The Internet as a Public Information Resource, with a case study on a Canadian controversy about radio-frequency fields

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Abstract:

Installations for four of the new digital telecommunications networks for personal communications services (PCS) began in Canada in 1997. These networks utilise the 2 GHz part of the spectrum, whereas the older cellular telephone technologies use frequencies in the 800-900 MHz range. One significant feature of these new networks is that they require numerous roof-top antenna installations. In Canada one federal department, Industry Canada, issues licenses for transmitter and antenna installations, while another, Health Canada, is responsible for the health and safety (risk) regulations, which are published as "Safety Code 6" (issued 1990). Safety Code 6 specifies exposure limits for workers and citizens and covers frequencies ranging from 10 kHz to 300 GHz.

In the summer of 1997 some citizens in Vancouver, British Columbia became aware of the new installations when their community was informed that a local school had been asked to allow the placing of a roof-top antenna on its building. Shortly thereafter, the citizens discovered that another antenna had already been installed inside the steeple of a nearby church; the church hosts a day-care centre in its facilities. Concerns about health risks were raised, public meetings (including meetings with representatives of the two federal departments) have been held, and the controversy has been simmering ever since.

An important part of subsequent events was that the citizens turned to the Internet for information and self-education in health risk issues of concern to them. We examined these resources, and this paper describes the results of a detailed search of the Internet on hypothesised human health effects of radio-frequency electromagnetic fields. A conceptual map was developed which captures linkages between concepts according to their proximity and interconnectedness in the Internet milieu. A key issue is the abundance of summaries of scientific information provided in lay terms by non-institutional sources. These summaries tend to include very frank discussions of key concerns in scientific and regulatory inference and frequent reference to the rationality of the burden of proof applied in science where public health protection is concerned.

This paper provides an account of the public controversy, down to the present, from the standpoint of the need for good risk management principles as well as good risk communication practices.

INTRODUCTION.

In late April 1998 Canada's national newspaper, *The Globe and Mail*, published a front-page story entitled "How the Net killed the MAI." MAI is the Multilateral Agreement on Investment, a proposed international agreement on investment rules which has been championed by OECD countries for the last few years. A consortium of advocacy groups around the world, opposed to this initiative (partly because it was perceived to be mainly in the interest of multinational corporations), used Internet resources to co-ordinate their campaign, creating attractive web sites, maintaining constant communication, and distributing key information instantaneously among their memberships, including leaked official documents. One noteworthy aspect of the campaign is the fact that allies in Third World countries can participate at very low cost. In the context of the announcement that the OECD had suspended its efforts to reach agreement among official government representatives, one diplomat commented: "This is the first successful Internet campaign by non-governmental organizations. It's been very effective."[7] In our opinion, it will not be the last.

[7] Madelaine Drohan, article in *The Globe and Mail*, 29 April 1998, p. A1.

One of the major arenas for advocacy-group intervention in global public policy issues is in the broad area of health and environmental risks, where the "official" players at the table are these same national governments and multinational corporations. For some time now organizations such as Greenpeace and the World Wildlife Fund have been active at a global level in matters such as persistent toxic chemicals, forest management, and wildlife preservation, utilizing competent scientists on their own staffs. Among other things, they have developed effective Internet web sites as a part of their campaigns.

One can expect that the more successful environmental advocacy groups will become increasingly skilled in their use of Internet resources to advance their causes. But as well, and increasingly, individual members of the public who do not necessarily have scientific expertise, but who have concerns about risk issues, have begun using Internet resources to gather information, establish contact with like-minded people everywhere on the globe, obtain guidance on how to ask questions of experts, and prepare themselves to become skilled intervenors in risk controversies. The information-search, documentary retrieval, and networking facilities of the Internet have huge advantages over earlier resources available to the general public, and these advantages will grow steadily in future years. From now on, all major controversies over risk management decision-making will be played out on a public stage with an international cast and audience.

In addition to the aspects already mentioned, such as ease of networking and relatively low cost (including the value of time), the World Wide Web has other important characteristics considered as an information resource. One is the ease with which linkages across related concepts and areas of interest can be tracked, especially types of linkages which very likely would not have occurred spontaneously to individuals, nor would they have turned up in the cross-indices of the older library card catalogues. Another is ease of access to a wide variety of very different information sources, many of which are interactive -- that is, an individual's queries will result in personal responses and offers of further assistance. These are two of many similar advantages responsible for the success of the Internet. These and other features can have very important impacts on the formation of connections between ideas, on the apparent plausibility of cause-and-

effect relations, on the almost imperceptible blending of scientific and anecdotal evidence, and on the basic framing of risk issues. All of these features represent new challenges, discussed later on in this paper, for those who are responsible for the social management of risk issues.

In this paper we concentrate on the implications, for risk communication and risk management, of the use of the Internet as an information resource for individuals and groups in controversies over health and environmental issues. Our case study is the recent and ongoing controversy in Canada over health risks associated with the radio-frequency (RF) fields that are utilized in wireless communications technologies.

Conceptual Map of Internet Coverage for RF/EMF Issues.

It is very difficult to describe the nature of the information on the World Wide Web in a linear format on paper. Our diagram[8] is an attempt to demonstrate the enormous ability of the Web to capture complex phenomena in ways that normal documents cannot. The diagram is based on an intensive survey of the Web carried out in a purely random, experiential mode. The connections indicated by arrows create a map of the thematic linkages which can be "discovered" by anyone who is browsing the Web. This is by no means an exhaustive representation of all of the possible links that may be followed. In other words, ours is only one of many such maps that could be drawn, and the network of connections as a whole is in fact far more complex than this diagram suggests.

The figure also reflects the position of health effects within the larger thematic map. Health effects are sandwiched between technology (at the bottom of the diagram) and the societal variables which drive the public determination of the acceptability of risks and the required interpretation of uncertainty. As an example of the connectivity of issues, the following example describes the path through various concepts as might be followed by browsing the Web.

[8] The diagram will be found at the end of the paper. For a sample of what may be found on such sites, go to:
http://www.cruzio.com/~rbedard/waveguide/library.html

One web page contains an excerpt from a 1987 editorial in the *New England Journal of Medicine*, suggesting more cautionary approaches to regulatory toxicology;[9] this thought leads to a discussion of the "orthodox" nature of science and the apparent inability or "refusal" of the scientific and regulatory communities to accept the possibility of adverse health effects beyond those known as thermal effects. This leads to a discussion of the inadequacy of current exposure limits and the fact that Soviet researchers have lower limits based on their belief in the possibility of non-thermal effects. Often, commentators will question why the burden of proof is on the government or the public.

Interestingly enough, most sites do not insist with certainty that there are adverse health effects from RF exposure beyond those described as thermal effects. However, there is considerable discussion of "prudent avoidance," which is described as a common-sense precaution in the face of uncertainty.[10] Here it should be noted that the doctrine of prudent avoidance is often supported on the web-sites of companies which provide exposure mitigation devices (such as antenna shields) or consultancies in how to measure the home environment for those who are "electrosensitive." Another site featuring prudent avoidance is maintained by an independent researcher in the U.K. who has launched a lawsuit to require hazard labelling on cell phones; this same researcher offers on the site an elaborate theory that homosexuality, AIDS, and Sudden Infant Death Syndrome (SIDS) are a result of damage to the brain in the area that controls the immune system.

"Electrosensitivity" is a much more mature issue in Europe, and in particular in Sweden, than it has been so far in North America. The "electrosensitive" contributors on the Internet Europe usually refer to

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[9] "Science is a hard taskmaster, and in the light of mounting evidence that suggestions of toxicity are for the most part ultimately confirmed by painstaking scientific inquiry, perhaps it is time to reexamine whether scientific standards of proof of causality – and waiting for the bodies to fall – ought not to give way to more preventative health policies that are satisfied by more realistic conventions and that lead to action sooner." (19 April 1987)

[10] See below, pp. 22ff., for further discussion of prudent avoidance applied to RF issues.

"electrosmog" and then make the link to a general concept of pervasive environmental decay resulting from the actions of insufficiently controlled industries.[11] The general environmental decay theory is linked to other feared exposures to widely dispersed contaminants and is further linked to any health impact that is, or is perceived to be, increasing in incidence in the population. Correlation between radio-frequency exposure and increases in brain cancer, breast cancer and asthma are frequently cited, with the asthma hypothesis supported by some scientific evidence of interference with the activity of antihistamines.

Usually, the discussion returns to what is perceived as denial or cover-up; parallels to the tobacco case are almost always provided, and some sites have exhaustive discussions of allegations about a long history of denial about RF effects – by the U. S. military, for example.[12] This leads in some cases to a discussion of the military/industrial complex and the sheer economic power and momentum of the mobile communications industry. The economic power is in turn seen as explaining how these impacts could be covered up; sometimes the cover-up is linked to the use of RF in brainwashing experiments by the CIA. Finally, RF and power-line (ELF or extremely low frequency fields) issues are closely paralleled on the Web, in particular with regard to the provision of resources (by grassroots activists linking communities with each other) to fight the siting of various types of installations. Any health effect in ELF is a candidate in RF and vice versa; for example, adverse health effects such as Alzheimer's and ALS in the ELF domain are also featured very strongly in the RF domain, and both are linked to findings on memory loss, CNS effects, and some so-called "subjective" effects reported by Soviet researchers in past decades.

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[11] In European countries the term "electrosmog" is a catchy shorthand phrase to denote the sum total of electrical and magnetic fields (EMF) disseminated through the operation of all communications-related technologies – cellular phones, short-wave radio, radio and television broadcasting, radar and other microwave installations. "Electrosmog" is not yet a prominent part of the lexicon of public controversy in Canada. See P. M. Wiedemann & H. Schütz, "The Electromagnetic Fields Risk Issue," *European Review of Applied Psychology*, vol. 45 (1995), pp. 35-39.

[12] The history is chronicled in Paul Brodeur, *The Zapping of America: Microwaves, Their Deadly Risk, and The Cover-up* (New York: W.W. Norton & Company, 1979).

"Electrosmog" in Canada.

Apart from a minor level of interest in the older controversy about cellular telephony and brain cancer, there had been no sustained controversy in Canada over RF fields until four networks (Cantel - AT&T, Clearnet Communications, Microcell Telecommunications, and Mobility Canada) began to install the newer digital personal communications services (PCS) networks, first in the larger urban areas, in 1997. While the older analogue cellular telephones operate at 800-900MHz in the high frequency band, the PCS systems occupy the ultra high frequency band (around 2GHz); this higher frequency allows the latter to operate at very low power. The output powers of the base-station antennas are on the order of 100 watts each, and the handsets themselves have a maximum output power of around 1 watt. However, the low-power mode requires a clear line-of-sight between the antennas in the network, which means that a comparatively large number of antenna installations is necessary (750 antenna sites in Metro Toronto, 500 in Montréal, and 500 in Greater Vancouver).[13]

Telecommunications regulation is a federal jurisdiction in Canada, and licenses for the transmitter and antenna sites needed for cellular telephony networks are assigned by Industry Canada. Antenna licenses for cellular systems are issued in groups of 80 to cover a defined geographical area, but particular sites are not specified. Licensees are required to comply with a set of safety guidelines issued by another federal agency, the Radiation Protection Bureau of Health Canada, and also to undertake consultations with "land-use authorities" (municipalities); obviously, consent of a property owner also must be obtained before an installation can be erected.[14] Except where violation of a valid municipal zoning

[13] Clearnet PCS, Inc., "PCS: What is it?" pamphlet, December 1997; Ericsson Radio Systems AB, "Health and Safety in Mobile Telephony," pamphlet, 1997.

[14] Radiation Protection Bureau, Health Canada, "Limits of Exposure to Radiofrequency Fields at frequencies from 10kHz – 300GHz [Safety Code 6]," 1991; revised draft, April 1997. Industry Canada, Spectrum Management, "Environmental Process, Radiofrequency Fields and Land-Use Consultation," 1995. At least some provincial governments, such as British Columbia, maintain staff with technical expertise in EMF and RF, but this level of government does not have an official role in siting decisions.

ordinance (such as height restriction) is at issue, the Industry Canada license cannot be legally challenged providing that consent of the property owner has been obtained. Not surprisingly, the perceived lack of community and local government control over such installations, especially in "sensitive" locations (e.g., on schools and churches), is itself a factor in public controversy.

In early June 1997 parents in the Fraserview area of Vancouver learned that Cantel had made an arrangement to install a PCS antenna on the roof of the local elementary school building. An outcry erupted at a school information meeting and Cantel quickly cancelled the deal; however, as a result of the publicity the community discovered that Microcell was in the process of installing a 1.2-metre antenna inside the cross atop the Fraserview Assembly Church located across the street from the school building.[15] Microcell refused to cancel this project, and some community members began to mobilize public opinion against it, preparing a news release which was picked up in newspapers and granting TV and radio interviews. Over the next months protest leaders prepared pamphlets for distribution in the community, wrote letters to papers, held meetings with local government officials, and filed an appeal against the installation with the Vancouver Board of Variance, which deals with zoning matters.

A Health Canada official had been present to discuss health risk concerns at the initial information meeting, but within a week newspapers were citing local school board officials as saying that New Zealand had banned such antennas on school buildings, and the states of Oregon and Washington were considering similar actions. The protest leaders began calling the scientific staff at Health Canada headquarters in Ottawa with requests for more details about the scientific evaluation of risk; a prominent researcher in this field at the University of Washington was also quoted in early media coverage, warning that "there has not been enough research for

[15] Church steeples are a preferred site for wireless telecommunications equipment locations, and in the United States some consultants are making hefty fees advising church congregations on how to bargain effectively with the industry representatives. Jon G. Auerbach, "Steeple chase a serious business for U. S. churches," *The Globe and Mail*, 1 January 1998, p. B5. Cf. Kevin Marron, "Antenna on church is a test of faith," *The Globe and Mail*, 2 September 1997.

scientists to know if there are cumulative long-term effects on children from these antennae."[16] As a result of direct contacts with Health Canada staff, university-based researchers, and their first Internet searches, the protest leaders began to inform themselves about the scientific risk assessments for radio-frequency fields.[17]

Within six weeks the issue was tabled in a formal setting (the Board of Variance meeting) with a structured mode of confrontation. Microcell filed an information package about scientific and regulatory matters with the Board in advance, and brought to the Board's public meeting not just its own personnel but also a university professor well-known in this field, who was acting as a consultant to the company.[18] The Microcell representatives made presentations and were asked questions by the Board members. The community protest leaders who had filed the appeal were there too, of course, led by Mr. Milt Bowling and Ms. Angela Sousi; they had filed a written brief of impressive proportions with the Board and made oral presentations, the nature of which tell a great deal about the forms of information traffic in the Internet age.

The reasons for appeal in the citizens' brief and oral presentations, which had been researched and written within about six weeks, ranged over regulatory and scientific matters and were based on personal discussions with some academic researchers in the field as well as on articles in a

[16] Professor Henry Lai, quoted in the *Vancouver Sun*, 10 July 1997.

[17] At about the same time (24 June 1997) the city council in the neighbouring community of Burnaby heard a submission against a re-zoning application to permit construction of an antenna in the parking lot of a shopping centre. The submission was made by a Mr. J. A. Whiffen, who described himself as an equipment designer for the nuclear diagnostics industry. Whatever the merits of the particular case being advanced, the submission presents what is on its face a highly sophisticated argument by someone thoroughly conversant with the scientific and technical terminology.

[18] The consultant, Professor Maria Stuchly of the University of Victoria, has a special significance in this controversy, because at an earlier stage in her career she was the federal government employee who was chiefly responsible for preparing Safety Code 6.

leading industry publication, *Microwave News*.[19] Bowling and Sousi opened the "credibility" gap by contrasting what they were being told – about the scientific studies (including animal studies) on which the current risk assessments are based – unanimously by health experts from their own local, provincial and federal governments, by the company, and by the company's own academic expert, with references to different views apparently held by some Harvard University researchers and by Michael Repacholi, the leader of WHO's EMF risk program. Safety Code 6 was said by them to be out of date, being based on the state of research in the 1980s and not having been revised to reflect any of the numerous research results published in the preceding ten years.[20] Of course the Vancouver Board of Variance was in no position to take up matters such as the possibility that recent studies had shown excess lymphomas in laboratory mice exposed to RF fields; in any case without giving reasons the Board concluded the meeting by revoking the construction permit for the antenna installation in the church.[21]

As mentioned earlier, the federal jurisdiction is paramount in these matters, and Microcell decided not to remove the installation (the church did not require it to do so), which in effect threw the issue back into Industry Canada's lap. For the citizens who had led the fight the effect of

[19] Traditional print-based publications are still important in the electronic age: *Microwave News* was a key source for the citizen intervenors in the early stages of their investigations into the health risk issues.

[20] Safety Code 6 is officially a guideline, not a regulatory instrument; federal officials maintain that this is actually an advantage, since guidelines can be changed far more easily than regulations. However, it does have the character of a "static" document, since no new material appears in the booklet itself since its original issuance in 1991. With the single exception of a 1990 publication which does not deal with health issues, there are no publications dated later than 1988 in the list of references in Safety Code 6.

[21] One week earlier (16 July 1997) another municipal official, the Medical Health Officer at the Vancouver/Richmond Health Board, had issued a one-page sheet supporting Health Canada's position: "... [T]he general scientific consensus holds that the power from cellular base stations is far too low in the community to result in adverse impacts." There was also a very pertinent comment on prudent avoidance, to which I shall return later; but this document does not appear to have exerted any influence on the course of the debate.

Microcell's perceived intransigence was to prolong the issue, and they responded by redoubling their efforts to prevail. As the issue persisted through the Fall of 1997, the role of the WHO program and its director increased in prominence. In October Angela Sousi remarked on a Vancouver radio program:[22]

[Our] concerns are based on the fact that we feel the scientists in the world can't unanimously agree on the safety of the long term non-thermal bioeffects of non-ionizing radiation and ... when we had a meeting at our school earlier this year, we were told that it was impossible to have non-thermal bioeffects, meaning that if it doesn't heat you, it can't hurt you. There was a study done recently that indicated that is a possibility that we could have non-thermal bioeffects. This was conducted by a doctor, Michael Repacholi, on behalf of Telstra [the Australian national telecommunications company],... [who] did some experiments with other individuals that suggested that there were some effects. So here we have one group of scientists saying it's possible and another saying it's impossible.

Expert disagreement – and the impacts it can have on the public perception of risk -- is not unknown in risk controversies, including all types of EMF risk.[23] The impact it may have under specific circumstances can vary greatly. In this case, it seems to us, the sequence of events and the nature of the actual players made a difference to the outcome.

In the present story one key event was a press conference in Geneva held on 19 December 1997, at the conclusion of scientific meetings sponsored by WHO and attended by experts from seventeen countries, at which Michael Repacholi called for more research on EMF and RF risks.[24] The lead paragraphs in the wire story ran as follows:

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[22]Interview with Rick Cluff, "Early Edition" program, CBU-AM (Vancouver), 24 October 1997.

[23] W. Leiss & C. Chociolko, *Risk and Responsibility* (McGill-Queen's University Press, 1994), chs. 4-5.

[24] Citations in this paragraph are from the nearly-identical stories published in many western Canada newspapers on 20 December, all based on a Reuters wire story from Geneva.

Hoping to sort out "mixed evidence" on the issue, the World Health Organization called Friday for more research into whether mobile phones, power lines and radar might cause diseases that include cancer and Alzheimer's. Dr. Michael Repacholi, manager of the WHO's Electromagnetic Fields Project, told a news conference that perceived risks from new technologies have become a serious public health issue. He expressed confidence that existing international standards are adequate for high-level exposure, but said study is needed on the effect of low-level exposure over longer periods.

