

**WHO workshop on sensitivity of children to electromagnetic fields**  
**Istanbul, Turkey**  
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**Rapporteur report**  
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Benjamin Franklin, as American Ambassador to France, in 1783 accompanied a Royal party to watch the first manned flight in a Montgolfier balloon. As the balloon floated into the air above Paris, one of the group remarked to Franklin: “What use will that ever be?” Franklin replied: “What use is a baby?” It is of course our concern for our children and all children that has brought us together for the workshop. These concerns were summarised by Dr. Repacholi in his introductory paper. The association of child leukaemia with power line fields, IARC’s classification of ELF as a Class 2B carcinogen, the Stewart Committee’s fear that children may be more susceptible to adverse health effects from mobile phones, and the widespread use of these phones by children as young as seven, provide the IAC project with ample grounds for giving consideration of this topic the highest priority.

The Workshop began with a tutorial given by three eminent medical scientists. Dr. Robert Brent of the Alfredi Du Pont Hospital for Children in Wilmington, Delaware gave us an entertaining and informative overview of the hazards that effect childhood development from conception to early life. His presentation was illuminated by reminders of how we have often banned things we needn’t have banned, ignored things we shouldn’t have ignored, and of how easily the public is alarmed when a new potential hazard to their children’s health is mooted. Dr. Brent reviewed childhood development in the presence of environmental agents and questioned the hypothesis that children are necessarily more vulnerable than adults to such agents. He reviewed those studies that help in assessing risk to health, and endeavoured to identify the soluble and the insoluble questions regarding child development in an environmentally unfriendly world. He was very supportive of epidemiology as providing the best information for assessing risk but much less enamoured with in vitro studies unless they were undertaken in association with and relevant to an epidemiological study.

Dr. Brent’s final comment was a warning that definitive conclusions on biological plausibility cannot be based on hypotheses.

Dr. John Scholes of University College, London took us on a tour of the brain and its development through pregnancy into adulthood. His description of the four developing cells: the neurons, the astrocytes, the oligodendrocytes and the microglia was dotted with some spectacular statistics.

In the cerebral cortex of the neonatal monkey some 800,000 synapses are formed every second; in the adult there are perhaps 10,000 on each nerve cell. The total area of neuronal membrane in the brain would cover the better part of one square kilometre Dr. Scholes discussed the key role of the hippocampus where short term memories are organised for long term storage. That the hippocampus is located near the ear and therefore near the mobile phone was a factor to consider when investigating mobile phone health effects. He reviewed some recent work with rats where under normal unstressed conditions the stem cells of the dentate gyrus produced thousands of neuroblasts each day of adult life that become new, but short-lived granule neurons. However under conditions of stress produced by cranial irradiation, for example, these same stem cells produce glioblasts and new astrocytes instead.

Dr. Scholes likened the development of a child's CNS to a computer that rolls off the production line, nearly complete after nine months gestation, for the software installation to take up the ensuing 24 years. This involves the elimination and refinement of synaptic connections, and is most intense during childhood. Given the high level of endogenous electrical activity in the neurons involved, it is not yet clear whether, and how, tolerated external field strengths may affect this process.

Dr. Tracy Lightfoot of the University of York wound up the tutorial with a summary of the aetiology of childhood leukaemia together with a review of the latest thinking on causative mechanisms. It has been hypothesised that the development of childhood leukaemia requires "two hits". The first hit, a chromosomal translocation, occurs in utero and is a relatively common event. In infant acute lymphoblastic leukaemia 85% of cases have the 11q23 translocation involving the MLL gene. It is believed that this genetic alteration is sufficient to cause leukaemia. Studies in newborns have shown that 1% have the TEL-AML1 gene fusion which is 100 times greater than the frequency of leukaemia cases with this translation. This demonstrates the need for a second hit and also that the second hit is the rate-determining step in the transition to the disease.

The search for the second hit continues; it may be an exposure or an additional genetic event. Candidate exposures or pathways include infections, DNA topoisomerase II inhibitors and folates, all of which require further investigation, not only in terms of exposure in the index child but also where relevant in the genetic pathways involving both the index child and the mother or father.

Professor Colin McCaig of the University of Aberdeen moderated the discussion session that followed the tutorial. He began by demonstrating that the direction of growth of axons in vitro can be controlled by the application of an external electric field. DC fields are essential to life. Endogenous electric fields are present in development and during regeneration. The targets of environmental electric fields therefore include all tissues that establish a potential difference, such as epithelia, epithelial wounds, germinal zones in the brain, stem cell populations, cancer cells and endothelial angiogenesis. Indeed all cell migration, division and orientation are regulated and directed by physiological electric fields both in vitro and in vivo.

