & van Dijck (2012) suggested that the risk of childhood leukaemia increased by 40-70% when children were exposed to EMF levels above 0.3µT. They advised reducing exposure from power lines near densely populated areas and schools.

An influential report (www.bioinitiative.org) by Hardell & Sage (2008) concluded that in view of the association between electromagnetic fields and childhood leukaemia, a new lower public safety limit for habitable space adjacent to all new or upgraded power lines should be applied. A new lower limit should also be used for existing habitable space for children and/or women who are pregnant.

Kheifets (2011) pointed out some of the difficulties in making sense of the measured levels and childhood leukaemia risk using various statistical tests, and we suggest that it may be as appropriate (if not more so) to take into account peak-level exposure and maternal exposure during pregnancy. Most studies are based on average levels, thus excluding what may be the most important metric, irrespective of analysis procedure.

It is possibly that if magnetic fields are causative, it may be the rotating quality of the fields that is responsible. This is rarely measured.

More than 25 epidemiological studies around the world have investigated the association between childhood leukaemia and EMF exposure. They have found an increased risk of childhood leukaemia with proximity to high voltage powerlines, substations or high residential magnetic fields (Boikat & von Manikowsky 1996, Kaatsch 1996, Thériault & Li 1997, Linet 1997, Michaelis 1997, 1998, Dockerty 1998, Li 1998, McBride 1999, UKCCS 1999, Angelillo & Villari 1999, Bianchi 2000, Abdul Rahman 2008, Kheifets 2010, Kroll 2010, Teepen & van Dijck 2012, Sermage-Faure 2013, Pedersen 2014), showing up to 5 times higher (Malagoli 2010, Wünsch-Filho 2011) or more (Sohrabi 2010), especially with a diagnosis of ALL under the age of 6 (Green 1999). Not all studies have found an association (Tynes & Haldorsen 1997, Kleinerman 2000), and some of these studies used wire codes and calculated fields rather than measured fields from specific sources of EMFs. A study by Lowenthal (2007) found that living within 300 metres of high voltage powerlines within the first 15 years of life tripled the risk of developing a lymphoproliferative or myeloproliferative disorder in later life; and Draper (2005), in the largest single study of childhood cancer and powerlines, reported an increased risk in children whose birth address was within 600 metres of a high voltage power line. The risk was increased 5-fold if the child lived there for the first 5 years of life. This may be due to the air ionisation effect referred to above, which is an electric field effect. Henshaw (2008) who proposed the air ionisation effect, suggested that about 11% of childhood leukaemia cases may be linked to magnetic fields. Swanson (2006) suggests the increased risk could be due to magnetic fields, corona ions, the characteristics of the areas power lines pass through, bias or chance, and Jeffers (2007) adds that population mixing in housing developments which followed the construction of the lines, could also be involved.

Auvinen (2000) and Schüz (2001) suggested that night-time levels were of particular importance, though when Schüz made a further analysis of his findings (2007) his conclusions were less clear. Schüz also looked at residential exposure to magnetic fields at 16.7 Hz from the electrified railway system in Germany, and found a moderate but statistically non-significant association with childhood leukaemia (Schüz 2001).

Exposure to various electrical appliances, both during pregnancy and in childhood were looked at by Hatch (1998) who found a link with childhood ALL and maternal use (during pregnancy), or child use, of some household electrical appliances.

A review of 152 articles (Pelissari 2009) suggested that *"an association may exist between exposure to low frequency magnetic fields and acute lymphoblastic leukemia in children, but this association is weak, preventing the observation of consistency in the findings."* The authors concluded that ALL should be the focus of future studies as this seems to be the subtype with the most likely association.

Yang (2008) found genetic markers that showed that those carrying this gene variant were four times more likely to develop childhood leukaemia if they also live within 100 metres of power lines or transformers, compared to those with a fully functioning version of the gene. This groundbreaking piece of research indicates a potential for identifying individual susceptibility. For those already genetically susceptible (children with some congenital syndromes, such as Down syndrome), exposure to magnetic fields seemed to increase the risk of developing leukaemia (Mejia-Aranguré 2007).

Individual studies are often limited because of the relative rarity of childhood leukaemia and the relatively low number of children exposed to high levels of EMFs. Three reports which have pooled the data from individual studies, have found an increase in risk with exposure to magnetic fields of 0.3 – 0.4 microtesla (Ahlbom 2000, Greenland 2000, Wartenberg 2001). This level was confirmed by further studies (Kabuto 2006, Feizi & Arabi 2007).

It seems unlikely that there is a straightforward answer to whether EMFs *cause* cancer. We believe there is increasing evidence that they may play a definite role in affecting the body's ability to cope with pre-cancerous cell damage. There almost certainly will be other factors, such as chemical and other physical exposures (Juutilainen 2006) involved in the final outcome of a diagnosis of leukaemia.