In the story as a whole there were references to "suggestions," "possible connections," "possible links," and "mixed evidence" between EMF at various frequencies and the following list of diseases: brain cancer, head and neck cancers, childhood leukaemia, lymphoma, breast cancer, central nervous system disorders, memory loss, neuro-degenerative diseases, and Alzheimer's. On mobile phones in particular, there was a direct quote from Repacholi, to wit:

"Mobile phones have only been around for less than 10 years now and the incubation period for cancer is at least 10, maybe 15 years. So we need to set up the studies so that if there is an impact, they [sic] can be found in a reasonable time."

The public might be excused for thinking, upon reading this statement, that ordinary citizens differed from laboratory rats chiefly in that the latter were used for short-term experiments and the former for the longer-term ones. More to the point, perhaps, the citizen intervenors in Vancouver might have been excused for thinking that the substantive health-risk basis for their bitter and prolonged fight against PCS antenna siting had been validated fully by an eminently credible international agency.

Risk Communication and Risk Management challenges.

In 1998 Microcell "voluntarily" removed its antenna installation from the Fraserview Assembly Church in Vancouver. And in August 1998 the Government of Canada asked the Royal Society of Canada to establish an independent expert panel on the health risks associated with radio-

frequency fields; the panel will issue a public report in March 1999.[25] Within hours of the press release announcing the panel's composition and mandate, the Society began receiving a continuous stream of return messages, including copies of queries sent by Internet activists to a variety of lists asking for an analysis of the panellists, with respect to their "positions" on issues and on sources of their research funding. Two of the panellists immediately were said to be compromised by close affiliation with the wireless telecommunications or electrical industries.[26]

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[25] Press release, Royal Society of Canada, Ottawa, 4 August 1998. The Terms of Reference for the panel report ask the panel to answer the following questions:

A) General Questions: With regard to Health Canada's Safety Code 6, in particular the draft version revised as of July 1998:
   1) What are the biological effects and/or potential adverse human health effects associated with exposure to radiofrequency fields emitted from wireless telecommunication devices such as wireless phones and base-station transmitters?
   2) Do the provisions of Safety Code 6 protect both RF workers and the general population from the "thermal" effects associated with the exposure to radiofrequency fields?

B) With regard to the issue of "non-thermal" effects of radiofrequency fields:
   3) What "non-thermal" biological effects and/or potential adverse health effects have been reported in the literature?
   4) Is there evidence that such effects, if any, could be greater for children or other population sub-groups?
   5) What research is needed to better understand the potential health consequences for "non-thermal" effects?

C) Implications of the foregoing for Safety Code 6:
   6) What are the implications for Safety Code 6 of the panel's scientific review of the currently available data on biological effects and the potential adverse health effects of exposure to radiofrequency fields? In particular, should the phenomenon of "non-thermal" effects be considered in Safety Code 6?

[26] The author is Chair of the Society's Committee on Expert Panels which screens and appoints panelists and oversees the procedures by which panels operate. The Society has published a "Manual of Procedural Guidelines" (October 1996) for panels which is based on procedures developed by the U. S. National Academy of Sciences and its affiliated institutions; these include provisions for a detailed review of "bias" and conflict of interest, and an effort to achieve "balance" in panel composition, in the course of the panel selection process. Of course, whether the

There is every reason to think that we are just at the beginning of the period when Internet resources will be used by individuals and groups to enhance their ability to be skilled intervenors in social controversies about health and environmental risks. The radio-frequency fields controversy in Canada allows us an opportunity to do an initial assessment of the role of Internet resources in these matters, within the broader context of society's own need for appropriate risk management processes. For it is one thing to observe that Internet-based information resources are vital new aids in the empowerment of citizens, and thus in the functioning of legitimate democratic decision making processes – which is the case, generally speaking, in my opinion. But it is equally true that sensible risk management is a complex high-stakes and long-term game in which we are obliged to reflect carefully on the assessments and perceptions of risks, as they evolve in protracted risk controversies, and to ask, for example, whether individuals and groups actually are serving their own interests in the outcomes. Thus the real heart of the matter is not the uses of Internet resources themselves, but rather it is the relation between these uses and the ability of individuals to promote their own "best interests" in the positions they take on how our society should manage risks.

The underlying structure of risk controversies is best understood as a state of legitimate and necessary tension between the expert assessment of risk, on the one hand, and the public perception of risk, on the other. Because the gap between the two is an enduring rather than a transitory phenomenon, we require a means of facilitating exchanges between the two domains, and this is in fact the function of good risk communication practices. More often than not, however, we find a systematic failure to employ such practices, leading to the creation of a risk information vacuum which makes sensible and publicly-credible risk management decision making virtually impossible to achieve.[27]

Society has achieved these objectives in any particular case is a legitimate subject for debate.

[27] For a full discussion of this perspective see chapter 1 in Douglas Powell & William Leiss, *Mad Cows and Mother's Milk: The Perils of Poor Risk Communication* (McGill-Queen's University Press, 1997).

The radio-frequency fields controversy in Canada is a perfect case study in the existence of a risk information vacuum and its consequences for risk management. This can be seen clearly once the elements presented earlier are arrayed systematically. In summary, there is clear evidence that governments had authorized private industry (in return for financial considerations) to introduce a new technology across Canada, including numerous installations at sensitive locations within communities, without *first* having in place a clear and credible explanation of the associated risk factors. This is in our opinion undeniably a dereliction of duty for governments, which have the primary responsibility for managing risks.[28] From a practical standpoint it is also asking for trouble. One hopes that both industry and governments have learned something from this venture.

We have organized the issue map into four sectors: risk communication, risk assessment, related "social" issues, and risk management.

Risk Communication Issues.

1. Insufficient explanation of technical and engineering factors: The full electromagnetic spectrum, and its radically different characteristics at various frequencies, is a complicated business. In addition, the trade-off between the frequency and the output power of transmitters (where higher frequencies make it possible to use lower output and thus – arguably – a net reduction in total risk, considering multiple risk factors) is directly relevant to perceived risk. Another example: The shape of the beam from a base station antenna has some specific characteristics directly relevant to exposure, and thus to risk;[29]

[28] This is just one in an almost endless list of such cases, where governments think they have finished their work after their risk assessment is completed, having devoted little or no effort to risk communication, including confronting the matter of credibility – and then usually only after a controversy has erupted, when it is virtually impossible to get one's message across.

[29] "The signal from a cellular or PCS base station antenna is essentially directed toward the horizon in a relatively narrow beam in the vertical plane. For example, the radiation pattern for an omni-directional antenna might be compared to a thin doughnut or pancake centered around the antenna while the pattern for a sector antenna is fan-shaped, like a wedge cut from a pie.... Consequently, normal

among other things, this is relevant to the application of the "prudent avoidance" maxim (see below). But none of this was explained *in advance* to the public in understandable terms. Once the controversy broke in a specific community in Vancouver, government and industry personnel scrambled to provide some explanations for these and other technical factors; but one cannot hope for much success in persuasive communications under such conditions. (A good time to initiate the dialogue with affected communities would have been when the installation siting was in the planning stage. But this would violate the time-honoured maxim, "Let sleeping dogs lie.")

2. Explanation of risk factors, (a): federal government – basic document. Safety Code 6 is an engineering-type document, containing nothing but the barest mention of the health risk factors. Most significantly, *it does not even name the established risk factor (thermal effect)*, much less any of the hypothesised, so-called non-thermal effects; thus it cannot serve the purpose of risk communication. Nor does a small Health Canada brochure with the odd title, "Safety of Exposure to Radiofrequency Fields: Frequently asked questions," mention any specific risk factor. The brochure states: "We hope it provides clear information about a complex and often misunderstood topic." Since the text mentions the possibility of adverse effects, but does not even say what they are, the intended clarity is a vain hope.[30]

3. Explanation of risk factors, (b): federal government – current science. Everyone who accesses the Internet on RF issues quickly learns about "non-thermal effects," but (so far as we know) *no document issued by the Canadian government has ever used these*

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ground-level exposure is much less than exposure very close to the actual antenna." U. S. Federal Communications Commission (FCC), Office of Engineering and Technology, "Information on human exposure to radiofrequency fields from cellular and PCS radio transmitters," January 1998, p. 2.

[30] The FCC has useful and up-to-date documents on its web site that are written in a reasonably accessible style (www.fcc.gov/oet/rfsafety), especially OET Bulletin No. 56, "Questions and answers about biological effects potential hazards of radiofrequency radiation."

words. The published scientific literature includes mention of the following types of such effects (note that any such effect may or may not be substantiated or that, even if it is, an effect is not necessarily an adverse effect in human health terms): brain cancer; other cancers; calcium ion efflux; ocular damage; electrosensitivity; stress; birth defects; headaches; asthma; immunosuppression and immunostimulation; alterations in drug metabolism; memory loss; behavioural changes; learning deficits; Parkinson's disease; Alzheimer's disease; ALS.

The federal government, elected by Canadians, has decided to authorise industry to install technologies in return for handsome payments; information in wide circulation (not all of which is suspect by any means) associates these technologies with certain risk factors. Why is it thought to be appropriate for public authorities in Canada to remain silent on these matters? Canadian citizens could, if sufficiently motivated, turn to the web site maintained by the U. S. Federal Communications Commission and at least read a brief discussion on non-thermal effects, and learn that at least two of them (the "calcium efflux" and "microwave hearing" effects) are regarded as well-substantiated. They would also find the following general statement: "It is possible that 'non-thermal' mechanisms exist that could cause harmful biological effects in animals and humans exposed to RF radiation. However, whether this is the case remains to be proven."[31] But why should they have to go to a foreign government for such a discussion, however minimal?

1. Explanation of risk factors, (c): industry. (i) Microcell official quoted in a newspaper: the antenna poses "no risk." (ii) Same official: "There isn't a safety concern." (iii) Cantel official: "There's absolutely no medical or scientific research that indicates any cause for health concerns."[32] The following comments are pertinent: (i) Of course it poses a risk – although the risk may be negligible, vanishingly small, acceptable, or whatever. (ii) Of course there is a safety concern – although that concern could be reduced

[31] *Ibid.* (OET Bulletin No. 56), p. 5.

[32] (i) *Vancouver Sun*, 10 July 1997; (ii))*The Province* (Vancouver), 2 July 1997; (iii) *The Vancouver Courier*, 8 June 1997.

with more complete or reliable information. (iii) Of course there is such research – although it may not turn out to be substantiated. It is surprising that such officials still do not seem to realise that such statements are both inaccurate and inflammatory.

2. Timeliness. The lack of advance discussion with respect to the installation of PCS network equipment is a serious risk communication failure, as already indicated. But the next generation of wireless communications technologies is already in the works; are these mistakes likely to be repeated? The terms of reference proposed to the Royal Society of Canada for its review of health risk factors associated with RF fields contain the following statement: "New technologies such as mobile data, wireless local area network (WLAN) in the 5 GHz range, specialized mobile radio (SMR)/enhanced specialized mobile radio (ESMR), wireless local loop and low earth orbit (LEO) mobile satellite service are forthcoming."[33] Indeed, sooner than many may suspect. A press release issued recently states: "Canada's largest advanced, wireless, broadband telecommunications network will be rolled out in all regions of Canada, beginning in Toronto in the first quarter of 1999..., [providing] connectivity for data, Internet, voice and video traffic over the air that can be delivered worldwide. The WIC Connexus advanced network represents the genesis of the 28GHz wireless access market."[34] These so-called "local multipoint communications system" (LMCS) wireless networks eventually may put the transmitter/receiver equipment in everyone's back yard. This may very well be just fine; but it would be wise to start talking about it with the public without delay.

Risk Assessment Issues.

1. Expert uncertainty and disagreement. Such matters ought always to be freely disclosed, assessed, and interpreted for the public by the risk managers. There is of course nothing surprising in the back-and-forth among researchers, especially where a relatively new area of

[33] *Supra* note 19.
[34] WIC Connexus press release, Toronto, 19 August 1998.

research (such as non-thermal effects of RF fields) is concerned. This would be a matter of idle academic curiosity were it not for the fact that governments are collecting monies for allowing others to generate these fields while the research effort proceeds, which gives rise to the corresponding responsibility for *regular* reporting and discussion.

2. Quality of the basic document. Some of the shortcomings of Safety Code 6 as a risk assessment document have been indicated earlier (*supra* note 14). A revised version has been under development for some time but is not yet available, partly because Health Canada's Health Protection Branch does not have nearly enough resources to cover its responsibilities. But the document format also has many deficiencies, especially in that it treats its subject-matter primarily as a matter of engineering rather than of basic science, and in that it does not explicitly refer to risk assessment (RA) methodologies or the incorporation of RA into a "formal" risk management process.

"Social" Issues.

1. Equity: This is always fundamental where siting is concerned, and since siting choices are left up to industry, it is industry who should deal with them. Communities are entitled to hear reasons in favour of particular siting choices and an answer to objections to those choices – without having to insist on having them.

2. Prior notice. This too should be provided without citizens having to ask for it, but it certainly did not happen with the Fraserview Assembly Church site. Both citizens and municipalities (which are first in line for complaints from their residents) deserve complete disclosure for the entire installation plan in their areas. In November 1997 the Municipality of West Vancouver's general services committee approved recommendations for mandatory notification to Council of PCS sites (even when approval is not required), a public notification and information process by companies prior to issuance

of permits, and an overall plan for all sites to be requested by a company, so that alternatives could be discussed.[35]

3. Role of governments. Both Industry Canada, which has legal authority to approve telecommunications installations by private industry all across Canada, as well as the various provincial and municipal authorities which are passive partners in these ventures, should be far more sensitive than they are now to the potential for community outrage. This is especially so since the actual authorization for licenses takes place in Ottawa, far from the localities where the impacts will be felt. The advent of the next generations of wireless technologies offers an opportunity for governments and industry to collaborate in designing an enhanced community liaison process.

Risk Management Issues.

1. Allocating responsibilities for enhanced risk communication: Where several agencies of government, in collaboration with industrial sectors made up of many different players, introduce new technologies and new risks, it is unclear who should be assigned responsibility for risk communication. The usual result is that no one picks up the ball. This should be sorted out before the crisis strikes. All these players may be perceived to have some conflict of interest with respect both to the risk assessment and scientific research overview as well as the risk communication activities, but this difficulty can be addressed by using independent third parties for such functions.

2. Uncertainty. The most problematic aspect of risk management from an ethical and equity standpoint – although it has never been adequately recognized as such – lies in justifying who in society should bear the costs of uncertainties in risk assessments.[36] In the

[35] Corporation of the District of West Vancouver, Council Report: Personal Communication Service (PCS) Antenna Cell Sites Approval Process," 28 November 1997.
[36] *Risk and Responsibility,* ch. 9.

earlier history of innovative risk-taking in industrial society those who could not avoid unequally distributed and often excessive exposures (workers) paid the price for the fact that new technologies were implemented for long periods while massive uncertainties about the associated hazards persisted. Others not so exposed reaped the greatest share of the benefits, but the rising standard of living for everyone also distributed widely a considerable share of the benefits.

Things have changed considerably on this score. *Generally speaking*, societal risk management has reduced the excess involuntary risk for sub-populations (e.g., those living in proximity to hazardous waste facilities, RF antennas, or nuclear power stations) to a mere fraction of its former level. Another way of putting this is to say that the benefit – risk ratios in involuntary exposures have widened enormously to the advantage of the former. Those risk levels are not and never can be zero; but they are not necessarily an unreasonable burden on those who now bear them, taking into consideration all of the known risk factors in the lives of people in contemporary society.

But the excess risk (however small) in *every* involuntary exposure itself, *and* the ever-changing elements of persistent uncertainty in the risk assessments, *and* the rationale for inequitably distributed exposure, *must be* articulated and defended to the citizenry by the risk promoters. (Risk promoters are industry and governments which introduce new technologies.) Such a defence may vary widely in terms of its rationale, but it can be constructed, and in any democratic society worthy of the name, the risk promoters have the duty to do so.[37] That duty rarely has been discharged at all, much less discharged well, in our own society, and it is past time to change this pattern.

1. Risk reduction. In all cases where unequally-distributed involuntary exposure is combined with a mixture of private benefit and public good, risk reduction to some defensible

[37] This is not the same as demanding consent from everyone who might be exposed at any level, because no new technology ever could be introduced under such a requirement, and on the whole, and collectively, citizens derive significant net benefits from them.

> point (say, "as low as reasonably achievable") is a sound and just risk management option. In EMF and now in RF issues the phrase "prudent avoidance" has wide currency in this context. It implies that the technology's social benefit is evident and that exposures should be minimized so far as especially sensitive populations such as children are concerned. This application of the maxim of prudent avoidance was articulated clearly by Milt Bowling: "We want sites located where children aren't going to be exposed for long periods of time every day."[38]

Ironically there is the possibility that the maxim could be applied best by choosing the site which was first the subject of protest, namely, the roof of the local school building. This has to do with the "shape" of the beam in a RF directional antenna (see note 23), which would result in virtually zero exposure in the building itself as well as its surrounding grounds. This point was made by Microcell's expert consultant at the Board of Variance meeting, and also in the circular prepared by the local Medical Officer of Health:

With respect to the particular installation and the specific request to the Board of Variance to institute a moratorium on cell phone antennae sites in the vicinity of schools and day cares, the benefits of a moratorium are at best questionable and at worst non-existent. Given the typical radiation patterns from cellular antennae, there is normally a "radiation shadow" directly beneath the antenna structure with very low levels (well below 1$\mu w/cm^2$) of radiofrequency radiation. Most of the antenna power is directed outward horizontally (within a 10° cone @ 100 ft) usually commencing at a height of several stories above ground level. The practice of "prudent avoidance" in this instance does not result in any increased level of protection as might be the case in requiring buffer zones next to high voltage transmission lines (where both magnetic and electric fields are present as opposed to RF fields).[39]

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[38] Cited in Kevin Marron's article in *The Globe and Mail* (2 September 1997) and in other news stories.

[39] See note 16.

This is an example of an important point where citizen intervenors themselves need to be very clear as to their own interests and objectives, first of all, and secondly, as to the risk management options that will serve those objectives well. The prudent avoidance maxim itself is not necessarily irrelevant to the RF fields issues; what is at stake here is whether or not it can be applied to achieve some sensible risk reduction objective and if so, how.

In the end the responsibility to propose such applications – more precisely, to initiate a dialogue with citizens in which the possibility of applying the prudent avoidance maxim sensibly to particular circumstances is raised -- does not lie with worried parents, but rather with the risk promoters. In other words, when the industry initiates -- as it should -- a community dialogue early in its own planning process for new installations, a part of its own contribution to that dialogue is to demonstrate that it has explicitly and seriously reviewed its preferred siting options from the standpoint of the prudent avoidance maxim.

Conclusion on Risk Management: A Note on SwissRe.

One of the most interesting documents yet to appear on RF issues is the booklet "Electrosmog – a phantom risk," published in 1996 by Swiss Reinsurance Company (Zurich). The document is also posted on the company's web site and thus can be downloaded anywhere, and this is how it was obtained by some of the citizen intervenors in Vancouver, who had seen a reference to it in *Microwave News*. It deals in a highly sophisticated way with the business -- and specifically the insurance -- risk posed by the existence of social controversy over health effects associated with EMF and RF fields, which in SwissRe's view gives rise to

... an extremely dangerous risk of change composed of two parts: the classical development risk, that is, the possibility that new research findings will demonstrate electromagnetic fields to be more dangerous that has hitherto been assumed; and the socio-political risk of change, in other words, the possibility that changing social values could result in scientific findings being evaluated differently that they have been so far.... We consider the risk of change to be so dangerous because it is evident that a wide range of groups have great political and financial interest in

electrosmog being *considered* hazardous by society. If these interest groups prevail, current and future EMF liability suits could be decided in favour of the plaintiffs, thereby confronting the insurance industry with claims on a scale which could threaten its very existence.... In this sense, this publication is a warning.[40]

This warning comes from an industry that is still paying out asbestos-related claims for exposures that occurred up to half a century ago. It carries the implication that liability insurance coverage for the telecommunications industry could be affected by the further development of these issues in "socio-political" terms.