The ensuing vigorous discussion, which involved the audience, dealt with cell migration, threshold effects, the electric fields induced in the body by an external EMF, the aetiology of leukaemia, and cognitive development in children. The topic assigned to the discussion: "Children's sensitivity to EMF: Is it plausible?" was somewhat ignored.

The afternoon session on the first day began with four presentations concerning dosimetry and dielectric properties. The basic problem addressed by these presentations was how one might determine the dielectric properties of a child and develop a realistic model of its head.

Dr. Camelia Gabriel, of Microwave Consultants, London explained that dielectric properties are intrinsic properties of matter that could vary with regard to the tissue selected, and with the frequency and temperature involved. She outlined work done in a study of 10, 30 and 70 day old rats and how these results might be extrapolated to the RF exposure of children and adults. One of the difficulties in this extrapolation is that in both the near and far fields the dielectric properties of the skin are a key factor in coupling efficiency. Unfortunately skin is an animal specific organ and extrapolating from animal to human skin must be done with caution. Dr. Gabriel concluded that there was no consistent picture: SAR dependence on dielectric properties is complex; the age factor increases the variation limits on published dielectric properties; and that the differences between healthy and diseased tissues must also be considered.

Dr. Philip Chadwick, also from Microwave Consultants, London dealt with the problems of modelling ELF exposure in children. He summarised the results of SPFD and impedance

computational methods. His conclusions were: that for uniform whole body exposure, adults had higher internal electric fields and current densities than children; that distributions are different and higher in some children's organs; that contact currents produce internal fields and current densities that are three times greater in children than in adults due to their smaller limbs. Dr. Chadwick cautioned that the computational models do not take account of the anatomical differences between the adult and the child.

Dr. Joe Wiart of France Telecom spoke about modelling RF in children with specific reference to a mobile phone hand set placed close to the head. SARs as measured in phantoms and calculated by computer were discussed. The problems of modelling a realistic child's head had resulted in the French programme "ADONIS", part of the RNRT research network. ADONIS is working on building six child's heads, based on MRI scans, covering ages from 4 to 15. The importance of employing a realistic head was underlined by studies which had shown that where a 12 year old modelled by MRI had a SAR of 0.7 watt/kg, a 12 year old scaled from an adult gave an SAR of 1.0 watts/kg under similar exposure conditions.

The dosimetry session was concluded by Dr. Jurgen Schuderer of the Swiss Federal Institute of Technology. Here SAR was measured in a series of phantom heads in order to compare the differences in energy absorption between adults and children. In one test, three adult phantoms and two child phantoms were compared. All five were based on MRI scans of adults and of children aged 3 and 7. No significant differences in SAR were observed among the phantoms under the same exposure conditions. However when SAM entered the picture some very significant differences arose. SAM is the phantom used in standardised compliance testing. Measurements made with different mobile phones showed that the SAR as measured using SAM was on occasion twice the level of that obtained with the more realistic phantoms. For testing purposes SAM clearly provides a conservative exposure value.

Dr. John Swanson of National Grid Transco, UK, and Dr. Joachim Schüz of the University of Mainz delivered presentations on EMF exposures in children.

Dr. Swanson provided data on both ELF and RF exposures in the UK. Dr. Schüz discussed studies on mobile phone exposures in Germany. Some interesting points emerged. If the ELF exposure metric is a simple arithmetic average, then in the UK the power supply system provides the bulk of the exposure and appliances only 5%. If however the metric was the square of the magnetic field, appliances would then contribute most of the exposure. Dr. Swanson was of the view that selecting a metric for RF exposure was even more difficult. He was of the view that we still had much work to do before we could characterise RF fields for epidemiological studies with confidence.

Dr. Schüz provided data from a recent survey in Mainz of 2000 children. In 2002, 69% of 12-13 year olds owned phones. The value for 18-19 year olds was 91%. He concluded that today's children will have a much higher cumulative exposure than today's adults when they are the same age. Among teenagers the number of non-users is now approaching zero.

The first day was brought to a close with three presentations on epidemiology by Professor Leeka Kheifets of UCLA; Dr. Patricia McKinney of the University of Leeds; and Dr. Maria Feychting of the Karolinska Institutet in Stockholm. Professor Kheifets provided a critical analysis of the strengths and weaknesses of the pooled ELF epidemiology studies of Greenland et al (2000) and Ahlbom et al (2000). These were the studies that tipped the scales in favour of the Class IIB classification for low frequency magnetic fields by IARC in 2002. The main strength of these analyses was that they effectively ruled out chance as being a possible explanation for the association. Her conclusion was that although some selection bias could not be ruled out, this would not, by itself, account for the observations. Dr. Kheifets found the studies of RF exposure in

the vicinity of TV masts uninformative because they were based on a small number of cases and on distance from source as the metric.