Maslanyj (2010) concluded that taking a precautionary approach with respect to the proximity of powerlines to children was an appropriate one in view of the consistent association with childhood leukaemia in the research. He suggested that low-cost intervention to reduce exposure is timely, accepting that this recommendation was a controversial one as this measure may not fully alleviate the risk, due to other possible interpretations of the data. He did, however, comment that EMF links with Alzheimer's disease may be worth taking into account.

Meanwhile, unaccountably, there seems to be mixed opinion as to whether to recommend more precautionary limits to EMF exposure, bearing in mind that precautions are appropriate when there is uncertainty. If a relationship between the two were *proven,* then it would be the time for legislation. Calvente (2010) called for an urgent reconsideration of exposure limits for both low frequency and static magnetic fields based on a review of experimental and epidemiological research into the link with childhood leukaemia.

The Stakeholder Advisory Group on ELF EMF (SAGE), the official Department of Health working group which was set up to recommend policy about powerlines to government, produced its First Interim Assessment in April 2007. They concluded that banning the building of new homes and schools within 60 metres of power lines is the best available option for reducing deaths from childhood leukaemia and possibly other diseases. The report fell short of recommending this as government policy because of fierce disagreements within the group. It said that such a policy, if implemented by the government would have a dramatic effect on property prices within power line corridors. It put the cost of restricting development at £1bn. Michael Jayne of the Royal Institution of Chartered Surveyors (RICS) called on the Government to take precautionary measures in order to ensure that the health risk is minimised by preventing the building of residential properties within specified distances of power lines.

Neuroblastoma

De Roos (2001) found that paternal exposure to battery-powered forklifts was positively associated with neuroblastoma in the child and there was also a weak association between 0.4 µT paternal, but not maternal, magnetic field exposure and neuroblastoma.

Other places of EMF exposure

Söderberg (2002) found a slightly elevated risk for AML, but not ALL in children who had been exposed to high magnetic fields from infant incubators.

Changes in magnetic field level above 1.6 microtesla, such as can be found when travelling in electric trains, have been linked with an increased risk of miscarriage (Li 2002). It is possible that the magnetic fields may also change DNA in ways that may not be destructive enough to result in a miscarriage, but may have health implications.

Ultraviolet light is part of the EMF spectrum. Mahé (2011) found that taking part in outdoor sports increases the risk of developing UV-induced skin lesions in childhood. However, it is also worth remembering that lack of vitamin D, the best source of which is sunlight, is responsible for many health problems, too.

Adverse effects of EMF exposure during treatment for cancer

It has also been suggested that exposure to EMFs may adversely affect the outcome of treatment for childhood leukaemia. The Regina Elena National cancer Institute in Italy carried out some EMF measurements because of the equipment used in some treatments. The author (Di Nallo 2008) concluded that EMF measurements were recommended because of the vulnerability of patients with cancer, their long stay near the equipment and the day-long exposure, which represent additional risk factors, necessitating a prudent avoidance strategy, possibly even for staff as well as patients.

Effects of EMFs on survival after treatment

Exposure to magnetic fields appeared to decrease the survival time of children in remission from leukaemia, at over 0.3 microtesla (Foliart 2006), or over 0.1 microtesla (Svendsen 2007), though a further study by Foliart (2007) concluded that elevated magnetic field levels were not associated with factors that predicted poor survival.

Hocking & Gordon (2003) also found an association between living near to TV transmitters and decreased length of survival after leukaemia diagnosis.

Radio-frequency radiation exposure

Older TV and radio masts transmitted analogue signals. No link was found between the radiation from AM radio transmitters and the incidence of brain tumours (Ha 2007), though Park (2004) had found that leukaemia mortality was higher in exposed areas, especially among children and young adults.

The situation has now changed with the arrival of digital radio and TV and the omnipresent telecommunications (mobile phone) masts. There are also other sources of digital signal transmission (digital cordless phones, WiFi, etc) that are being increasingly situated within houses, schools, offices, leisure facilities, etc. that is increasing the general public's exposure to radiofrequency radiation significantly.

It has been suggested by many scientists that digital signals may well have a greater biological impact on living systems than analogue signals; this possible impact includes not only people, but also animals and plants. If this is so, we would expect to see increasing evidence of health problems associated with exposure, though this may not include an increase in childhood cancer risk.

Navarro (2003) and R Santini (2002, 2003) found evidence of ill-health as a result of living near to mobile phone masts, but they were not specifically looking at cancer incidence. A study by C Li (2012) noted a significantly increased risk of all neoplasms in children with higher-than-median RF exposure to mobile phone base stations.