Perhaps the most curious aspect related to this publication is that at least some of the citizen intervenors in Vancouver who read SwissRe's booklet found succour in it: They thought that it validated their expressions of concern, even though this very carefully written document gives no support to the idea that there are now unacceptable levels of risk associated with RF fields, or that they are likely to be found unacceptable in the future. What can explain this reaction? True, the document has beautiful graphics, including a superb one on the EM spectrum; it has a most intelligent and readable scientific summary of EMF; it takes the matter of persistent uncertainty seriously; it concedes the point that "it is theoretically possible for even the weakest signal to induce biological responses and in this way affect organic processes" (p. 17); it rejects the false comfort of zero risk, stating clearly that "EMF health risks cannot be eliminated entirely ... [but] can at best be reduced, insofar as they are known and measurable" (p. 20); and, above all, it has a sophisticated discussion about the relation between scientific risk assessment and the social evaluation of risk. But none of this probably explains the reaction of some of the readers in Vancouver. We suspect that their reaction reflects, perhaps subconsciously, a sense of appreciation for the fact that a major industry player had taken the trouble to write about these things at all.

[40] "Electrosmog – a phantom risk," pp. 4-5 (italics in original). Recently another global player in the forest industry, Canada's MacMillan Bloedel, conceded that changing social values about clearcutting and old growth forests had affected significantly its business risk .

Strengths and Weaknesses of the Internet as an Information Resource.

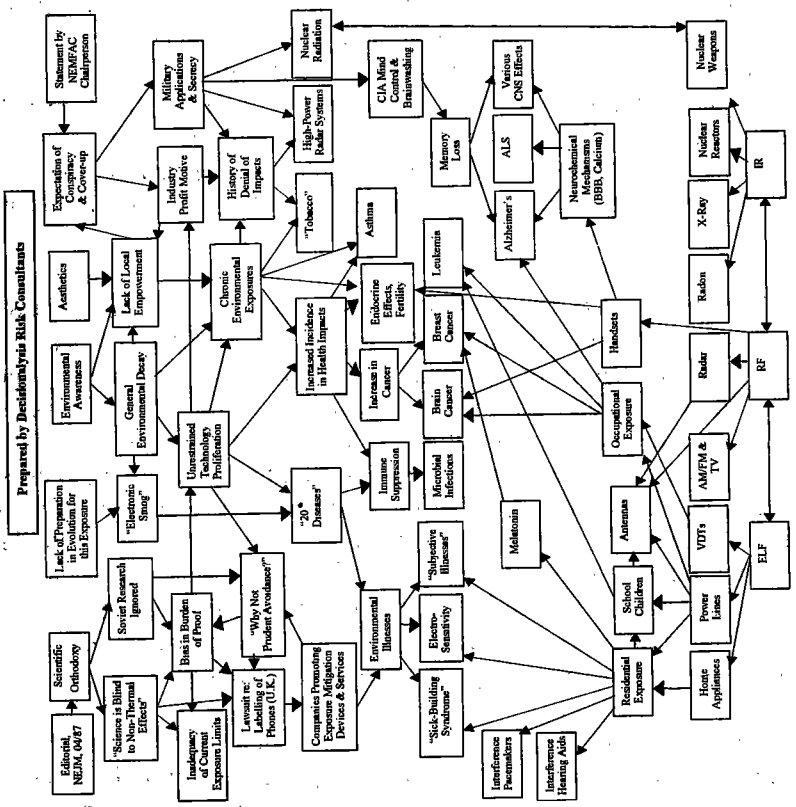
Earlier we noted that individual members of the public who have concerns about risk issues have begun using Internet resources to gather information, establish contact with like-minded people everywhere on the globe, obtain guidance on how to ask questions of experts, and prepare themselves to become skilled intervenors in risk controversies. Those who wish to do so can find on the Web complete copies of many peer-reviewed scientific publications and other documentary material from excellent sources. The information-search, documentary retrieval, and networking facilities of the Internet have huge advantages over earlier resources available to the general public, advantages that will grow steadily in future years.

There are some corresponding disadvantages as well. Many sites are maintained by activists who are committed to a particular perspective on issues and who also have (judging by the contents) reasonably good scientific training; individuals visiting these sites who are non-experts in these matters can end up just with a wider array of opinion on what the scientific issues are, without any way of evaluating the relative merits of what they find. Second, much (but by no means all) Internet activism has the tenor of "guerrilla warfare" and conspiracy, a crusade against the large institutional players in government and industry, which influences the presentation of material. Third, straightforward scientific reports are mixed liberally with anecdotal evidence; casual visitors to their sites need to exercise some caution in sorting through what they find.[41]

These and other weaknesses are serious matters, but on the whole they do not cancel out the offsetting advantages. In any case the Internet as a public information resource is here to stay. Citizens concerned about health and environmental risk issues will derive greater benefit from

[41] The author's e-mail address was given on the press release from the Royal Society of Canada; within days there was a regular return flow of communications about RF issues, containing among other things detailed cases about alleged adverse health effects for both humans and farm animals in Australia, Canada, Germany, and the former Yugoslavia.

Internet resources over time as more players set up shop there – including those who have a mission to deliver balanced, disinterested, up-to-date, and credible accounts of ongoing risk controversies.



Public Debate on Electric and Magnetic Fields and Health in Quebec

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INTRODUCTION

While the first public debate on electric and magnetic fields (EMF) and human health took place in 1975 during hearings held by the National Energy Board (NEB) of Canada in conjunction with a proposal to export energy to the United States (Cardinal, 1996), it is, above all, through the public hearings of the Bureau d'audiences publiques sur l'environnement (BAPE) that this issue has been repeatedly examined in Québec

This article focuses on the examination of the problem during five public hearings before the BAPE involving Hydro-Québec, the promoter, in respect of five different projects. I will look at the increasingly important role that the health sector is playing in the debate and how, through the interplay between Hydro-Québec, the BAPE and the health sector, future developments can be anticipated. In light of these observations and my experience, I will formulate a number of suggestions concerning risk management and EMF.

OVERVIEW OF THE ISSUE

Certain projects in Québec, including the construction of 351 kV and higher power transmission lines are subject, by regulation, to an environmental impact assessment. Under the process, the promoter must issue notice of the project, the government department concerned must issue a directive concerning the environmental impact study, and the promoter must produce the study under the supervision of the Minister of the Environment and Wildlife. Once the impact study has been completed, it is made public. Any individual or institution wishing to request the holding of public hearings may do so within 45 days. Unless the request is deemed to be frivolous, the minister must grant the hearing and mandate the BAPE to conduct it.

The BAPE has four months to carry out its mandate to conduct an investigation and organize public hearings. While the procedure is quasi-judicial in nature, public hearings in Québec are political and popular in nature. The hearings are held in two stages. The first stage is devoted to questions and the dissemination of information and the second, to the submission of briefs. At the conclusion of its deliberations, the BAPE presents its conclusions and analyses in a report. The body does not have decision-making power but plays an advisory role, i.e. it engages in non-binding arbitration. Cabinet makes the final decision, on a recommendation from the Minister of the Environment and Wildlife. In order to exert some influence in decision-making and maintain its credibility with the public, the BAPE tends to draw attention to its conclusions.

Hydro-Québec is one of the biggest promoters in Québec. It is a government corporation with very close ties to the government. Established in 1941, Hydro-Québec earned US$5 billion in 1995 and has become a symbol of the Québec identity and a key lever in the government's economic strategy. A love-hate relationship has developed with respect to the utility: it is admired but vehemently criticized as well (Paquet, 1988). The deregulation of the energy market and Hydro-Québec's determination to export energy to the United States also complicate the situation. For the past 20 years, no enterprise has done as much as Hydro-Québec in the realm of impact assessments and with respect to a knowledge of the territory. At the same time, the utility's projects invariably arouse strong resistance and lively criticism.

FIVE PUBLIC HEARINGS

Between 1983 and 1996, Hydro-Québec appeared successfully on five occasions before the BAPE. The Great Whale project was also subject to a detailed environmental impact assessment, under a federal and provincial commission encompassing five jurisdictions. However, the utility withdrew the project before public hearings were held.

1983

From June 17 to October 17, 1983, the BAPE held public hearings on a proposal to build a 735-kV power transmission line running above all through

farmlands, a converter station, and a "450 kV line for an interconnection with the New England states. During the hearings, Quebecers strongly contested Hydro-Québec's position, on the strength of recent studies by Wertheimer and Leeper, and demanded that the utility take a much greater interest in health issues. The farming community also expressed considerable anxiety about the effect of power transmission lines on animal health. The BAPE commission expressed the opinion that current knowledge did not warrant halting the project or imposing a moratorium on it. However, it did request that Hydro-Québec contribute more extensively to research and suggested that epidemiological studies be carried out.

When the BAPE authorized the project on March 28, 1984, the Québec government demanded that Hydro-Québec conduct an epidemiological study on human health in collaboration with the ministère des Affaires sociales (MAS), which later became the ministère de la Santé et des Services sociaux (MSSS), and the ministère de l'Environment (MENVIQ), now the ministère de l'Environnement et de la Faune (MEF), and a study on the health of livestock, in collaboration with the ministère de l'Agriculture, des Pêcheries et de l'Alimentation (MAPAQ) and the ministère de l'Environnement.

1987

From December 8, 1986 to April 8, 1987, the BAPE once again held hearings on a "450 kV line. During the hearings, Hydro-Québec explained that the epidemiological study requested was undergoing a feasibility analysis. Moreover, in its directive concerning the impact study, the MENVIQ did not deem health to be a significant factor from the standpoint of the location of the line. Consequently, it simply requested information documents on the question. The most striking intervention during the hearings was the brief submitted by the Département de santé communautaire of the Centre hospitalier de l'Université Laval (DSC-CHUL), presented by three health experts, i.e. Pierre Lajoie and Patrick Levallois, physicians specializing in community health, and Éric Dewailly, a physician and toxicologist. In response to this highly critical brief, the Commission took the MENVIQ to task for attaching little importance to health, criticized Hydro-Québec for its lack of concern with health, and recommended that the MAS establish a committee to assess the value of Hydro-Québec's studies on health and EMF. On June 10, 1987, the Québec government set up the committee requested to

monitor Hydro-Québec studies on electric and magnetic fields. It also encouraged Hydro-Québec to take into account human exposure to EMF when reviewing design and operating criteria.

1992

In order to pursue its deliberations, the interdepartmental committee called upon the services of the DSC-CHUL. In 1991, three members of the DSC, Patrick Levallois, Pierre Lajoie and Denis Gauvin, published a report on the state of knowledge of health and EMF (Levallois, Lajoie and Gauvin, 1991). Two experts from Hydro-Québec also collaborated. The publication of the report heightened awareness in the Québec medical and public health sectors of EMF and human health.

From October 30, 1991 to February 29, 1992, a new BAPE commission examined another Hydro-Québec 735-kV power transmission line project. The commission did not hire a health expert and the DSC did not submit a brief. However, the MSSS delegated Patrick Levallois and Denis Gauvin to represent it at the hearings. In light of documents submitted by Hydro-Québec and Patrick Levallois's testimony, the commission did not object to the project on health grounds but recommended that the interdepartmental committee assume responsibility for overseeing the studies and that a feasibility study be conducted in respect of epidemiological research on the level of exposure of the population to EMF and the latter's' effect on health. Furthermore, the commission referred to the Prudent Avoidance mentioned in the report by Levallois, Lajoie and Gauvin (1991) and recommended that Hydro-Québec bolster its information strategy.

1993

From March 29 to July 29, 1993, a different BAPE commission examined another 735-kV transmission line project, which was to cross an agricultural and tourist zone with high potential because of the scenery. The MSSS delegated to the hearings three experts, i.e. Dr Marc Dionne, Dr Patrick Levallois and Dr Denis Gauvin. The DSC submitted to the commission the report by Levallois, Lajoie and Gauvin (1991). The commission devoted an important chapter of its report (68 pages) to the question of health and EMF and published a review of the literature prepared by the DSC-CHUL, research

projects, the Québec plan of action on EMF, and the list of epidemiological studies then under way (document submitted by the utility). The commission examined the question at length. It first summarized expert opinions that had appeared between 1990 and 1993, the position of the interdepartmental committee and Hydro-Québec management, described EMF and took stock of studies devoted to health, i.e. experimental and epidemiological studies. The commission then reviewed the mitigation measures suggested by various studies. It expressed the opinion that posing the problem in terms of health and technical and economic advantages was insufficient. "The decision on whether or not to develop and apply mitigation measures in respect of electromagnetic fields should be taken in light of general public protection guidelines and satisfy public expectations concerning security and the quality of life" (BAPE: 263) (our translation). The commission pointed four possible solutions: the adoption of a standard, prudent avoidance, the status quo, or a moratorium. The commission opted for prudent avoidance and requested the elaboration of a mitigation strategy, the reassessment of transmission and distribution technologies (the designing of power lines that produce less electric and magnetic fields, the designing and manufacturing of electrical appliances that produce low EMF, and the training of electricians). The commission recommended the adoption of mitigation measures when new lines are located and the supervision of research and technological development to reduce exposure to EMF. In order to implement what it called "prudent management," the commission requested the reorganization of the interdepartmental committee and its application to the Hydro-Québec development plan.

From a critical standpoint, the commission's position seems paradoxical. The commission deemed the health effects to be simply plausible. It mentioned the concept of prudent avoidance, submitted to it by Patrick Levallois, although it did not analyse it in light of the writings of Granger Morgan and did not discuss it at length. However, in practice, in my opinion it went well beyond prudent avoidance and proposed, under the term "prudent management," a fundamental change in planning and management, with a view to mitigating exposure to EMF. The commission temporarily overlooked scientific uncertainty and requested the implementation of a prevention policy. This stance was a political choice aimed at protecting the public and satisfying public expectations concerning security and the quality of life. It seems evident that the members of the commission expected the

numerous studies then under way to demonstrate beyond a shadow of a doubt the impact of EMF on health.

On May 29, 1994, the follow-up committee, in the wake of an examination of the CHUL report and the analysis of the findings of research conducted by Dr Gilles Thériault, EDF-OH-HQ, acknowledged that "certain doubts exist about the cause relationship between high-voltage lines and some cancers" but that scientific data and results do not warrant "recommendations to the effect that changes be made in the design and operating practices used for electrical facilities." However, "it seems fitting that H-Q, the utility and its partners examine ways of implementing *prudent avoidance* with respect to new electrical facilities" (Cardinal, 1996: 4).

Hydro-Québec then initiated research on prudent avoidance. It concluded that the concept of prudent avoidance is inconsistent from a conceptual standpoint, and inadequate. It is inopportune for medical, ethical, legal, engineering and communications reasons. H-Q defined its strategy, which it called "prudent management" and regarded as more attractive than prudent avoidance, although not the prudent management mentioned in BAPE report 68 (H-Q, 1996). Confusion surrounding the terms is astonishing: there are two different concepts of prudent avoidance and two different concepts of prudent management.

1996

From April 23 to [?] 19, 1996, another BAPE commission examined the Duvernay-Anjou 315-kV power transmission line project, which was to cross a near-urban agricultural zone, Rivière-des-Prairies, and a completely urban zone in the Montréal Urban Community. Strong opposition to the project was voiced. The participants opposed the choice of the route and wanted the line to be located somewhere else. They opposed the construction of an overhead power line and demanded an underground line for the urban section of the route and the portion crossing Rivière-des-Prairies. Opponents were deeply concerned about health risks.

During the hearings, the commission devoted an entire session exclusively to the question of health. Three specialists, Dr Louis Drouin, a physician with the Direction régionale de la santé publique de Montréal-

Centre (DRSP), Dr Gilles Thériault, a researcher at McGill University and the director of extensive research on the health of workers in the electricity sector, and Paul Héroux, also from McGill University, represented the MSSS at the hearings. The MSSS emphasized uncertainty and the impossibility of concluding that a cause-effect relationship exists. During debate on the matter, Dr Michel Plante from Hydro-Québec expressed the opinion that the cause-effect relationship was simply plausible. Dr Thériault confirmed that this relationship is probable. A participant submitted at the hearing a videocassette of an interview with Dr Thériault on the French-language CBC network. When asked if he would buy a house near a high-voltage power line, Dr Thériault answered No, especially out of concern for his family's health. The question was obviously loaded since it confused expertise and personal attitude. If the expert answers No to this kind of question, he is confirming that there is a risk; if he answers Yes, he is undermining his own credibility. Opponents frequently cited Dr Thériault's testimony in their brief.

During the hearings, the commission received 28 briefs, of which 15 referred to health, all of them confirming that EMF affect health. Ten of the briefs requested, among other things, that power lines be buried. Some witnesses adopted a rhetorical stance when dealing with health issues, while others deemed such issues to be more important. Simply stated, the argument ran as follows: doubt exists; in the face of doubt, it is essential to abstain; therefore, ...

During the hearings, the RRSP submitted a brief signed by Dr Louis Drouin and Dr Gilles Thériault. In light of the review of the literature conducted by Levallois and Gauvin (1994) and an unpublished synthesis of few studies by Thériault and Chung Yi-Li (1996) on the risk of leukemia, the brief concluded that:

- the proposed power transmission line did not pose a health risk for people then living along the route;

- the users of a linear park planned along the line were likely to be exposed to fields of over 2 mG;

- because Thériault's studies tended to demonstrate excessive risk of leukemia among individuals exposed to more than 2 mG, it would be advisable to analyse the hypothesis of setting an exposure limit of 2 mG along new lines in respect of day care centres, playgrounds, schools and homes.

BAPE Commission 107 is closely monitoring the RRSP brief. It deems Hydro-Québec's rejection of the concept of prudent avoidance and the utility's proposal concerning prudent management to be equivalent to maintaining the status quo. Without analysing in detail Hydro-Québec's arguments, the commission believes that a prospective and preventive approach must be advocated. The commission rejects Hydro-Québec's concept of integrated development, which allows for the use of the right-of-way for recreational purposes, one of the main benefits for the public. Moreover, the commission has requested a moratorium on the concept and has requested that the proposed 30-m right-of-way be widened, in light of the 2 mG (0.2 μT) value suggested by the RRS. "We are facing considerable uncertainty concerning the procedure for action and the scope of the direct and indirect risks for human health of EMF. Everything therefore become conditional and perception and apprehension take the place of truth" (BAPE 107: 137) [our translation]. According to the commission, perception figures with respect to five factors: inadvertent risk, scientific uncertainty, potential risk for children, the invisible nature of EMF, and the spectre of cancer. The commission has asked the interdepartmental committee to examine the timeliness of establishing an exposure standard, given the wide margin between the Hydro-Québec, IRPA (100 μT) and RRS (0.2 μT) standards pertaining to magnetic fields. Furthermore, the commission recommends burying the line without discussing the impact of such a decision on magnetic fields.

The government has approved the construction of the Duvernay-Anjou overhead line, as requested by Hydro-Québec, without the broadening of the right-of-way and without restriction on the use of the right-of-way.

Since then, the January 1998 ice storm has revealed the fragility of Hydro-Québec's system under extreme conditions and appears to warrant extensive intervention by the utility in order to bolster the system.