Dr. McKinney dealt with childhood brain cancers, their incidence, cause and aetiology. CNS tumours are the second most common childhood cancers after leukaemia and account for 20% of all childhood cancers. Including benign tumours their incidence is 3.9 per 100,000 per year among 0-19 year olds. Most cases occur in the under 15 year olds. The causes are still unknown. Some 5% of tumours are thought to be genetic in origin, with environmental influences accounting for most of the rest. Incidence is associated with ionising radiation and any chemical, physical or biological agent that can damage DNA. Dr. McKinney considered the evidence implicating ELF as a possible cause was weak; early findings of an association with brain tumours have not been replicated. She concluded her talk with a review of the factors that should be taken into account in designing a good epidemiological study to investigate brain tumours.

Dr. Feychting provided a wide ranging review of epidemiological studies involving EMF but examining associations other than those of cancer. The bulk of such studies had examined an adverse pregnancy outcome. While one or two studies showed a positive association, most reported no effect. Heating was seen as the main biological mechanism that would affect pregnancy outcome. However Dr. Feychting cautioned that absence of an observed effect does not necessarily mean exposure is harmless.

The final day of the workshop began with three papers outlining new hypotheses concerning possible mechanisms to explain an association between EMF and cancer. These papers were given by Dr. Rob Kavet of EPRI, Professor Dennis Henshaw of the University of Bristol, and Professor Lawrie Challis of the University of Nottingham.

Dr. Kavet advanced the hypothesis that the grounding systems employed in the United States created conditions that could lead to a positive voltage building up on bathroom plumbing and so deliver contact currents of up to 50 $\mu$ A to small children, and indeed to adults exploring their bath. A major investigation of this phenomenon and a related epidemiological study is about to get underway in Northern California. The main point here is the positive association, established by measurements and modelling, between magnetic field and voltage driving contact currents. Contact currents as low as 10 $\mu$ A can create conditions in the body that would otherwise require a magnetic field of several hundred microtesla to produce.

Professor Henshaw made an elegant presentation in support of the melatonin hypothesis. Exposure to magnetic fields suppresses melatonin production. Melatonin, which is produced during the hours of darkness in the pineal gland, is a powerful anti-oxidant which protects DNA from free radical attack. In medical treatment there is now strong evidence of its effectiveness in the treatment of certain cancers. The combination of magnetic fields and melatonin is to the detriment of the latter, reducing melatonin production and thus leading to a lowering of a child's natural defence against disease and so providing the second hit required by Greave's leukaemia aetiology hypothesis.

Professor Challis, reviewed a succession of promising hypotheses that had appeared in recent years to explain how RF fields might interact non-thermally with biological tissue and eventually lead to cancer. Playing the Devils Advocate, Professor Challis identified and discussed their weaknesses, errors and shortcomings. At the moment the only valid interaction theory to explain adverse health effects is that based on raising tissue temperature.

Dr. Isabelle Lagroye of the University of Bordeaux provided a comprehensive review of animal studies that investigated RF and ELF exposures. While there have been many such studies few have focused on prenatal and young animals that might assist in evaluating children's sensitivity.

ELF animal studies have been mostly negative with no effects reported on leukaemia, lymphoma, or leukaemia progression. Data on mammary cancer is contradictory. On the question of RF exposure she touched on the mixed reactions to the Repacholi (1997) and Utteridge (2002) studies using transgenic mice. Dr. Lagroye concluded that ELF required more studies involving in utero and post-natal exposures and further transgenic models of ALL. Concerning RF, she felt that Ross Adey's work should be followed up and deal specifically with post-natal exposure.

Dr. Jukka Juutilainen of the University of Kuopio startled the audience when he announced at the start of his presentation on RF and animal development that RF fields are teratogenic. This was supported by 20 studies that demonstrated a thermal effect. Dr. Juutilainen reviewed recent literature, dealing in turn with animal behaviour, the 'Henhouse' model, new developmental instability studies, and research on thermal and non-thermal effects. There would appear to be a great volume of work undertaken in this area with very little to show by way of positive effects. Dr. Juutilainen felt additional studies would be useful in increasing our understanding of both ELF and IF (intermediate fields).

Dr. Zenon Sienkiewicz of NRPB provided us with an energetic and comprehensive review of the neuro-behavioural effects of exposure to ELF and RF fields. He dealt with studies involving the effect of ELF on EEG and evoked potential on volunteers while asleep and awake. The results exhibited no well defined responses. In cognitive studies using volunteers there was only a suggestion of an effect. Dr. Sienkiewicz also reported on the two cognitive studies undertaken on children by Preece and Haarala for COST 281. In these studies children were exposed to 0.25 watts from mobile phones. In neither study were any field dependent effects observed. His overall conclusions were that low level EMF exposures (of both ELF and RF) may cause some subtle effects on adults, but none that we know about children.