Two studies on adult cancer incidence near masts found significant increases (Wolf & Wolf 2004, Eger 2004) and the Wolf study found a ten-fold increase in female cancer. Neither looked at childhood cancer incidence.

Brain and CNS tumours

People have expressed concern about the use of mobile phones and brain tumours, but this is a relatively new technology. Children have only just begun to use them extensively and brain & CNS tumours can take some time to develop and be diagnosed. Meanwhile, this uncertainty may influence whether we discourage our young people from exposing themselves to such a potential

hazard, especially as in May 2011, The International Agency for Research on Cancer (IARC) classified radiofrequency RF as a possible human carcinogen.

As well as the risk from phones, people have wondered whether the radio-frequency emissions from the mobile phone network of masts and other sources may also result in an increased risk of tumours in children who live nearby.

Professor Stefaan van Gool, who is a clinic supervisor at the children's Haematology/oncology department at Louvain University hospital in Belgium and treats children with brain cancer says, *"Cordless baby alarms, toys and phones expose children to daily radiation. Although the intensity is less than a mobile phone, children are more susceptible to the effects. A lot of young people have WiFi at school, so their exposure is continual."* He continues "*There is irrefutable proof of the harmful effects of electromagnetic radiation. It should actually be the responsibility of the operators and the industry to demonstrate that they are not harmful*"

The first study on mobile phone use and the risk of brain tumours in children and adolescents contains several indications of increased risk, despite low exposure, short latency period, and limitations in the study design, analyses and interpretation (Söderqvist 2011).

There was an increased incidence of CNS tumour risk with the highest level of exposure from radio-frequency EMFs from broadcast transmitters in Switzerland (Hauri 2014).

Leukaemia

There have been some studies that have found increases in leukaemia risk as a result of living in proximity to radio or TV transmitters (Hocking 1996, Dolk 1997a, 1997b, Michelozzi 2001, 2002), that mean we cannot be complacent about the effects of RF signals. The study authors concluded that there was a small increased risk in adult and childhood leukaemia for those who lived within 2 kilometres (Ha 2007), but the confidence levels were low due to the small number of cases involved. One study showed no such increase in risk (Merzenich 2008), and Elliott (2010) found no link between childhood cancer and maternal exposure to base stations. Elliott has a tendency to find negative links between the environment and health problems, including the fact that he found no evidence for the reality of Gulf War Syndrome; not everybody concurs with his findings.

Neuroblastoma

De Roos (2001) found that maternal and paternal occupational exposure to a broad grouping of sources that produce radiofrequency radiation was associated with an increased incidence of neuroblastoma in the children.

Skin cancer

Paediatric melanoma is rare, but increasing in incidence. Solar and artificial (sunbed) UV-exposure is the main risk factor for the development of epithelial skin cancer as well as for malignant melanoma. UV exposure in childhood and adolescence is especially important (Greinert & Boniol 2011).

The UK has the highest incidence of skin cancers in children and adolescents. In Europe, melanomas are more common in adolescents in the North and West and skin carcinomas in the South and East. Between 1978 and 1997 the annual increase in incidence for adolescent cancers has been 4.1% for melanoma and 2.5% for skin carcinoma (de Vries 2006). The number of children affected was significantly smaller than the number of adolescents. The study authors suggest that the aetiology between childhood and adolescent skin cancers may be different, or it may also be

that parental care with respect to skin screening is more influential for children than for adolescents.

Musselman & Spector (2011) found a link between sunlight exposure and risk of childhood cancer, possibly due to the role of vitamin D as a regulator of cell growth and differentiation and there was an inverse relationship between NHL risk and sun exposure (Petridou 2007).

Conclusion

At an International Commission for Non-Ionising Radiation Protection (ICNIRP) workshop on risk factors for childhood leukaemia, Anders Ahlbom reviewed the epidemiological data looking at childhood leukaemia and electromagnetic fields. He said "*Generally the exposure measures have been too crude, however this would tend to decrease the estimated association rather than increase it. Significant confounding is most unlikely – there would have to be a very large new factor that has not already been considered. Selection bias is possible, but unlikely to be a large effect given the number of very different pooled studies. It will not be due to chance. The evidence that ELF magnetic fields are a causal factor in the development of childhood leukaemia is stronger than that for passive smoking and lung cancer.*"

We believe that childhood cancer is unlikely to be *caused* by exposure to electromagnetic fields, but there seems sufficient evidence that they may have a promotional effect that we think taking a precautionary stance, minimising exposure, is the best course, whilst further research takes place. In 2010, The US President's Cancer Panel emphasised that children are far more vulnerable to environmental toxins and radiation than adults. The panel requests more research from ELF to RF to clarify the cancer risk and also long-term monitoring of the exposure.