1983	735 kV 450 kV	(Plante) Simplified summary	C	Step up research Conduct studies on health	Authorizes project Requests feasibility study
1987	450 kV	(Cardinal) Update	DSC-CHUL brief (Lajoie, Levallois, Dewailly)	Denounces MENVIQ health directive Calls for inter-departmental committee (MSSS)	Authorizes project Inter-departmental committee (MSSS) (Contract DSC-CHUL)
1991	C	C	Publication of Levallois, Lajoie, Gauvin report (1991)	C	C
1992	735 kV	Updating of summary of studies	MSSS: Levallois, Gauvin	Request to broaden mandate of inter-departmental committee (MSSS) Request for epidemiological feasibility study Request that H-Q bolster information	Authorizes project Refers matter to inter-departmental committee
1993	735 kV	(Goulet, Pineau) Updating of summary of studies	MSSS: Dionne, Levallois, Gauvin	Summarizes knowledge Requests political intervention Requests reorganization of committee	Authorizes project Refers follow-up to MSSS committee
1996	315 kV	(Goulet, Plante) Document on prudent manage-ment	DSC: Drouin, Thériault, Héroux	Criticizes H-Q's prudent management Criticizes H-Q's integrated development Recommends prospective and preventive approach Recommends consideration of exposure standard Recommends burying the line	Authorizes project as request by H-Q Refers follow-up to MSSS committee

Consequently, the government has authorized two 735-kV and one 315-kV lines while suspending the environmental impact assessment procedure and adopting a streamlined procedure. The individuals concerned perceive these rapid decisions by the government as a strong-arm tactic. Critics suggest that the stabilization of the system also masks an electricity exporting strategy. Debate over the effects of EMF on health has been vigorously revived, all the more so as the procedural fairness of the decision seems dubious or at least a big step backward in relation to previous cases. In the absence of fairness, the perception of health risks is changing. Once merely plausible, such risks are now at least regarded as probable, if not uncertain. It is hard to predict at present further developments in this respect.

REVIEW OF 15 YEARS OF DEBATE

- An analysis of 15 years of debate on the question of electric and magnetic fields elicits, in my view, the following observations:

- The BAPE has been the focal point of public debate on EMF. From one hearing to the next, the media display almost no interest in the issue. During public hearings, debate resumes among participants in the hearings and the specialized media. Until now, debate during the hearings has not received prominent coverage in the media and has scarcely affected public opinion.

- Debate on EMF and health during BAPE public hearings has led, first and foremost, to the pursuit of research in this field. In light of BAPE reports, the government has put pressure on Hydro-Québec to fund new studies, constantly take stock of studies under way and bolster its international presence. It is reasonable to think that it is the possibility of a new examination of a proposed power transmission line before the BAPE that is compelling Hydro-Québec to pursue its studies, produce interim reports and formalize its strategy.

- In the realm of EMF and health, the BAPE's reports, while they have had little effect on public opinion, have forced the government to intervene constantly in this regard. The matter has progressed through a

follow-up committee. There is a growing discrepancy between the BAPE's recommendations and the government's decisions.

- Over the past 15 years, it is the health sector (MSSS, DSC, RRSP, follow-up Committee) that has displayed genuine leadership in this field. It has exerted pressure to obtain resources. It has made accessible to the public scientific studies under way and disseminated the concept of prudent avoidance. It has heightened awareness in the public health sector of the possible effects of EMF on health. The BAPE's recommendations have been inextricably linked to the suggestions of experts form the Québec health sector (DSC, MSSS).

- Health experts have played a number of different roles, including that of representing the health sector, i.e. as independent experts, before the BAPE, and as interveners, i.e. militants, through the submission of briefs during public hearings. This situation can be explained by the limited number of experts available in Québec and the disproportionate resources available to Hydro-Québec and experts on EMF in relation to those available to the health sector.

- In the course of 15 years of debate on EMF and health, almost always the same experts have appeared on behalf of Hydro-Québec and the health sector. Some 15 experts seem to have formed a club and to repeat their performances from one hearing to the next.

- While Granger Morgan, who conceived the notion of prudent avoidance, constantly refers to the calculation of the costs involved, this aspect is almost totally absent from debate on EMF in Québec. Granger Morgan deems prudent avoidance to be a concept to manage uncertainty over the very existence of a risk. Levallois, Lajoie, Gauvin (199) give the concept a broader meaning, approaching prevention. BAPE reports 68 and 107 emphasize this trend. While acknowledging uncertainty over the existence of risk, the BAPE's recommendations suggest that such risk must be regarded as established, either because it is probable or because the public perceives it to be so. BAPE reports 14, 22 and 47 clearly consider uncertainty to be too great to impose constraints. The reports emphasize research and development and

knowledge. Reports 68 and 107, while they recognize uncertainty, insist on the urgency of strategic modifications and the consideration of EMF during the design phase of projects, as if their effect had been demonstrated. The recommendations largely exceed the concept of prudent avoidance. The last two BAPE reports (68 and 107) clearly attach a great deal of importance to studies under way, which should confirm the harmful effects of EMF on health. Has the weight of this foreshadowing been confirmed? Here, we are shifting from the analysis of completed studies to the outcome of studies under way or planned.

- It strikes me that there is an obvious difference between the private deliberations of the follow-up committee, including the issuing of opinions on health matters, and the prospective suggestions made publicly to the BAPE by the same health experts. The opinions on health matters maintain that "in the current context, we do not have at our disposal sufficiently conclusive scientific data and results to recommend changes in existing practices respecting the planning and management of electrical facilities" [our translation]. During their testimony, health experts have called for preventive management, the elaboration of a standard, or the prohibition of certain activities. This suggests that the health experts change their viewpoint depending on whether they are discussing the matter among themselves or expressing themselves in public. Science prevails when experts discuss matters among themselves, and health protection predominates when they discuss matters in public.

- In the course of public discussions, we never have access to the actual studies, which are much too complex and difficult, but to reviews of studies and, occasionally, reviews of reviews. Since each review is also a reading and an interpretation, it is hard to sort out the matter.

- A militant who participates in a public hearing to protest the routing of a power transmission line or to reject the project itself tends to view risk as being established. Through rhetoric, uncertainty surrounding risk turns into certainty on risk. From one debate to the next, the perception of risk tends to become stronger. From the standpoint of social dynamics, debate over EMF and health constantly eludes the

experts and becomes a social issue. A few vague indications are all that is needed for an issue to take on a social cast. There is an overriding impression that the government would like to close the door and refer the matter to experts, while the public formulates its own discourse on the limitations of expert knowledge.

- Research concerning perception and communication on risk tends to reveal that risk management cannot rely solely on the scientific measurement of risk, which is never entirely value free, without simultaneously taking into account perception and, consequently, the manner in which the populations concerned define risk. The procedure suggested by the Presidential-Congressional Commission (1997) is probably the most appropriate. Debate in Québec, and a steering committee that I chair, are moving in the direction. For the time being, the main field of application contemplated is that of the contaminated soils policy, where it seems easier to weigh the benefits and drawbacks and control measures. Can this type of procedure be applied to the question of EMF when there is uncertainty over the very existence of risk? In my view, it can. In Québec, this would demand either a review of the environmental assessment procedure or the implementation of a credible, virtually permanent parallel procedure among the various partners. Some examples are a citizens' panel or a permanent committee, which would enable the citizens concerned to become familiar with EMF.

- In light of current uncertainty and the difficulty of drawing conclusions, will research simply be abandoned in the absence of convincing results with respect to a seemingly limited number of effects? Will research continue and if so, in what manner? Or, will a systematic prevention policy be adopted? Given the current situation in Québec, unless the international community and, above, the United States, exert heavy pressure, or unless evidence is obtained rapidly, it is unlikely that the government will compel Hydro-Québec to adopt a vigorous mitigation or prevention policy. The burying of power transmission lines in urban areas will probably serve as a mitigation measure, despite the expense incurred and the dubious effectiveness of the measure in terms of EMF. The exemplariness argument will probably prevent the government

from ordering the widening of the right-of-way or the integration of health issues into the planning process. Such decisions would involve enormous cost for an uncertain benefit.

- With regard to perception, if the public fails to once again get involved, we are likely to enter a stalemate, partly because of emerging uncertainty about the threat of cancer and leukemia and because the routing of a power line can always be contested. It would be sufficient for a child living near a power distribution or transmission line to die of leukemia to crystallize public opinion and cause panic. Generally speaking, despite the openness of the procedure adopted by the BAPE, procedural fairness remains dubious because of Hydro-Quebec's influence on the government the BAPE's late intervention in the process. Substantive fairness is not obvious, above all if Hydro-Quebec's concept of integrated development were to be contested. Progress must be achieved by means of clear, transparent information and a personalized approach to various clienteles. For the time being, Hydro-Québec has established the Électrium, an centre devoted to electricity and EMF that is designed to initiate the public to the issue. However, other personalized means of intervention could be contemplated, such as in-home measurement of EMF to reassure anxious individuals, including measurements before and after the construction of a power transmission line.

- From the standpoint of public debate, it strikes me that the most complex question whose scope must be specified is that of false positives and false negatives and the inability of science to ever demonstrate a non-effect on health. We could refine the measurement or lengthen the period of observation. Consequently, it is inevitable that we attempt to apply to the EMF the principle of precaution put forward above all in the realms of climatic change and biodiversity.

- Beyond the theoretical debate between realists, constructivists and the proponents of a cultural approach to risk, we know that there is a considerable difference between personal risk willingly assumed and imposed risk that cannot be inferred from one to the other to legitimize an imposed risk. Sound studies written in French nonetheless reveal

that individual risk is very widespread in our society and appears to reflect two different strategies, that of the limiting experience and ecstasy and that of the rite of passage or the test of bravery equivalent to the ordeal in ancient societies (Le Breton, 1995, 1996; Volant, Lévy, Jeffrey, 1996).

- Ultimately, it is in the political arena that an issue such as EMF and health unfolds. In debate such as that on EMF, it is not risk that is initially debated, nor the infinite refinement of calculation, but the quality of the social bond (Beauchamp, 1996a and 1996b). For this reason, the anticipated reforms of risk management are very important, although complex with respect to their implementation.

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Principles of Risk Assessment with Application to Current EMF Risk Communication Issues

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Introduction

In a previous symposium (Bailey, 1998) I drew attention to the importance of imbedding risk assessments within the risk communication process. If we acknowledge that every element of the risk assessment process has both technical and social aspects, then throughout the entire process - beginning with the way we define the issue to the way we chose to solve the issue - public involvement and communication are critical. In this 'new' concept of the risk assessment process, risk communication activities should begin before risk analysis and continue after the risk management stage (Figure 1). The first part of this paper presents a check list to rate how well a risk assessment communicates to the public and other stakeholders. To illustrate how this check list can be applied, assessments of potential health risks associated with electric and magnetic fields (EMF)[42] prepared by a Working Group for the U.S. National Institute of Health Sciences (NIEHS) and the International Commission on Non-ionizing Radiation Protection (ICNIRP) are rated to identify areas in which communication about EMF risks can be improved. Particular attention is given to the scientific and technical confusion surrounding the proposal by ICNIRP that EMF exposure limits for the general public be lower than for workers.

In the second part of the paper, a problem for both risk assessment and risk communication - the characterization and use of information about

[42]The use of the term EMF is usually restricted to fields with frequencies in the extremely-low-frequency (ELF) range of 0 - 300 hertz (Hz).

uncertainty - is described. The advantages of probabilistic methods for addressing this problem have been described (Bailey, 1998). Preliminary results of the use of this method in estimating the acute risks of cardiac stimulation by electric and magnetic fields are presented. In contrast to the deterministic approach used by existing guidelines to set exposure limits, this approach explicitly acknowledges and quantifies the uncertainty in estimates of 'safe' exposures to magnetic fields.

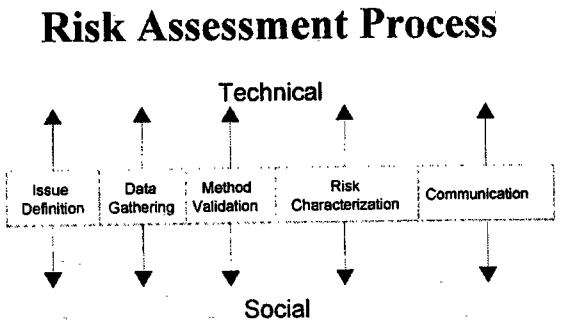

Figure 1. Illustration showing time sequence of risk assessment activities.

Aspects of Risk Assessment that Favour Good Risk Communication

Risk assessments are typically performed by experts in science and technology and their reasoning and conclusions are summarized in complex technical reports. Such reports are poor vehicles for communicating information about risk because decision makers and the public are unlikely to understand, believe, and make appropriate use of technical risk assessments. Nevertheless, it is possible to minimise such obstacles to good risk communication. Below I have summarized seven characteristics of the risk assessment process which favour good risk communication.

1. Openness to input

It is essential that the objectives of the risk assessment be responsive to the interests and concerns of the stakeholders or other audiences to whom the results of the risk assessment will be communicated. Unless the public and other stakeholders have the opportunity to identify what issues and what methods should be considered, and even which scientists might participate in the risk assessment, the relevance and credibility of the risk assessment may be undermined.

2. Evaluation according to predetermined scientific criteria

Risk assessments should follow methodologies generally accepted and recognized by scientists and regulatory agencies. While all scientists are trained in scientific methods, few scientists are familiar with the formal scientific methods used to assess health risks. Guidelines for the evaluation of research to establish human health risks that are widely cited are EPA (1996) and IARC (1992). The application of these methods serves two purposes. First, it helps to ensure that the assessment is grounded upon good scientific principles. Second, it helps to ensure that the assessment is organized and carried out objectively without favouritism to any stakeholder group.

3. Comprehensive assessment

Risk assessments need to be based on all the relevant data. Many risk assessments fail to define the scope of the information to be evaluated and the method by which data were selected for consideration and weighted. When this happens, it is difficult to assess the depth and breadth of the assessment. A more vexing problem is that if the risk assessment is not totally comprehensive, or fails to establish a rational approach to the selection of data to be considered, then it may appear that the outcome has been biased by the selection of data that support a particular point of view.

4. Thorough documentation

Thorough documentation of the data, methods, and assumptions used in a risk assessment is good scientific practice. Documentation permits

others to judge the comprehensiveness of the evaluation - whether there are gaps in the data or the data are not up-to-date - and provides the primary sources to determine whether the findings were fairly characterised or used in the risk assessment.

5. Transparent evaluation

By describing the methods by which the assessment was conducted in detail, and giving examples if necessary, the entire assessment becomes more 'available' to a wide range of experts and non-experts. While thorough documentation of the data and relevant literature consulted is essential, it is not sufficient to ensure that readers and users of the assessment can evaluate the methods and process by which the evaluation of the data was performed. From a risk communication perspective, the presentation of a transparent evaluation also demonstrates a willingness to open the risk assessment to independent scrutiny and evaluation by the broader scientific community as well as other stakeholders, and the confidence that others will understand, if not confirm, the conclusions of the assessment.

6. Acknowledgement of uncertainties

Scientists need to spend more effort in communicating the uncertainties in such a way that the confidence of the public and regulators is increased, not diminished, by the way in which issues relating to uncertainty and reliability of the assessment are addressed. While scientists are often keenly aware of all the potential limitations of the data, methods, and their interpretations and applicability, the public and regulators typically want assessments and guidance to reflect a total lack of uncertainty about any aspect of the risk being considered. The desires of the public and regulators put tremendous pressure on scientists performing assessments to ignore or to limit discussion of uncertainties. Furthermore, many scientists believe that if they were to acknowledge uncertainties, public apprehension would unnecessarily increase and their risk assessments thrown open to criticism. Such beliefs should not allow scientists to mislead stakeholders.

7. Clear and unambiguous language

The need for clear and unambiguous language is obvious. However it is often overlooked when advice is given on risk communication. A difficulty with risk assessments, as well as many other scientific communications, is that they are too technical and, if not clearly written, susceptible to misinterpretation. There are daily examples in newspapers and magazines where statements taken from interviews with scientists or from their reports are misinterpreted because of poor drafting.

Opportunities for Improving Risk Communication:

A Look at Recent EMF Risk Assessments

Before concerns about potential health effects of EMF became a worldwide topic of discussion there was little need for attention to the impact of EMF regulatory and risk assessment activities on the communication process. But, beginning in about 1989 in the US and 1992 in Europe, public concern became widespread. Regulators and risk assessors were unprepared to respond to this new level of concern. In response to greater concern with little new data and a lack of understanding of uncertainty, the concept of 'prudent avoidance' was seized upon as an interim policy option and cornerstone for communication. Although initially defined as the exercising of fiscal prudence by individuals in dealing with speculative or unknown health risks (Morgan, 1989), it soon was popularized to refer to precautionary actions taken to mitigate likely, but not totally definitive health risks. With the advent of many new epidemiology and laboratory research studies, there is now a firmer basis for risk assessment and the opportunity to examine the need for new policies and guidelines regarding EMF exposures.

NIEHS Working Group and ICNIRP Reports

Recently, new risk assessments have been offered to update legislative actions and exposure guidelines. These risk assessments have been published by a Working Group organized by the National Institute of Environmental Health Sciences (NIEHS, 1998) and the International Commission on Non-Ionizing Radiation Protection (ICNIRP, 1998). The

goal of the risk assessment prepared by the Working Group is to identify the level of risk, if any, that is associated with electric and magnetic field exposure and develop a basis for the US Congress to propose legislation to manage or limit exposures. The foci of concern in this risk assessment are adverse health effects, cancer being the most important, alleged to be caused or exacerbated by EMF exposure. The risk assessment prepared by ICNIRP addressed these same concerns but tersely concluded ". . . that the results from the epidemiological research on EMF field exposure and cancer, including childhood leukaemia, are not strong enough . . . to form a scientific basis for setting exposure guidelines." ICNIRP then addressed the issue of short term effects of fields at frequencies less than 1 kHz related to induced currents, surface electric fields, and contact currents. The ICNIRP risk assessment serves as the basis for recommendations to national authorities for exposure limits of workers and of the general population.

Ratings of Effective Risk Communication

Stakeholders need more and better communication about EMF and health research. It is therefore important to assess how much progress has been made in using risk assessments as a vehicle for improved communication. Using the seven characteristics of effective risk assessments described earlier as a nominal set of evaluation criteria, I rated the ICNIRP and NIEHS risk assessments on an ordinal scale from 1-10 with one representing the most effective and 10 the least effective in communicating risk (Table 1).

For those who are familiar with these two risk assessments, it is obvious that the differences in their ratings vis à vis risk communications largely reflect different organizational goals and policies and not differences in their fundamental scientific quality. With an awareness of the need for risk communication, future EMF risk assessments can be designed to support this function as well as meet scientific goals. This may be difficult for organizations that set guidelines because of insufficient budgets and staff resources, time, and planning. More important, risk communication may not even be a part of their mission. In general, insufficient planning for risk communication is common where risk

communication has been selected by default as the 'last task' of a risk assessment.

Table 1
Opportunities for Improving Risk Communication

Risk Assessment Characteristics Favouring Effective Risk Communication	Ratings	
	1998 ICNIRP	NIEHS WG
Open to input	7	1
Predetermined criteria	3	2
Comprehensive assessment	6	4
Thorough documentation	8	3
Transparent evaluation	8	2
Characterisation of uncertainties	9	9
Clear and unambiguous language	7	5

Rating Scale 1 = Small opportunity for improvement
10 = Great opportunity for improvement

The low ratings given to both risk assessments for characterization of uncertainty reflect inadequacies in describing uncertainties in the underlying scientific data and in providing a method for addressing these uncertainties. A later section of this paper discusses how the uncertainties regarding effects of tissue stimulation by induced currents - the basis for all exposure guidelines to date - can be characterised by probabilistic methods.

Communication About EMF: Possible Occupational Risks vs Phantom Risks to the General Public

There is sufficient theoretical and experimental basis to be concerned about possible adverse effects caused by the induction of voltages and currents in the body by intense alternating electric and magnetic fields (Bailey et al, 1997). Yet, guideline-setting organizations (including ICNIRP) and regulatory organizations, e.g., the Bureau of Radiological Devices, U.S. Food and Drug Administration have not cited as evidence a single safety incident in which an acute induction effect has occurred in occupational or other environments. Nevertheless, the possibility remains that some exposure scenario in the workplace, perhaps involving some unique technologies, conceivably could present a direct or indirect hazard to workers. Hence the need exists for guidelines like those proposed by ICNIRP and other organizations to limit the intensity of occupational exposures. ICNIRP specifies that an adequate level of protection can be achieved by setting occupational exposure levels 10-times lower than thresholds for some biological effects of concern.