The morning ended with summary reports on three recent conferences and the COST 281 mission.

Dr. Rick Saunders of WHO reported on the workshop held at NRPB in March 2003 which dealt with weak ELF electric fields, and also on the workshop concerned with thermal effects held at WHO, Geneva in March 2002.

Dr. Gerd Friedrich of FGF in Bonn reported on the COST 281 Workshop on "Mobile Phone Exposure and the Brain", held in Budapest in September 2003.

Dr. Christof Olivier of the University of Ghent reviewed the present status of the COST 281 Short Term Mission Project on "Mobile Communication and Children.

The final afternoon began with the presentation of eight short contributions dealing with;

- The polarisation of magnetic fields – an interesting hypothesis well presented by Elizabeth Ainsbury of the University of Bristol.
- "A cautionary approach to precaution" – by David Black from New Zealand, who gave hands-free-kits as an example of precaution that wasn't.
- "A review of ELF epidemiological studies" by Selcuk Comiekci of the University of Suleyman Demiera – which illustrated the growing interest in EMF across Turkey.
- A reminder by Joe Elder of Motorola that while there has been a huge amount of work done on the RF exposure of animals, this has singularly failed to show any positive effect.
- An interesting survey of ELF levels in schools by Halil Hussain of the Tenaga National University in Malaysia.
- A computational model providing SAR data for energy absorption in the eyes of children and adults, presented by Jafar Keshvari of Nokia. This study appears to anticipate a wider use of picture phones.

- A discussion of phone mast siting and related policies in Austria by Eva Marsalek of the PMI Platform in Klosterneuburg.
- A staggering description of the Tokyo Tower, its forest of antenna and the associated power densities at ground level – an impressive presentation by Akifumi Ueda of the Citizens Science Initiative, Tokyo.

The workshop concluded with three presentations on policy development and a panel session discussing the WHO Precautionary Framework.

Dr. Marco Martuzzi brought us up to date with the plans for the 4<sup>th</sup> Ministers' Conference on Environment and Health to be held in Budapest from 23–25 June 2004. Some 52 Member States, IGOs, and NGOs will be attending. The priorities for the conference are reflected in its subtitle: "The Future of Our Children".

These priorities are;

- improved access to clean water and sanitation
- improved opportunity for physical activity
- reducing indoor and outdoor pollution
- reducing exposure to physical and chemical agents

EMF comes into the latter category. Under measures to reduce exposure to emf we have;

- prudent avoidance policies to reduce exposure
- education about mobile phones and limiting exposure to them
- enactment and enforcement of legislation based on ICNIRP guidelines

Dr. Martuzzi then went on to detail WHO's specific objectives for the conference.

Dr. Hilary Walker of the UK Department of Health outlined the development of the UK's "EMF Policy for Children". This stems from the conclusions and recommendations of the Stewart Report. The actions taken were;

- the adoption of the ICNIRP guidelines for RF exposure
- publishing the SAR values of phones and an audit of exposures near 200 schools
- launching a £7.5 million research programme
- improving consultation procedures for mast siting
- publishing Department of Health leaflets on phones and phonemasts
- completing a review of RF by the Advisory Group on Non-Ionising Radiation in Jan 2004

The UK is now considering the application of the Precautionary Principle to ELF in the light of both the IARC report and in particular the NRPB guidelines published in 2004. This will enter a consultative process soon.

Dr. Paolo Vecchia of the National Institute of Health in Rome, and the recently elected President of ICNIRP, reviewed ICNIRP's policy concerning children. It is heartening that ICNIRP is standing its ground. Its recommendations for limiting exposure will continue to be based on the "Critical Effect": that is, the established adverse health effect that is relevant at the lowest level of exposure. Were the Critical Effect to be one that involved children, that would then become the basis of the ICNIRP guidelines in the relevant area. Without a recognised health effect it is not possible to produce science based standards. There is therefore no need, nor justification, for a special approach to the protection of children. ICNIRP will continue to closely monitor data on children with special attention. It is clear from this statement of Dr. Vecchia that ICNIRP is not prepared to compromise its principles.

The meeting ended with Dr. Repacholi reviewing the draft WHO document on the Precautionary Framework which prompted an entertaining and lively argument involving a wide cross section of the participants.

And with that Dr. Repacholi thanked his staff and our Turkish hosts for their unstinting efforts to ensure a magnificent and smoothly run meeting.

Tom McManus

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