ICNIRP[43] has also recommended that the exposures of the general public to electric and magnetic fields in the ELF range be limited to much lower levels than those recommended for workers. From a risk assessment and risk communication perspective it is important to understand the rationale used to choose a biological 'dose' limit for the general population that is 5-times lower than that set for workers. By recommending limits for the general public, ICNIRP assumes a responsibility to succinctly communicate the basis for its recommendations. Unfortunately, no explanation supported by data or analysis is presented. All that ICNIRP considers is "the general public . . . may include particularly susceptible groups or individuals" (p. 508) and that there is some uncertainty regarding the appropriate safety factor because of "a lack of knowledge regarding the appropriate dosimetry." (p. 508). These statements alone without supporting data and analysis are the sole justification for requiring greater protection for members of the general public than for adult workers. The former may not be informed, trained, or expected to take precautions, but

[43]The ICNIRP and the interim CENELEC (1995) guidelines are similar so that comments about ICNIRP often apply to CENELEC as well.

this may be unimportant if exposures below occupational exposure limits are truly without adverse effect. In his editorial for the recent special issue of *Radiation Protection Dosimetry* on non-ionizing radiation, John Dennis laments that "[t]he present choice of 5 for this [safety] factor by ICNIRP appears to be due more to the number of fingers on the human hand than any rational evaluation. . . .[t]he justification advanced . . . [is] subjectively appealing, but hardly stands up to any logical analysis." (Dennis, 1997).

Another explanation for the recommendation of a large safety factor (10 for occupational x 5 = 50) for public exposure could include an attempt by ICNIRP to respond to concerns of the public about cancer from long-term, low level exposures. ICNIRP may have felt that the recommendation of a larger safety factor, even based on short-term effects, not cancer, would respond to, and calm, public fears and perceptions without committing to a guideline that could not be justified based on the existing epidemiology and laboratory data regarding cancer.[44] Or, it might be that the purpose was to provide an additional safety factor to protect against unknown effects of long-term exposure. If so, ICNIRP should have publicly discussed this approach in the interest of fully communicating the basis for its recommendation of a public exposure guideline. Until ICNIRP provides further explanation of the biological data and rationale underlying the application of the safety factor for public exposure, such speculative explanations cannot be discounted.

For electric fields, ICNIRP appears to have intended recommended exposure limits for the general public to meet two perceived needs: 1) to minimise internal induced current densities; and 2) to minimise perception of electric fields at the surface of the body and perception of indirect contact currents. The guideline attempts to simultaneously address both goals yet does not explain how this affects the selection of exposure limits.

The basic restrictions given in the ICNIRP guideline are specified in terms of induced current density. Studies in the literature are cited to show that current densities above 100 mA/m^2 might have adverse stimulating effects on the nervous system. No rationale for exposure guidelines other

[44]A close reading of the rationale given by DG V (1997) for limits on public exposures to EMF would appear to follow this interpretation.

than the prevention of such effects is given. Because ICNIRP points to no evidence for cumulative effects of exposure, one must therefore conclude that for these phenomena of concern, exposures less than the occupational exposure criterion, 10 mA/m^2, would not adversely affect either workers or the general public. Hence, it is not at all clear how ICNIRP can justify a lower exposure limit for the general public than for workers based on potential risks of current induction alone. Indeed, the Electromagnetic Field Project of the World Health Organization states that "there is no need for any specific protective measures [from ELF fields] for members of the general public." (WHO, 1998).

For electric fields, ICNIRP justifies basic restrictions and reference levels to limit exposures of the general public to levels below those recommended for occupational environments on the prevention of surface field effects. Although painful shocks might be experienced in electric fields greater than 10 kV/m when grasping large conducting objects, sensations experienced at lower field levels in touching smaller objects are merely annoying (CRP, 1997). Hence, the electric field limitation for the general public is designed to prevent perception, not "detectable impairment of the health of the individual." The meaning of this position is further clarified by ICNIRP's Response to Questions and Comments on ICNIRP Guidelines (Matthes, 1998) which states, "[t]he reference levels for electric fields at power frequencies were set to limit indirect effects of contact with electrical conductors in the field."

Although the relationship between the limits for electric field exposure and contact currents are not discussed in the guideline, there is obviously considerable overlap in their goals. The rationale to limit induced current densities in the general public to levels one-fifth of those recommended for workers is inconsistent with ICNIRP's assertion that "[t]he [occupational reference level] value of 10 kV m^{-1} for a 50-Hz or 8.3 kV m^{-1} for a 60-Hz occupational exposure includes a sufficient safety margin to prevent stimulation effects from contact currents under all possible conditions." (p. 510). The WHO EMF Information Project also states, "the effects of exposures of up to 20 kV/m are few and innocuous" (WHO, 1998). This raises the question why reference limits on electric fields are needed to prevent field perception by the public if ICNIRP has

concluded there are no significant risks for this exposure and has recommended separate reference limits for contact currents.

The above discussion highlights the need for ICNIRP to initiate a more extended discussion of its guideline setting process so that important questions regarding the formulation and communication of guidelines for public exposure to ELF fields can be resolved.

Progress in Characterizing Risks of EMF Induction

Communications about risks can be improved by conveying the type and magnitude of the uncertainties associated with an evaluation or risk estimate. Yet all too often scientists are unfamiliar with the tools for addressing and communicating uncertainties or shy from discussing these uncertainties lest lay persons 'misinterpret' the discussion. If there is concern that the mention of uncertainty in a risk assessment may cause the public to either lose faith in the credibility of the assessment or overestimate the magnitude of potential risks, it is the responsibility of scientists to do a better job in presenting and communicating the uncertainties. In the previous symposium I have summarized the advantages of a probabilistic approach to risk assessment, including communication and guideline setting (Bailey, 1998). The advantages of this approach also apply to assessing the potential risks of EMF induction (Bailey, 1997). To update our progress in quantifying relevant uncertainties with probabilistic methods, I have performed preliminary analyses to illustrate how a probabilistic method approach is used to calculate the likelihood of acute risks of cardiac stimulation from exposure to power frequency magnetic fields. The details of the method and the results are described elsewhere (Bailey et al, 1998).

Probabilistic Method for Modelling 'Safe' Magnetic field Exposures

A model was constructed to predict a level of whole-body magnetic-field exposure below which no cardiac stimulation (ncs) is expected (B_{ncs}). The model demonstrates how the estimation of 'safe' exposure levels is affected by uncertainties in critical input variables.

Stimulation of the heart by ELF magnetic fields was chosen as a critical effect because it is a clearly identifiable, potentially adverse effect that is typically considered in setting guidelines for occupational exposures to magnetic fields. A probabilistic model offers advantages: it is possible to estimate the likelihood of effects at specific exposure levels and with sensitivity analyses it is possible to determine priorities for future research.

The form of the model was chosen to reflect the dosimetric approaches used by existing guidelines (Bailey et al, 1997).

$$B_{ncs} < (CST) / (S * F * C) \qquad (1)$$

B is the root-mean-square (rms) magnetic-field level in tesla (T), CST is the cardiac-stimulation-threshold (CST) current density in amperes per meter-square (A m^{-2}), S is the shape factor in meters, F is frequency in hertz (Hz), and C is conductivity in siemens per meter (S m^{-1}). The CST is the induced current density required to stimulate contractions of the heart. For this study, probability distributions were developed to characterise the CST, S, and C input variables. The input distributions were developed based on empirical data and/or assumed probability distributions. The values chosen were meant to be consistent with the range of values typically referenced in ELF guidelines. Initially, frequency was assumed to be fixed at 60 Hz; in later studies, not discussed here, a distribution representing 60 Hz and higher harmonics was also derived.

Distribution of B_{ncs} were computed for two scenarios by selecting single values from the CST, frequency, shape factor, and conductivity distributions by Latin Hypercube sampling and calculating a value for B_{ncs} using the model described by expression (1). The two scenarios differed in the dosimetric model assumed; one used the circular loop model described by IRPA/INIRC (1990), the other used the ellipsoid model described by ACGIH (1996). Each B_{ncs} value represents a calculated threshold for a combination of circumstances such that whole-body magnetic field exposures lower than B_{ncs} are without risk of cardiac stimulation. The input distributions were sampled and B_{ncs} values calculated on 5000 trials. Distributions of the B_{ncs} values obtained reflect the effect of the combined uncertainty of all the input variables on the predicted value of B_{ncs}.

The frequency distributions of calculated B_{ncs} values assuming the circular-loop dosimetric model used by IRPA/INIRC (1990) and ICNIRP (1998) and the ellipsoid dosimetric model used by ACGIH (1996) are shown in Figure 2 for a 60-Hz magnetic-field source. For convenience, the data are presented as complementary (i.e., reversed) cumulative probability distributions. The graph shows the relationship between magnetic-flux density and the probability that stimulation would not occur i.e. the probability of obtaining a value less than B_{ncs} calculated by the model.

Insights from Probabilistic Modelling

The wide range of simulated B_{ncs} magnetic-field values indicates that there is considerable uncertainty about what constitutes a safe level of exposure predicted by either model.

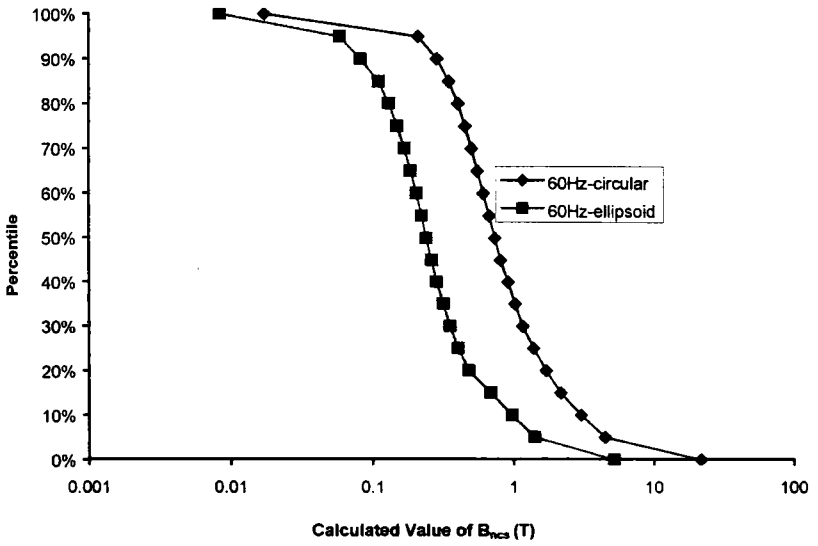

Figure 2 Distributions of B_{ncs} for 60-Hz magnetic-field exposures based on circular-loop and ellipsoidal dosimetry models.

However, all of the uncertainty relates to exposures greater than about 0.01 T. About a tenfold increase in exposure level to 0.1 T would be

required before the risk of stimulation occurring would be about 5 %. These results confirm that the major occupational-exposure guidelines are very conservative with respect to risks of cardiac stimulation. The minimum B_{ncs} values computed here are roughly ten times greater than the workday magnetic field exposure values recommended by ACGIH (0.001 T) or ICNIRP (0.004 T) at 60 Hz. The lowest 5% B_{ncs} value calculated for the circular-loop model is about 50-times the IRPA/INIRC (1990) and ICNIRP (1998) occupational exposure limits; the lowest 5% B_{ncs} value calculated for an ellipsoid model is more than 100-times the ACGIH (1998) occupational exposure limit. The probabilistic analysis thus supports the degree of conservatism that was suggested from a cruder analysis (Bailey et al. 1997).

The differences between the B_{ncs} estimates obtained with the ellipsoid model and those obtained with the circular-loop model indicate the uncertainty associated with the choice of dosimetry model. Guidelines frequently cite stimulation of peripheral nerves as also of potential concern. The implications of this analysis are relevant to this effect as well because the threshold for stimulation of peripheral nerves in humans may be only slightly below that for cardiac stimulation (Reilly, 1992) and the relevant variables affecting the stimulation of nerves are similar to those affecting the heart.

To characterise the relative importance of each input variable to the overall uncertainty in B_{ncs}, probabilistic sensitivity analyses were performed. The magnitude of the Spearman rank order correlation (r) between the values of the input distributions and the output B_{ncs} distribution provides a relative estimate of the contribution of each input variable to the uncertainty in the B_{ncs} distribution based on their entire range of values. The results of the sensitivity analysis for the ellipsoidal model are shown in Figure 3. None of the input variables are strongly associated with the distribution of calculated magnetic-field levels. However, the correlation analysis indicates that, of the variables considered, the CST is the variable that most strongly affects the uncertainty in the predicted values of B_{ncs}. The results of sensitivity analyses for the circular-loop dosimetry model are similar (data not shown).

The most important insight provided by the analysis that the greatest source of uncertainty as to what is a "safe" level of exposure to magnetic fields is knowledge as to the CST. Although the ranking of the CST was just marginally higher than the other input variables to the model, its significance is that it appears at all as a major contributor to the uncertainty in B_{ncs}. In recent decades, guidelines have given very little attention to the need to verify and characterise biological thresholds of tissues to stimulation by induced currents. Much of the biological data regarding stimulation thresholds that have been considered in the setting of guidelines for ELF field exposure are out-of-date, inconsistent, and characterised by considerable uncertainty (Bailey et al. 1997). Despite interest at this time in effects of induced currents and the development of new exposure guidelines, the literature has not to this point addressed the critical importance of defining biological thresholds in the determination of safe exposures.

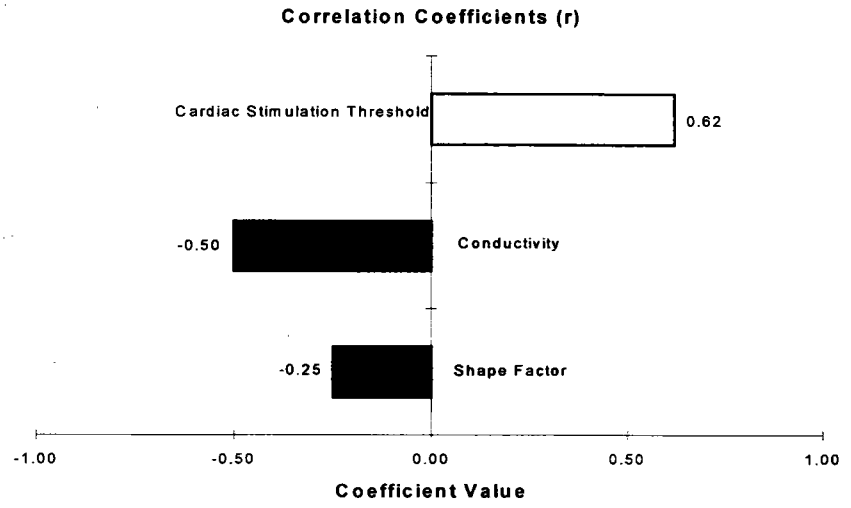

Figure 3 Probabilistic sensitivity analysis for ellipsoid dosimetric model showing Spearman rank order correlations between cardiac stimulation threshold, conductivity and shape factor values, and calculated B_{ncs} values

Summary

A new concept for risk assessment is that risk communication activities anticipate and continue throughout the assessment process. This means that the risk assessment process and its findings be fully transparent and available to scientists and the public. This paper discusses seven characteristics of science-based assessments that can improve the effectiveness of risk communication to the public and decision makers. I rated the EMF risk assessments published by NIEHS and ICNIRP on these characteristics to illustrate opportunities for improved risk communication. The observation that my subjective ratings are largely determined by the purposes and goals of these risk assessments should foster a closer look at structuring future risk assessments to meet both risk communication and scientific goals.

One particular recommendation of the ICNIRP risk assessment was a guideline to limit exposures of the general public to electric and magnetic fields at frequencies less than 1 kHz. As discussed here, the scientific basis for this recommendation needs to be examined more carefully. It is also important that the purpose and rationale be clarified so that the general public will not mistakenly perceive that exposures to EMF at levels commonly encountered in the environment pose any likely health risk.

Both the NIEHS and ICNIRP EMF risk assessments were given low ratings for the characterization of uncertainties. One way to address uncertainty is to develop quantitative characterizations of the potential risks of EMF for various exposure scenarios using probabilistic models. The method is also applicable to describing a realistic range of risks associated with specific exposure scenarios in quantitative terms.

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How Dangerous Is It Really? Some Approaches for Inferring Risk

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The assessment of the possible human health effects of exposure to electric and magnetic fields remains a controversial issue. Although two recent "blue ribbon" panels have concluded that there is limited evidence of an association,[16] many remain skeptical and some disagree strongly.[17] I will address this issue in two parts. First, one must determine whether an agent causes disease. Second, if causation is shown (or accepted at least for arguments sake), one can infer the magnitude of this risk. In this presentation, I briefly review the criteria for causation and then consider three different approaches for assessing possible human health risk: (1) weight of evidence review; (2) meta-analysis; and, (3) quantitative risk assessment. I apply each to the magnetic field data.

Causation

In modern epidemiology, assessments of causation most often refer back to Sir Bradford Hill's Presidential Address to the Royal Society of Medicine in which he outlines nine aspects of an association that one ought to consider, "before deciding that the most likely interpretation of it is causation."[8] There are two statements in Hill's paper that I highlight as these issues are often overlooked. First, the list Hill presents is a set issues to consider in evaluating the likelihood of causation, not a list of strict criteria. In his own words, "I do not believe we can usefully lay down some hard-and-fast rules of evidence that *must* [his emphasis] be obeyed before we accept cause and effect none can be required as a *sine qua non.*" Rather, one must undergo a careful assessment of the available data and studies in reaching a conclusion about a body of work. And yet, each body of information differs, and one may have to make different judgements about data for each agent and/or situation.

To reach a conclusion, Hill suggests that in light of the set of available observations one should consider whether there is any equally likely or more likely explanation than cause and effect. That is, one should review all possible explanations for a given set of observations and accept causation as an explanation only if there is no other explanation that is at least as well supported by the data.

The second often overlooked point Hill raises is that one should consider the aspects of causation only after one has observed, "an association between two variables, perfectly clear-cut and beyond what we would attribute to the play of chance." In other words, he suggests ruling out random error prior to the consideration of causation, as one might do using meta-analysis. Results that are equivocal from a statistical perspective do not merit consideration as causal and thus should not be considered until the data more clearly show an unusual set of results or circumstance.

The nine items Sir Hill lists for consideration are: strength, consistency, specificity, temporality, biological gradient, plausibility, coherence, experiment, and analogy. One must use judgement considering each of these, and integrating them into a holistic evaluation. In concluding, Hill notes that tests of significance cannot answer the question of causation. As Sander Greenland paraphrases him, one must be weary of equating statistical significance with scientific significance.[6] That being said, we consider three approaches for assessing causation and inferring risk.

Weight of Evidence Review

Weight of evidence review is a careful and systematic evaluation of a body of literature. Studies ranging from *in vitro* to *in vivo* to epidemiology are considered in reaching an overall assessment of the possible carcinogenicity of a substance. While literature searches are often used to identify appropriate studies, generally the specifics of the literature search, the databases accessed and the criteria for inclusion or exclusion of specific studies are not stated explicitly. Then, the review of each study is also subjective, based on the reviewer's best judgement of the quality, relevance and importance. Typically, inference is guided by consideration of various

criteria for causality.[8] There is concern that investigators may idiosyncratically focus on particular studies or specific issues within studies that are not representative of the whole body of the literature.

Agencies have developed specific criteria for undertaking such evaluations. For example, the International Agency for Research on Cancer has a long-standing program for the review of agents that are suspected of being human carcinogens.[9] As part of the review process, members of the panel conducting the review determine which studies are of sufficient quality and relevance to be included in their deliberations. While there are explicitly stated criteria for inclusion/exclusion criteria, some question the objectivity of this approach and its application to a set of studies.

Similarly, the United States Environmental Protection Agency, through its risk assessment program, reviews the possible human carcinogenicity of suspected agents.[20,21] Again, a careful but subjective review is conducted. Some interested parties often challenge the objectivity of the process.

Both of these programs consider the full range of studies, from laboratory to human, for evaluation. They also propose classification schemes to summarize findings, addressing both the adequacy of the data and the likelihood of carcinogenicity. Paraphrasing, the categories differentiate agents not likely to be carcinogenic, from those possibly carcinogenic, to those likely to be carcinogenic to people. Often holding meetings of panels of experts, these agencies ask scientists for their best judgement about the carcinogenicity of specific agents. While criteria for evaluation are set out, the final decisions are ones of interpretation of a body of literature as a whole.

Meta-Analysis

Meta-analysis is the systematic review of a body of literature and the application of statistical methods to summarize (i.e., average) the quantitative results of individual studies, in the hopes of identifying consistent patterns and sources of disagreement among those results.[2,7] To conduct a meta-analysis, all epidemiological studies are retrieved

systematically and reviewed on the basis of a consistent set of criteria. This review also can be achieved by a more traditional literature review, but those efforts typically are less systematic and less comprehensive. Some meta-analyses evaluate the completeness of the study selection by conducting a test for publication bias.[3,19] These tests assess whether studies with large effect sizes have greater precision, as would be expected, or how many null studies would it take to reduce a statistically significant average effect to a non-statistically significant average effect. If the set of identified studies is viewed as appropriate, meta-analysis can be used to assess the consistency, comparability and heterogeneity of results of each of the identified studies. Finally, if the studies are sufficiently homogeneous, meta-analytic tools can be used to estimate average study relative risks. If heterogeneous, meta-analysis can be used to try to explain the differences in study results. Sometimes, the influence of individual studies on the average effect size is assessed by excluding each study and determining how much the average effect would change.[18] This is considered particularly for index studies, those which first generated concern on an issue, or for studies of poor quality.

Quantitative Risk Assessment

The primary goal of quantitative risk assessment is to estimate the hazard for an exposure or situation that for some reason cannot readily be measured directly.[15,23] Where possible, epidemiological assessment typically provides a more valid and reliable estimate of the human health hazard than does risk assessment. But often, we cannot conduct or do not have time to wait for the completion of an appropriate epidemiological study. For example, one may wish to estimate the hazard that will result from some activity that is proposed but has not occurred (e.g., application of a particular pesticide to the food supply or the construction of a new incinerator) or one in which the complexities of the true situation make it too difficult to study (e.g., wide variations in the diet of a small population or the impact of emissions from an incinerator in an urban setting). In such situations, quantitative risk assessment offers a more tractable approach to infer the magnitude of the potential hazard in a timely manner.

There are four main stages of risk assessment: hazard identification, exposure assessment, dose-response analysis and risk characterization.

Hazard identification is the identification of all situations or substances that can, under any circumstances, pose a risk to human health, and all adverse health effects that could possibly result. It is meant to include all hazards regardless of the size or amount, and all possible health endpoints regardless of the likelihood of detectable response. If a hazard cannot be identified, many believe the risk assessment should be discontinued.

Exposure assessment is the estimation for each situation or hazard listed in the Hazard Identification of the amount of exposure to the hazard that a typical person is likely to encounter. This must include a characterization of the source(s) of exposure and the intersection of a person's activity pattern with the hazard due to the source.

Dose-response analysis is the stage in which one determines generically the amount of exposure which causes harm. For carcinogenicity assessed in animals, this is typically called the "cancer potency." For adverse outcomes assessed in epidemiological studies, the measure of effect is usually called the relative risk. Typically, risk assessors fit a mathematical equation to the data to describe how the risk of disease increases with the amount of a substance a person is exposed to.

Risk characterization is the stage in which the information from the three other stages is combined into a single overall estimate of risk. That is, for the hazard, the exposure information is combined with the dose-response information to predict a risk of an adverse effect for some exposed at the specified level. Risk can be reported for an individual, or for a population as a whole.

Application to Magnetic Field Data

By comparing the application three approaches presented above to magnetic field data, one can begin to appreciate where and why some of the disparities in scientific assessments have arisen.

Weight of Evidence

The weight of evidence approach has been applied several times to the EMF issue, by both individuals and expert panels. There have been over

two dozen expert panel reviews of the EMF issue, far too many to review here. The two most recent reviews were conducted in the United States.[16,17] The first,[16] under the sponsorship of the National Academy of Sciences, utilized their own process for evaluation (Table 1). First, a series of workshops were held at which the group was briefed on the state of the research. Then, members reviewed papers in their own fields of expertise and wrote summaries. These summaries were then considered and commented on by the whole group until consensus was reached and then formed the basis for the final report. Their bottom line was that while, "no conclusive and consistent evidence shows that exposures to residential electric and magnetic fields produce cancer," they also asserted that, "an association between residential wiring configurations" and childhood leukemia persists in multiple studies. Interpretations of these statements varied.[25]

The second panel,[17] convened by the National Institute of Environmental Health Sciences (NIEHS), was instructed to follow the procedures developed by the International Agency for Research on Cancer (Table 1).[9] After a series of topical workshops during the months prior to the panel meeting, commissioned draft chapters of the final report were written and circulated among those invited to attend the Working Group meeting. At the Working Group meeting, these chapters were reviewed, edited and rewritten until the subgroups approved them. Then, the Working Group as a whole considered each part of the report, making comments, editing and eventually voting on the acceptance and specific conclusions of each chapter and the report as a whole. They concluded that, "ELF EMF are possibly carcinogenic to humans (Group 2B)." This was based principally on, "the results of studies on childhood leukemia in residential environments and on CLL [chronic lymphocytic leukemia] in adults in occupational settings." In addition, the participants stated that the *in vitro* and mechanistic data provide weak support based on studies at very high levels of exposures (>100 μT).

One recently published article using weight of evidence criteria reached somewhat different conclusions (Table 1).[5] After reviewing the literature, they placed greater emphasis on *in vitro* and *in vivo* studies than the expert panels, pointed out the lack of genotoxicity of EMF, the lack of plausible biological mechanism and the apparent inconsistencies between

epidemiology study results, and concluded that "the evidence in support of links between the [electromagnetic] fields is weak and inconsistent." The assert that, "the issue is not whether fields *could possibly* be related to human cancer but whether they *probably are* [original emphasis]." The latter sentence is interesting in that it reframes the question into one that requires a much higher and more consistent standard of evidence.

Table 1: Weight of Evidence

	NRC[16]	NIEHS[17]	Foster[5]
Emphasis	Residential epidemiology	Residential and occupational epidemiology	In vivo and in vitro studies
Observed effects driving concerns	Childhood leukemia	Childhood leukemia, adult chronic lymphocytic leukemia	None
Causation	No consistent and conclusive evidence	Possible human carcinogen	Not a probable carcinogen
Quantitative Risk Assessment	Not conducted	Conducted	Not conducted

Meta-Analysis

Meta-analysis is conducted only if you believe that the epidemiology is reliable and of sufficient quality for further consideration. Some EMF investigators believe it is not. Others do and several meta-analyses have been conducted for both the residential[1,12-14,16,22,24,26] and occupational[10,11] exposures.

The most recent residential exposure meta-analysis,[24] conducted as part of the NIEHS Working Group review noted above, extends previous work by providing:

1. analyses including several more recent studies;

2. a more careful and detailed review of the exposure metrics motivating and justifying particular analyses;

3. estimates for fixed effects, random effects, heterogeneity, and sample size needed to negate the observed results, for a variety of exposure classifications;

4. analyses stratified by various study characteristics to provide preliminary evaluation of possible confounding and effect modification;

5. analyses for publication bias, including the fail-safe N and funnel plots;

6. dose-response meta-analysis including heterogeneity assessment.

Results are summarized in Table 2. First and foremost, it is important to review the analyses for heterogeneous studies. The study showed intermittent heterogeneity, although sometimes it was substantial. When present (e.g., wire codes scored by 24-hour measurements), summary estimates of effect can be misleading. Stratification to identify particular sources of heterogeneity did not provide specific insights. Overall, summary relative risks ranged between 1 and 2, and these were not subject to substantial influence by individual studies. There was only limited evidence of publication bias. A large number of not statistically significant unpublished studies would have to exist for the observed results to be due to random variation (according to the fail-safe N), and an extremely large, negative study would be required to reverse these observations (the number needed calculation). Based on these findings, the association between wire codes and childhood leukemia is most striking, and the association between measured fields and childhood leukemia also difficult to explain. While confounding and bias cannot be ruled out as possible explanations, several investigations into these factors have failed to identify plausible factors responsible for the observed effects.

Table 2: Meta-Analysis

Criterion	Index	Measured/Calculated Fields			Proximity to Source		
		Dichotomy	Continuous		Dichotomy	Continuous	
			Spot Measure-ments	Calculated Fields		Wire Codes scored by spot	Wire Codes scored by 24-hour
Strength	Summary RR[A]	1.4 (1.0-2.0)	1.1 (0.9-1.3)	1.2 (0.9-1.5)	1.4 (1.1-1.8)	2.7 (0.8-8.7)	1.6 (0.5-4.6)
Consis-tency	% positive studies (number of studies)	80% (10)	75% (4)	75% (4)	73% (11)	100% (2)	50% (2)
	Hetero-geneity	0.2	0.3	0.2	0.1	0.1	0.02
Publica-tion Bias[B]	Fail-safe N[C]	7	--	--	30	--	--
	Subjects needed	>6000	--	--	>3400	--	--
Influence Analysis	Hetero-geneity	0.11-0.50	--	--	0.04-0.20	--	--
	Relative Risk	1.2-1.6	--	--	1.3-1.5	--	--

[A]Random Effects Model (Reference [4])
[B]Calculated only for dichotomous exposure categorizations
[C]Calculated only if result is statistically significant (References [3,19])

Quantitative Risk Assessment

The first stage of quantitative risk assessment is the identification of likely hazards and outcomes. If present, one proceeds; if not, one does not conduct a risk assessment. The National Academy of Sciences Committee did not believe that there was sufficient evidence of causation to conduct a risk assessment of EMF exposure.[16] The NIEHS Working Group, however, concluded that EMF was a possible human carcinogen (Group 2B) and therefore believes that there is sufficient evidence to conduct the assessment.[17] The outcomes they identify are childhood leukemia for residential exposures and adult chronic lymphocytic leukemia for occupational exposures. NIEHS staff are currently conducting such an assessment. Below, I provide a preliminary and cursory quantitative risk

assessment of residential exposure to EMF based on the data from the NIEHS Working Group Report.[17] Results are summarized in Table 3.

Having identified both the hazard (residential EMF exposure) and the outcome (childhood leukemia), we next have to quantify exposure. Using exposure data developed from surveys of homes throughout the US, we have both distributions of wire codes and spot measured magnetic fields.[27,28] For wire codes, it was reported that 28% of homes have ordinary high (OHCC) or very high (VHCC) current configurations. For spot measurements, the data were reported to follow approximately a log-normal distribution with a mean of 0.09 μT and a standard deviation of 2.2 μT. Using the relative risks of 1.4 for OHCC or higher wire codes and 1.1 per 0.1 μT for spot measured magnetic fields, as reported in the NIEHS meta-analysis,[24] and the reported annual 2,200 cases of leukemia cases to children under 15 years of age (source: Leukemia Society of America), one can calculate the number and proportion of cases attributable (PAR) to EMF exposure each year. Based on the wire code data, we predict about 175 cases, or 8%, attributable to EMF exposure. Based on the spot measurement data, we predict about 240 cases, or 11%, attributable to EMF exposure. From a policy perspective, these are substantial numbers, if somewhat uncertain.

Table 3: Quantitative Risk Assessment

Stage of Risk Assessment		Wire Codes	Measurements
Hazard ID		Group 2B carcinogen	Group 2B carcinogen
Exposure Assessment		28% ≥ OHCC[A]	Log-normal (0.09,2.2)[B]
Dose Response[C]		RR=1.4	RR=1.1 per 0.1 μT
Risk Characterization	PAR	8%	11%
	# cases	~175	~240

[A]Zaffanella[27]
[B]Zafanella[28]
[C]Wartenberg[24]

Discussion

To summarize the disparate viewpoints on the possible human health risk from exposure to magnetic fields, one can review Hill's aspects of causation in assessing the plausibility of a hazard (Table 4), and one can consider the risk assessment to estimate (albeit crudely) the magnitude of that possible risk (Table 3). First, one sees a fairly weak but fairly consistent effect in the epidemiological studies reported. While the result is not highly specific, there is evidence of temporality and biological gradient. Relatively newly developed models do exist which may explain adverse effects at high dose in *in vitro* studies, levels which border on rare occupational levels, although models have yet to be developed that are relevant at doses equivalent to residential exposures. Thus, there is some support for causality from the perspective of Hill's approach, but more data are needed to further clarify this issue.

Table 4: Hill's Aspects of Causation Applied to the Magnetic Field Issue

Strength	RR=1.1-2.7
Consistency	Heterogeneity varies but appears moderate with exceptions
Specificity	Other causes are known but explain only a small proportion of total cases
Temporality	Yes
Biological Gradient	Some evidence
Plausibility	Model exists for high dose effect
Coherence	Possible
Experiment	Not applicable
Analogy	No obvious case

From a public policy perspective, the plausibility of causality encourages consideration of the magnitude of the problem. Using a fairly crude and conservative approach, as many as 150-250 cases of childhood leukemia may be due to EMF exposure each year. This is a substantial number of cancers, and does not consider other cancers, other adverse outcomes or non-residential exposures. Some would argue that

consideration of exposure reduction, if possible at limited cost and inconvenience, is warranted.

In light of these results, why do interpretations of causality and consequence differ among scientists, particularly among scientists from different disciplines? In part, I believe that there is substantial scientific uncertainty in the data. Each study has limitations, and subjective judgements are made about the size and importance of these limitations. In part, different scientists place different amounts of emphasis on different types of data. For example, in light of the uncertainties and inconsistencies, bench scientists are likely to give more emphasis to the *in vivo* and *in vitro* studies while epidemiologists give more emphasis to the epidemiological studies. Beyond that, the appropriateness, importance and interpretation of meta-analyses, risk analyses and other summaries are judged differently by different individuals. While most agree that the data are suggestive, gaining consensus beyond that is difficult as reflected in the many "Blue Ribbon" Panel reviews. As more studies are conducted and released, perhaps we will get greater clarity and consensus on this important issue.

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Assessment of health effects from exposure to power line frequency electric and magnetic fields

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Abstract

From June 16, 1998 to June 24, 1998, a group of thirty scientists both within and outside of electric and magnetic fields (EMF) research community met to examine the strength and robustness of the experimental data pertaining to EMF. The scientists came from a broad array of disciplines including epidemiology, biostatistics, toxicology, physics, cellular and molecular biology, pathology and mathematics. Their report covered the range of research available on EMF and drew a number of conclusions as part of a hazard identification for EMF health effects. This report is part of the evidence being used by the National Institute of Environmental Health Sciences to evaluate the potential for health risks from exposure to EMF. This brief report summarizes the conclusions from this Working Group.

INTRODUCTION

Research into the health effects of extremely low frequency (ELF) electric and magnetic fields (EMF) has progressed for greater than thirty years. The catalyst that sparked increased study in this area of research was the 1979 report by Wertheimer and Leeper that children living near power lines had an increased risk for developing cancer. Since that initial finding, there have been numerous epidemiological and laboratory studies aimed at

clarification of this finding and subsequent findings of similar concern. Despite this multitude of studies, there remains considerable debate over what, if any, health effects can really be attributed to ELF-EMF. In 1992, the U.S. Congress instructed the National Institute of Environmental Health Sciences (NIEHS) and the Department of Energy (DOE) to direct and manage a program of research and analysis aimed at ending this debate. This resulted in the formation of the EMF Research and Public Information Dissemination Program (EMF-RAPID). The program was funded jointly by Federal and matching private funds.

The EMF-RAPID Program has three basic components: 1) a research program focusing on health effects research primarily through mechanistic studies of ELF-EMF and engineering research targeting measurement, characterization and management of ELF-EMF; 2) information dissemination consisting of brochures, public outreach and a hotline for communicating with the public; and 3) a health assessment including an analysis of the research data aimed at summarizing the strength of the evidence for evaluation of any hazard possibly arising from exposure to ELF-EMF. The NIEHS was directed to oversee the health effects research and evaluation and DOE has responsibility for the engineering research. The research program was a four year program which terminates in December, 1998. Much of the EMF-RAPID research is just now being published. The public outreach program developed a number of brochures which proved extremely useful as tools for informing the public about the nature of EMF and the types of research which address the potential for hazards.

The part of the EMF-RAPID Program aimed at the analysis and summary of research findings began in 1996 with the development of a program consisting of a series of workshops addressing different areas of the research database. The first workshop was held in March, 1997 and reviewed the literature on in-vitro and mechanistic findings. Subsequent workshops focused on in-vivo and clinical research and on epidemiological findings. These workshops were aimed at including a broad spectrum of the research community in the evaluation of EMF health hazards, identifying key research findings and providing opinion on the quality of this research. A description of this series of workshops is given in Portier and Wolfe (1997b) and the risk communication strategy used in developing this series

of workshops is given in Portier and Wolfe (1998a). Each workshop produced a report which is available from the NIEHS (Portier and Wolfe, 1997a, 1998b, 1998c).

Starting in late 1997, in preparation for an EMF-RAPID Working Group meeting, a group of select scientists were given the task of providing formal reviews of the literature in the areas of research identified from the three workshops. Eventually, twelve separate documents were prepared covering the areas of animal carcinogenicity, animal non-cancer findings, neuroendocrine effects, cell signalling effects, effects on DNA, effects on cellular replication, effects on cellular differentiation, biophysical theories, exposure, adult environmental epidemiology, childhood epidemiology and adult occupational epidemiology. These documents were distributed to thirty scientists chosen to form the NIEHS EMF Working Group. From 16-24 June, 1998, these scientists met in Brooklyn Park, Minnesota where they rewrote the draft documents into a single book (NIEHS Working Group Report, 1998). In addition to reviewing the literature, the Working Group also characterised the strength of the evidence in each category of research using the criteria put forward by the International Agency for Research on Cancer (IARC). These criteria are given in Appendix B of the Working Group Report.

WORKING GROUP FINDINGS

Levels of evidence

Evaluations of the various health end-points using the IARC criteria fall into four basic categories; sufficient evidence, limited evidence, inadequate evidence, and evidence suggesting the lack of an effect. Without repeating the definitions given in Appendix B of the Working Group Report, these categories can be viewed respectively as strong evidence generally including dose-response, weak evidence with an indication of dose-response, mixed evidence for negative findings from a limited number of studies and strong evidence of a no effect. Many of the effects covered in this report relate to 'limited' and 'inadequate' evidence. 'Limited evidence' is not an unusual finding for epidemiological data in the IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. This degree of evidence is generally provided by studies for which there is credible

evidence of an association and for which a causal linkage cannot be established with a high degree of certainty. This does not mean the effect is weak (e.g. shallow dose-response), nor does it mean there is clearly an effect, although these issues enter into the evaluation. In most cases, this degree of evidence is associated with one or more of the following problems: questionable identification of the exposure factor(s) associated with the disease outcome (either a weak dose surrogate was used or individuals were misclassified as to their exposure category), bias may have played a small role in the finding, confounders were not ruled out to the satisfaction of the original investigator and/or the Working Group, the observed effect was small, making clear detection of an effect difficult, and/or there is little information on dose–response in the available report. The careful reader is directed to the individual sections of the report for a clear description of each study. For experimental animal bioassays, 'limited evidence' for an effect is generally driven by clear findings in only a single study for a single end-point or minor problems with a set of data which otherwise would have been positive; confounding, bias, and exposure misclassification generally do not exist in laboratory studies.

'Inadequate evidence' can imply one of four possibilities: (1) there are insufficient data for making a judgement of any kind (e.g. poor study design, making interpretation impossible); (2) the data suggest a positive effect but, due to limitations in design or very weak findings, cannot be interpreted as suggesting a causal linkage; (3) the data suggest a negative effect but, due to limitations in design or very few findings, cannot be interpreted as suggesting no effect; and (4) the data are contradictory and no clear pattern is discernible. For case (1), given a solid hypothesis, it may be beneficial to continue to study an inadequate finding using a better design in the same experimental system. For case (2), if the effect seen is of public health consequence, it should be studied further but with a clear hypothesis and perhaps in conjunction with other studies such as those providing mechanistic interpretation. In case (3), unless there is a clear scientific reason for further study, again involving a defined hypothesis, there is little need to continue to study the observed effect. Finally, for case (4), the effect might be further studied if the scientific issues are compelling or if health concerns are raised, but it is unlikely that another study of similar design would be performed. Additional studies might not be needed. Again, a careful reader searching for scientific hypotheses for

further study should read the more detailed descriptions of the findings presented in the Working Group Report.

Votes were taken for most of the conclusions given in the Working Group Report. The counts for each of these votes are reported in the text of the report. In most cases, the votes were nearly unanimous; however, some of the votes were very close. The range of votes is indicative of the degree of uncertainty among members concerning the strength of evidence for ELF-EMF associated health effects.

Carcinogenicity In Humans

The conclusions drawn by the Working Group on the evidence for carcinogenicity of ELF-EMF in humans are predominantly derived from epidemiological studies which were designed to detect associations between health effects and exposure to EMF. This evidence is subdivided into adult occupational studies, adult residential studies and studies of childhood exposures. In each subdivision, the Working Group developed criteria mostly based upon experimental design and how fields were measured, for determining the inclusion or exclusion of studies in its evaluation. For each study included in the evaluation, the Working Group carefully assessed study quality, focusing on issues such as control selection, exposure assessment, confounding, and other possible sources of error which could lead to misinterpretation of the study findings. These issues are discussed in detail in the Working Group Report for each epidemiological study. The Working Group also evaluated six meta-analyses of childhood cancers, focusing on a recent analysis done by Wartenberg *et al.* (1998).

For adult occupational studies, the Working Group considered different cancers in the following categories: all cancers combined, leukaemia, brain cancer, breast cancer, lung cancer, central nervous system cancers in the offspring of parents occupationally exposed, and sporadic reports for other cancers. In addition, the Working Group reviewed meta-analyses of brain cancer and leukaemia. With the exception of chronic lymphocytic leukaemia, the Working Group concluded that there was inadequate evidence of carcinogenicity of ELF-EMF in adults. In most cases, this finding was driven by either a paucity of studies of adequate

design to address the question of association or by mixed results with some studies showing a positive association and other studies showing no association with no predominant pattern.

Leukaemia was the first cancer associated with occupational exposure to EMF and has been investigated in over 70 studies, all of which were at least considered by the Working Group. Many were excluded because of limitations of the exposure metric or because better studies were available. In the one meta-analysis evaluated, a small but significantly increased relative risk for leukaemia and its main subtypes was found. In a careful evaluation of four studies on chronic lymphocytic leukaemia, three of the four studies showed increased relative risks (Feychting et al., 1997; Floderus *et al.* 1993; Theriault *et al.* 1994), although not all were statistically significant, and one showed no association (Savitz and Loomis, 1995). Taken together these studies suggest an association between EMF exposure and chronic lymphocytic leukaemia for which a causal interpretation is possible but not established; chance, bias or confounding could not be ruled out and may have led to the observed association. It should be noted that the Working Group based this decision upon the bulk of this evidence and not on any one study since not all cohorts showed statistically significant results.

The evaluation of cancers associated with adult residential exposure focused mainly on leukaemia, breast cancer, and cancers of the central nervous system. As for occupational exposures, leukaemia was the initial cancer cited (Wertheimer and Leeper, 1987). Nine studies met the criteria for inclusion in this evaluation for an association between ELF-EMF and leukaemia. Breast cancers and nervous system cancers had fewer studies. In general, the Working Group felt there was inadequate evidence for an association between any of these cancers and adult residential exposure to ELF-EMF. These studies generally demonstrated no association or a weak association with no statistical significance which led to the Working Group's opinion of inadequate evidence.

Wertheimer and Leeper (1979) initiated the hypothesis that EMF from electrical power lines and substations are associated with childhood cancer through their use of wire codes as a surrogate to characterise exposure. Their seminal paper led to a number of epidemiological studies

investigating this hypothesis. These studies have examined either all cancers, leukemias (sometimes specific subtypes), lymphomas, or brain cancer. The Working Group focused on studies with measured or calculated magnetic fields giving less weight to studies using wire codes. With the exception of childhood leukaemia, the Working Group concluded there was inadequate evidence to support an association between ELF-EMF and childhood cancers. For childhood leukaemia, the Working Group concluded there is limited evidence for an association. The most compelling evidence supporting this finding came from four Nordic studies (Feychting and Ahlbom, 1993; Olsen *et al.* 1993; Verkasalo *et al.* 1993; Tynes and Haldorsen, 1997) in which calculated magnetic fields were used as the metric of exposure. Three of these studies found leukaemia risk increased with increasing calculated exposure while the smallest study (Tynes and Haldorsen, 1997) found no association. These findings were further supported by three studies with 24-hour magnetic field measurements (London *et al.*, 1981; Linet *et al.*, 1997; Michaelis *et al.*, 1998) and by studies using wire-codes as exposure surrogates but not by studies using spot measurements. While all of these studies had limitations, the Working Group felt that chance was an unlikely explanation for the observed associations. It should also be noted that, for some studies, the conclusions of the Working Group did not coincide with the conclusions of the original authors.

Carcinogenicity in Animals

Animal carcinogenicity studies are routinely used to identify environmental agents which may increase cancer risks in humans. While animal studies are not plagued with many of the problems associated with epidemiology studies, they do present two additional problems: extrapolation across species and extrapolation from laboratory exposure patterns to environmental exposure patterns. In these studies, the potential for increased carcinogenic risks of EMF has usually been studied at intensities of exposure that are much higher than environmental exposures and have greater uniformity in frequency and intensity than would appear in environmental settings. These experimental conditions are chosen to maximize the ability for a researcher to detect an effect for a clearly defined exposure. However, because animal studies do not mimic the human situation, animal data are usually used to provide support for

epidemiological data but seldom are used to refute that data. The IARC rules used by the Working Group (NIEHS Working Group, Appendix A, 1998) for ranking carcinogenic hazards approaches laboratory data in this fashion.

Several experimental designs and animal models have been used to study the potential carcinogenicity of ELF-EMF. In some cases, the choice of an animal model is based upon tradition whereas in other cases a model is chosen to address a specific mechanism. Lifetime studies of ELF-EMF as a complete carcinogen have been conducted in three separate studies (NTP, 1998b; Mandeville *et al.*, 1997; Yasui *et al.*, 1997). In two of these studies, the Working Group concluded there were no increases in cancer that could be attributed to EMF exposure. In the final study (NTP, 1998b), there was an isolated finding of an increase in thyroid C-cell adenomas and carcinomas in one sex-species group making this study equivocal according to the original report. One additional long-term study of 32 weeks duration also indicated no cancer effects from exposure to ELF-EMF (Marganato *et al.*, 1995).

Mechanism-based models of carcinogenesis in mammary tissue, skin, leukaemia and liver were also evaluated. These studies showed inconsistent results across laboratories with a general trend toward no effect. Similar findings held for the few studies using transgenic animals. There was considerable debate over differences in the responses seen in a multistage model of mammary carcinogenesis done in a German Laboratory (Loscher *et al.* 1993, 1994; Mevissen *et al.* 1993, 1998) versus replicate studies done in a U.S. laboratory (NTP, 1998a). The U.S. studies were negative whereas the German studies showed some effects. A Swedish study (Ekstrom et al., 1997) using a similar protocol but slightly different exposure patterns was also negative. The Working Group concluded that this ensemble of studies did not provide convincing evidence for a co-promoting effect of EMF on chemically-induced mammary carcinogenesis.

Following extensive debate and some degree of controversy, the Working Group voted 19 to 8 that there is inadequate evidence for carcinogenicity in animals (the 8 remaining votes were all for lack of carcinogenicity).

Non-Cancer Effects in Humans

Numerous epidemiological studies have looked at the possibility of health effects other than cancer arising from exposure to ELF-EMF. In general, the Working Group concluded the data were inadequate to support an association between ELF-EMF and any adverse health outcome other than cancer. These included adverse birth outcomes, reproductive effects, Alzheimer disease, lateral sclerosis, suicide, depression and cardiovascular disease. In most cases, these findings are severely limited by the experimental designs and the number of studies performed.

Laboratory studies of biological effects (non-adverse) were also evaluated. These were treated as mechanistic studies and evaluated using the categories weak, moderate and strong. It was concluded there was weak evidence that short-term human exposure to ELF-EMF causes changes in heart rate variability and sleep disturbance. There was no evidence that exposure to ELF-EMF had effects on any other biological endpoints studied clinically.

Of particular interest to scientists in this field is melatonin, a neuroendocrine hormone having multiple effects throughout the mammalian system. Several authors (e.g. Stevens *et al.*, 1997) have proposed that modulation of melatonin production and release following exposure to EMF could explain some of the possible effects seen in the literature. Clinical and epidemiological studies were available for evaluating this hypothesis. The Working Group concluded there was weak evidence to support an effect of ELF-EMF on circulating melatonin levels but drew no conclusions concerning the linkage between altered melatonin and health risks.

Non-Cancer Effects in Animals

Non-cancer effects studied in laboratory animals cover a broad range of experimental animals, study designs, exposures and biological effects. Most of these endpoints have been evaluated in multiple studies with more than one species. The review of these studies covered over 60 pages in the Working Group report with detailed evaluation of over 100 studies.

An extensive range of assay systems has been developed to evaluate the effects of environmental agents on the immune system. These assay systems are targeted at different aspects of the immune system; most notably acquired (humoral or cellular) and innate immunity. Animal models studied include baboons, rats and mice. Two research groups (House *et al.*, 1996; Tremblay *et al.*, 1996) reported significant effects on NK cell activity, but in different directions and with mixed results when repeated in one laboratory (House *et al.*, 1996). The studies had varied quality and suffered from experimental difficulties. The Working Group concluded there is no evidence for effects of ELF-EMF on the immune system in experimental animals.

Haematological effects of ELF-EMF included measures of red blood cells, haemoglobin concentration, red cell volume, corpuscular volume (of various sorts), hematocrit and cell number (various cell types). In addition, bone marrow cellularity and bone marrow smears were also evaluated. The Working Group concluded there was no evidence for effects of ELF-EMF on haematological parameters in rodents.

There is little doubt that animals can detect electric fields with detection thresholds in the range of 3-10 kV/m. This is a well-established phenomenon supported by numerous studies and can be shown to alter behaviour through studies of avoidance, aversion, performance and learning. The Working Group found no evidence suggesting the same was true for magnetic fields at environmentally -relevant exposures. ELF-EMF effects on neurophysiology and electrophysiology were not as clear. The Working Group concluded there is weak evidence for effects of electric and magnetic fields on neurobehavioral, neuropharmacology, neurophysiology, and neurochemistry in experimental animals.

Reproductive and developmental effects of ELF-EMF have been studied in birds, mice, rats and hamsters. A few laboratories have reported alterations in the development of chick embryos but the results of teratogenic and reproductive effects in mammalian systems have generally been negative. No studies were available on other developmental endpoints. The Working Group concluded there is no evidence for reproductive and developmental effects of exposure to ELF-EMF in experimental animals.

Several studies were specifically designed to evaluate the melatonin hypothesis; most of these studies were done in either rats or hamsters. Study designs included both short-term and long-term exposures. The evidence for a quantitative and consistent effect is lacking but generally supported a slight depression in melatonin in rats. High exposure and field orientation appear to play an important rule in modulating this response. It is unclear what biological significance may be attributed to this reduction. The Working Group concluded there was weak evidence that exposure to EMF alters the levels of melatonin in rodents, but there was no evidence supporting such an effect in sheep or baboons.

For several years, EMF has been used as a non-invasive therapy for the promotion of bone healing. In this clinical use, it is believed that the induced electric field is the agent stimulating healing. Numerous studies in humans and experimental animals were reviewed by the Working Group. Additional research has been done investigating the possibility that EMF can also heal damage to soft connective tissue (skin and ligaments) and nerve tissue. The Working Group concluded there is strong evidence that exposure to electric and magnetic fields affects bone repair and adaptation. The Working Group could not reach a conclusion for the other two tissues.

In-Vitro and Mechanistic Studies

The number of cellular components, processes and systems which can possibly be affected by ELF-EMF is very large. Most of the studies in this area have focused on the cell membrane, gene expression and signal-transduction pathways. Initial research also evaluated genotoxicity of ELF-EMF but was mostly negative; recent research has renewed efforts to study possible roles of EMF in causing DNA damage. Most of the experimental evidence in this area arises from studies using cultured cells exposed in-vitro. The Working Group evaluated a broad range of studies in this category of research, focusing on studies designed with a clear mechanistic hypothesis. In evaluating these studies, the Working Group considered three critical factors: independent validation of a finding, demonstration of a physical mechanism supporting the observed effect, and an understanding of a linkage between the observed effect and an adverse health outcome.

The Working Group highlighted a series of recent studies (1996-98) demonstrating effects of EMF on gene mutations. They noted that studies of ELF-EMF exposures below 0.1 mT have consistently shown no effect on mutation rates; however, exposures of 0.2-400 mT produced significant enhancement of mutation after x-ray and gamma-ray initiation (Walleczek et al., 1998; Miyakashi et al., 1996, 1998). In addition, exposure at 400 mT induced mutations in the absence of ionizing radiation (Miyakashi et al., 1996). Some studies were found to produce strong effects in other endpoints commonly associated with cancer (e.g. cell proliferation, disruption of signal transduction pathways and inhibition of differentiation). These studies demonstrated effects at exposures associated with a plausible mechanism (magneto-chemical transduction; exposure > 0.1mT).

One set of studies received considerable attention at both the Working Group Meeting and at subsequent meetings: the studies looking into a possible reversal of the oncostatic effects of melatonin and tamoxifen by low intensity (1.2 μT) ELF-EMF exposures (Liburdy et al., 1993; Harland and Liburdy, 1997; Blackman et al., 1998, Liburdy and Levine, 1998). While these studies are intriguing, the Working Group members were concerned about possible design flaws in these studies and the very small effect observed. Additional studies should soon be reported clarifying this issue.

The Working Group concluded that a limited number of well-performed studies provide moderate evidence for mechanistically-plausible effects of EMF at exposures exceeding 0.1 mT. There was weak evidence for effects below this exposure level.

The Working Group also summarized the biophysical mechanisms which have been hypothesised to support or refute the possibility of ELF-EMF biological effects. No conclusions were drawn from this review; the pros and cons for each theory were described. In summary it was noted that multiple theories may be applicable at different field intensities in different species; thus several models may be appropriate depending upon the case being studied.

DISCUSSION

The Working Group was asked to provide an overall evaluation for the carcinogenicity of ELF-EMF in humans. The best way to summarise their overall finding is to simply quote it:

"A majority of the Working Group concluded that classification of ELF-EMF as possibly carcinogenic (Group 2B) is a conservative, public-health decision based on limited evidence of an increased risk for childhood leukemias with residential exposure and an increased occurrence of CLL associated with occupational exposure. For these particular cancers, the results of *in-vivo*, *in-vitro*, and mechanistic studies do not confirm or refute the findings of the epidemiological studies. The overall body of evidence has, however, laid a foundation for furthering our understanding of the biological effects, mechanisms, and exposure circumstances that may be related to the possible carcinogenicity and other adverse human health effects of exposure to ELF-EMF."

This is not the end of the evaluation for ELF-EMF but instead the beginning. The Working Group Report is a recommendation to the NIEHS on the strength of the evidence for health effects from exposure to ELF-EMF. The NIEHS is currently seeking comment on this report as it prepares to develop and write a separate report (the NIEHS Director's Report) mandated under the 1992 Energy Policy Act. To this end, the NIEHS has distributed over 1000 copies of the Working Group Report to scientists, regulators, industry and the public. In addition, the NIEHS has hosted a series of public meetings to receive comments on this document. At each meeting, NIEHS officials and other scientists involved with preparation of the NIEHS Director's report were present to receive comments on the report. Attendees had the opportunity to voice their opinions and comments on the report to the panel orally and/or in writing at these meetings. In addition, the public meetings were preceded by poster sessions describing the NIEHS and its mission, the EMF-RAPID Program and the major findings from the Working Group Report.

All aspects of the Working Group report are important to the NIEHS and our considerations of the potential health effects from EMF exposure, but some may have more impact than others. One aspect of critical

importance is the conclusion by a majority (19) of the Working Group members that EMF should be considered a "possible human carcinogen". As mentioned earlier, the vote for possible carcinogenicity was based largely on epidemiological evidence in the face of animal and other laboratory studies that the panel agreed did not support or refute the population studies. No members of the Working Group concluded that EMF could be classified as a "known human carcinogen" (IARC class 1) or as a "probable human carcinogen" (IARC class 2A). The largest minority (8 members) concluded that EMF was "not classifiable as to its carcinogenicity" (IARC class 3) and one member concluded EMF was "probably not a human carcinogen" (IARC class 4). These conclusions about the possible carcinogenicity of EMF is an area where we are encouraging opinion.

There has been considerable debate about how the conclusions in this report compare with a recent National Academy of Sciences (NAS) Report (NAS, 1997). The NAS Report stated that "no conclusive and consistent evidence shows that exposures to residential electric and magnetic fields produce cancer" (page 2, NAS Report). As noted above, the Working Group also did not conclude that EMF is a "known human carcinogen" (IARC class 1) or a "probable human carcinogen" (IARC class 2A) which is consistent with the NAS Report. However, the NAS and Working Group reports do differ in their assessment of the level of evidence from epidemiological studies linking EMF exposure and childhood leukaemia. The NAS concluded "Average magnetic fields measured in the homes of children have not been found to be associated with an excess in childhood leukaemia" (page 117, NAS Report). In contrast, the Working Group concluded the data "support an association between exposure to calculated magnetic fields and the incidence of childhood leukaemia" (page 186, Working Group Report) and give "some support for a possible association between exposure based on 24-h measured magnetic fields and the incidence of childhood leukaemia" (page 187, Working Group Report). This assessment of the epidemiological data led a majority (20) of the Working Group to conclude that there is "limited evidence" that EMF is carcinogenic to children (page 189, Working Group Report). The remaining members who voted (6) concluded the evidence was "inadequate". This vote of "limited evidence" in children drove the Working Group's classification of EMF as a "possible human carcinogen"

since, according to IARC criteria (page 499, Working Group Report), one way in which an agent falls into the 2B category is if "there is limited evidence of carcinogenicity in humans and less than sufficient evidence of carcinogenicity in experimental animals.".

The remaining steps in the process used by the NIEHS will include comment from the Federal regulatory community and final preparation of the NIEHS report for Congress. It is clear that some evaluation of the possible risks for childhood cancer from exposure to ELF-EMF will need to be given under the assumption that the association seen in the epidemiology studies is causal. This is not to imply a zero risk is unlikely, but simply a means to gauge the magnitude of any potential health risks which might arise.

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Public Participation: Guiding Practice With Research

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INTRODUCTION

One often-cited article calls public participation a "practice in search of a theory" (Wengart, 1976). Fortunately, theoretical frames for public participation are now discussed seriously although there is by no means consensus about a theory of public participation (e.g., Fiorino, 1990; Laird, 1993; Renn et al, 1995).

On the other hand, empirical research on public participation is sorely lacking. Agency practitioners who conduct public participation use guidance documents that are based largely on wisdom from accumulated experience (e.g., DOD and EPA, 1994). While this experience is invaluable, it is not a substitute for empirical research. But, practitioners have relatively little choice. There has been little systematic research to guide public participation practice (NRC, 1996), and much of the seminal research in the U.S. dates before the mid-1980s. In short, public participation is also a practice in search of research.

The usefulness of the relatively small research literature is also further hampered because studies often use vastly different criteria to explore public participation efforts. Some studies define public participation in terms of public participation process, that is "how" a public participation program is conducted (Tuler and Webler, 1995). Others look at the substantive outcome of a public participation effort (e.g., progress in remediation, control of non-point source pollution, etc.) and others explore both (e.g., DOE, 1996).

In addition, goals for evaluating public participation reflect conflicting values about and expectations for public participation. For example, three handbooks on public participation agree little on criteria for evaluating models of public participation (Webler, 1997). The peer-reviewed literature is equally heterogeneous and mentions, among other goals, acceptance of agency plans, consensus, improvement of agency plans, social learning, public education about environmental problems, and agency awareness of citizen concerns.

In this paper I draw on research about public participation in North America to discuss implications for practice. I explore the assumptions currently made about public participation and the extent to which those assumptions are substantiated with the empirical research. (For a more comprehensive review, see Chess and Purcell, 1998, which raises similar issues.)

1. Timing of participation

The public participation rule of thumb suggests that public participation should be conducted early in the decision-making process (e.g., Kasperson, 1986). Although empirical research is far from definitive, investment in these preliminary stages of public participation appears prudent. Studies faulted the timing of the participatory effort when participants were asked to react to agency plans--the proverbial "decide, announce, and defend" approach--rather than join in earlier discussions of alternatives (e.g., Gariepy, 1991; Mazmanian and Nienaber, 1979). Insufficient or inappropriate outreach was cited as a problem in some public meetings (Sinclair, 1977). Two studies of workshops also found that workshop participants wanted a greater role in planning participation (Brandt, 1994; Young et al., 1993). Similarly, the success of CACs may depend on agencies' willingness to involve participants in all phases of the planning process (Lynn and Busenburg, 1995).

2. Relationship between the process and the outcome of public participation

"People are more willing to accept the results of processes they perceive as fair, balanced and reasonable and that allow them an adequate

opportunity to have a fair say," according to a report from the National Research Council (1996). The NRC report backs this assertion with citations of case studies that tie involvement of stakeholders in decision making with reducing conflict about the siting of hazardous waste sites (e.g., Kraft, 1988; Heiman, 1990).

Because siting can be seen as an extreme test of public participation due to the extent and nature of the conflict, the NRC's evidence of strong links between process and outcome are arguably particularly significant. If improved process can engage participants in dialogue about hosting a locally unwanted land use, then improved process might have an even greater impact on less controversial environmental issues.

In fact, many studies show a link between participants' satisfaction between process and outcome. On the other hand, four carefully conducted studies suggest that although stakeholders may respond favourably to a participation process, they may not respond as favourably to the outcomes. For example, participants rated an Army Corps workshop that explored wetlands permitting satisfactory on process but unsatisfactory on outcomes, leading the researcher to suggest that "participants' support for the process does not lead to immediate support for outcomes" (Rosener, 1981:594). Another early, but much cited, study of participatory efforts of the Corps of Engineers described a case where the final meeting found both Corps and citizen participation self-congratulatory (and the process ratings more than satisfactory), yet participants rated the outcome as less than satisfactory (Mazmanian and Nienaber, 1979).

A more recent study surveyed advisory boards at major DOE sites on both process and outcome and found more overall satisfaction with the process of citizen involvement than with the outcome (U.S. DOE, 1996). For example, based on combined responses to 13 items, 71% of respondents agree or strongly agree that SSABs facilitate interaction and exchange of viewpoints on SSAB site issues. Yet based on combined responses to six items, a much less substantial majority (53%) of respondents agree or strongly agree that the SSABs lead to more acceptable agency actions.

Surprisingly a study of two military advisory boards found that members of one were positive about the outcome despite discontent with elements of the CAC process, including poor facilitation (Beltsen, 1996).

Based on this evidence, the link between process and outcome should not be assumed. On the other hand, without a positive participation process, dissatisfactions with outcome might have been even greater. Further research is critically needed to explore the association between process and outcome.

3. Selection of participatory form

There have been attempts to characterise forms of participation (e.g., public meetings, citizen advisory councils, citizen juries, surveys, etc.) in a way that makes explicit when they should be used. However, the NRC (1996) concluded that "there is no rigorously or generally accepted classification scheme" to predict which participatory form will work in any given situation. In other word, selecting the "correct" form of participation may not be the factor that most shapes the outcome of a given participatory effort. Briefly, I discuss this concept in terms of two forms of participation: public meetings and citizen advisory committees.

Public meetings

For years practitioners have been advised to reduce the use of public meetings (e.g., English et al., 1993). The two most prominent normative theories of public participation suggest that public meetings are not particularly useful because they do not promote competence and fairness (Renn et al., 1995) or promote face-to-face discussions over time (Fiorino, 1990). Agency staffers can be equally derogatory about public meetings, as exemplified by one agency staffer who defined his goal for an upcoming public meeting as "to survive" (Chess et al, 1989).

Public meetings have also been disparaged for other reasons, including the lack of representativeness of opinions or the demographics of those at meetings (e.g., English, 1993). However, some empirical research undercuts this generally-accepted public participation truism. For example, opinions based on responses to randomized surveys and comments at

public meetings were found to be comparable (O'Riordan, 1976; Gundry and Heberlein, 1984). Analysis of meeting transcripts about transportation plans found considerable diversity in reasons for and intensity of concern, suggesting that merely counting opponents and proponents oversimplifies the complexity of issues and the nature of representation (Kihl, 1985). Interestingly, surveys of four public participation efforts held by the Corps of Engineers found that people preferred public meetings over workshops and seminars (Mazmanian and Nienabur, 1979).

Another charge levelled at public meetings is that they legitimate agency decisions that have already been made (Fiorino, 1990; Checkoway). However, some studies suggest that participation can have important impacts on plans (e.g. Rosener, 1982; Elder, 1982). Most notably, public meetings have served to block agency decisions due to overwhelming opposition (e.g., Mazmanian and Nienaber, 1979; Gariepy, 1991).

While public meetings have come under increasing attack, citizen advisory councils (CACs) are ascendant. Chemical manufacturers, ranging from small companies to multinational corporations have created hundreds of them over the past 10 years. In addition, the U.S. Departments of Defense and of Energy have both mandated development of site-specific advisory boards to explore remediation of contamination at the agencies' facilities.

Yet CACs have also had their share of critics who argue that advisory committees are often unrepresentative, require large time commitments, and may not have legitimacy in the eyes of other citizens (English et al, 1993). A review of 14 studies of CACs points to examples "where broadly based CACs, with well-defined charges, adequate resources, and neutrally facilitated processes had significant policy impacts" (Lynn and Busenberg, 1995:159). However, the authors caution that the CACs' influence was "highly contingent" on the agencies' intentions. For example, when the agency's goal was merely gaining support for the agency or mollifying critics, CACs were less likely to have an impact. If agencies truly wanted input, then CACs were more effective.

The results of these studies are sufficient to raise questions about how much the planning of public participation should focus on selection of

the "correct" form of public participation. Process or outcome results may be due as much to how an agency uses these forms as the form itself. For example, public meetings take less agency time than CACs that usually meet on a routine basis. Agencies that care little for public input are likely to take the fastest approach - often public meetings - and then, not surprisingly, fail to find the forum useful. In addition, public meetings are characterised as promoting posturing and increasing conflict. However, from the research studies it is unclear whether the timing of public meetings, often after the "decide and announce" phases, is the problem or the form itself is inherently flawed.

Conversely, CACs are seen, in general, as allowing for more interaction, information exchange, and growth of mutual understanding. This may be so, in part, because agencies convened the CACs before decisions were made. In short, forms of public participation are tools; their success may depend as much as how they are used as whether they are the right tool for the job. While no doubt different forms of participation may have different strengths and limitations, these characteristics may not determine either process or outcome success - the history of the issue, level of conflict, scientific data, and existing power dynamics may influence outcome as much as the method" (NRC, 1996).

4. Modification of participatory forms

Instead of characterizing a participatory process as appropriate for some situations and not others, modifying the form may provide agencies with more options. In the case of public meetings, it is possible to hold them earlier in the decision making process or to develop meeting agendas that include presentation or generation of alternative proposals, as requested by participants in one Corps effort (Mazmanian and Nienaber, 1979). Group discussions can serve as a part of, or supplements to, public meetings (e.g. Sinclair, 1977). Some agencies have also experimented with meetings in which agency personnel serve as resources on specific topics at dialogue stations around the room, allowing participants to visit the station that most interests them (Hance and Chess, 1996). Others have used neutral facilitators (e.g., Young et al, 1993) or have co-sponsored meetings with non-government organizations to improve on the meeting process.

New media are also facilitating different approaches to meetings. For example, the Alaskan Department of Transportation created a dynamic public meeting soliciting input via telephone and a consensor, a hand held electronic device hooked to a computer that tallied responses to questions in 3-4 seconds. While the 4,000 participants were not demographically representative of the seven urban areas in which this experiment took place, more than 50% of the 95,000 people who watched the program had observed a public meeting for the first time. (Slaton, 1992). Particularly promising are innovative participatory programs that are designed with multiple participatory forms, such as public meetings and citizen advisory councils, each involving different audiences.

5. Agency action

Some empirical research suggests that agency actions (or inaction) such as delayed requests for stakeholder input, failure to publicize forums, lack of technical support, and lack of commitment are associated with process and outcome limitations. Agencies also contributed to success, according to researchers, by providing technical assistance (e.g., Elder, 1982), providing experienced facilitation (Beltsen, 1995), and committing to the process (e.g., Rosener, 1981; Lynn and Busenberg, 1995), among others.

The question of agency commitment has been a recurring theme in discussions of public participation. For example, practitioners and academics at a national symposium were so concerned about agency resistance that they called for the agencies themselves to be a major topic of research (Chess et al, 1995). In addition, investigations of interactive forms of public relations, in which both the organization and outside stakeholders change in response to each other, has found that the structure and staffing of organizations is associated with its responsiveness (Dozier and Grunig, 1992). Also, study of corporate efforts to involve community stakeholders suggests that organizational factors both facilitated and impeded these efforts. In particular, the organizational strength of the functional links between what an organization says to stakeholders and what it actually does may be particularly important (e.g., Chess, 1997). Evaluators of policy also underscore the importance of exploring institutional variables, "... what is

evaluated is political architecture, architecture that influences outcomes, structures, processes, and constructs..." (Bartlett, 1994).

6. Evaluating public participation

While many articles call for more research on environmental public participation, more attention needs to be paid to how to do so.

Form of evaluation

Most evaluations of public participation are retrospective, which can help agencies consider whether to expand, modify or terminate programs. Retrospective evaluations also provide invaluable contributions to knowledge about public participation. However, such hindsight does not provide agency managers with feedback to make midcourse corrections in their participatory programs.

On the other hand, formative evaluations, which take place during program design (e.g., in the form of needs assessments) or during program development (e.g., routine evaluations of meetings), are aimed at improving efforts in progress. Formative evaluations can be seen as analogous to medical testing that takes place before treatment and periodically after initial treatment and diagnosis. Just as a physician can decide to alter treatment based on test results, formative evaluation provides managers with feedback during program development and implementation (Posavac, 1991).

To improve programs as they evolve, formative evaluation can consider complex issues such as how well agencies (or units in agencies) are co-operating, what kind of data needs to be recorded to track a program, where resources are flowing, and how implementation differs among sites (Chelimsky, 1997), as well as more obvious concerns such as the relationships among stakeholders, perceptions of agency communication, the effectiveness of meetings, etc. Formative evaluations which involve participants in design and/or implementation can also help citizen initiatives stay on track (e.g., through workbooks that help groups determine their goals and if they are meeting them) (Linney and Wandersman, 1996).

Participatory evaluation

Currently, one of the most contentious arguments in the evaluation field is about the extent that program personnel and stakeholders should be involved in evaluation. Evaluators' opinions range from maintaining objectivity through distancing (e.g., minimizing interviewing if it is possible to use extant data) (Scriven, 1997) to empowering stakeholders to design and implement their own evaluations (Fetterman, 1996).

In contrast to the argument for as much separation as possible between evaluator and program personnel, a participatory perspective views an evaluator as an educator, who encourages learning, rather than a referee who determines right from wrong. Participatory evaluation exemplifies this process by involving agency staff and other stakeholders in the design and/or implementation of evaluation. According to advocates of this type of evaluation, this process increases the likelihood that the evaluation will be viewed as credible and useful because the diverse needs of participants are more likely to be fulfilled (e.g. Greene, 1987; Guba and Lincoln, 1989).

DOE's assessment of its Site Specific Advisory Boards is an example of participatory evaluation. A work group of representatives of headquarters' managers, site staff and stakeholders, advised by consultants and academics, developed the evaluation design; outside consultants administered a survey and conducted the data analysis. The rationale for involving these participants included the desire to develop an evaluation design that would yield information helpful to "program implementers and decision makers," ground the evaluation in "mutually understood and agreed upon goals," take into account different participants' ideas of the actions that would lead to achieving these goals, and respond to local needs and processes. (DOE, 1996: 4-5).

Agency practitioners and academic researchers, who gathered at a 1994 symposium about participatory forms of risk communication, focused on ways to encourage agency evaluation (Chess et al, 1995). Discussions of organizational impediments to evaluation took precedence over methodological ones. Both practitioners and researchers expressed concern that the lack of documentation makes it difficult to demonstrate to

managers the usefulness of communication. However, the supporting data are not collected in part, due to limited management support, according to symposium participants. DOE's effort to evaluate its site-specific advisory boards is an innovation other agencies are considering. If they do emulate DOE, public participation may become, over time, a practice supported by research.

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Elements of a Prudent Avoidance Policy

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Introduction

I recall the first time I was asked about Ireland's EMF policy. It was April 1993. The location was Vancouver and the occasion was a workshop organised by Dr Kelly Gibney of BC Hydro. It was my first invitation to an EMF meeting as a participant. Until then I had been another anonymous body in the audience at Contractors Reviews and EPRI conferences. Now, at last, I was rubbing shoulders with the rich and famous, or at least the famous.

The workshop was opened by Dr. Gibney asking us to summarise our corporate or national EMF policies. Now policy statements by governments more often than not become the sticks their opponents use to beat them with. Ireland had no EMF policy then. Indeed, it has no formal EMF policy even now. So in response to Kelly's question I answered:

> *"Ireland's EMF policy is not to allow the EMF-health issue affect the growth and prosperity of the Irish economy".*

Looking back I see that was more of a prayer than a policy. Yet prayer or policy, since 1993 the Irish economy has powered ahead with annual growth rates exceeding 8%. This year the forecast is for over 10% growth. The extra 2% is being attributed to our exports of sildenafil citrate of which Ireland is the world's sole producer. Those of you interested in finding out more about this remarkable chemical must ask their physician for a prescription for Viagra.

Economic growth in Ireland is closely related to energy consumption, and particularly to the consumption of electrical power. We

have been successful, so far, in our handling of the EMF issue as it relates to power lines, to ensure that no new industry nor housing development is ever kept waiting for a power supply. Were these new industries as dependent on mobile phone communications as electrical power the story would be different.

The subject of this paper is 'prudent avoidance' and how this policy is applied in Ireland to the EMF- health issue. In discussing this I shall concentrate on three main areas:

- ELF fields and powerlines - where we have done a lot and have kept problems largely under control.
- RF fields and mobile phone base station towers - where we are doing even more and the problems keep growing.
- Electrical hypersensitivity - where we are not sure what we should be doing, try many different approaches and find few of them work.

ELF Fields & Power Lines

Denver is where it all began. I searched for a suitable religious metaphor to describe the city. Not quite the Bethlehem of EMF, but undoubtedly a birthplace. Not quite the Mecca of EMF, but certainly a place to which we keep returning. The best I could come up with was EMF's Garden of Eden - where all the trouble started. Nineteen years later and one month ago I was in woodland near Cork tracking down a band of eco-warriors who are trying to stop the construction of a new 220 kV transmission line. Ten years ago my own involvement in EMF began when residents south of Dublin objected to a similar high voltage power line being built in their area.

So what has changed you might ask? One major significant change is the basis for the objections. Ten years ago it was EMF and health and childhood leukaemia. Today it is aesthetics. EMF appears to be taking a back seat. Cork has a magnificent deep - water harbour and is home to Ireland's greatest concentration of industry. Power is supplied to this

industry by overhead power lines. Industrial expansion - including a $½ billion expansion to the Pfizer plant, to make more of you know what - means more power lines and more pylons. Some among the local population are saying enough is enough.

Essentially the public are displaying an attitude with which we are all familiar. People are happy to enjoy the benefits of science - in this case, electricity; they just don't want the technology that produces these benefits. A particular difficulty faced by those in Ireland who object to a development on aesthetic grounds is that under Irish law no one has a right to a view. Although the Cork transmission line has passed all legal obstacles, the electrical utility may have to serve injunctions to remove trespassers from the right of way before construction can proceed.

The evolution of our approach to handling power line problems was discussed at the WHO meeting in Vienna, (McManus, 1997). This paper is confined to discussing what we do today.

New power lines

As far as is practical the centreline of a new high voltage (220 kV+) power line will be no closer than 50 metres to a farm, factory or residential building. In any event the line will not come closer than 23 metres (25 yards in Imperial measure). Double circuit lines are now always asymmetrically phased to minimise magnetic field levels.

The electricity company submits its application for permission to build the new line to each of the counties (the planning authorities) through which the line passes. The county councils will seek a report from the Dept. of Public Enterprise which will review all recent developments relevant to the power lines EMF - health issue. That review will encompass the results of the latest epidemiological and animal exposure studies, the current views and opinions of overseas national and international health advisory groups, the prevailing exposure standards and guidelines issued by ICNIRP and various national agencies, and the actions and decisions being taken by governments in other countries relating to similar developments.

The Department of Public Enterprise endeavours to hold the high middle ground on EMF by providing to all parties who seek it, including objectors, information that is balanced, fair, accurate and up-to-date.

New housing

In recent years Ireland has been building nearly 40,000 new houses a year. This is a substantial number for a country with a population of only 3½ million. Many of these new homes are encroaching on existing overhead transmission lines and a good proportion of the prospective owners in such cases will contact the Dept. of Public Enterprise. Their concern is invariably a worry over exposure to electromagnetic fields from the adjacent power line. We will receive an average of twenty such calls a month.

Our response to these enquiries has three main elements:

- First, we will spend up to 30 minutes on the phone discussing the caller's concerns and answering their questions.

- Secondly, we will send them that day a standard letter which is updated regularly and which summarises the Department's position concerning powerline fields. With this letter we will also enclose a wide selection of recent papers, statements and reports from around the world.

- Thirdly, we will organise a survey for the caller. This survey will involve measuring electromagnetic fields at the new home, between the new home and the power line, and - this is very important - in the caller's present home. The surveys are undertaken usually within a few days of the call and even by the following day, if a decision on purchasing a new property cannot be delayed. The surveys are carried out by consultants to the electrical utility and at no cost to the caller or to the Department. The caller or a representative is encouraged to accompany the surveyors on their rounds.

In over 95% of cases we find the callers well satisfied with our response. Indeed the openness with which we provide information and the speed with which we can carry out surveys goes a long way to reassuring the caller even before the survey has taken place.

We always make the point in our standard letter that domestic exposures to ELF are invariably well within the ICNIRP guidelines. However the main reassurance, I believe, comes from the individuals being able to compare the fields in their old home, which is associated with comfort, safety and normality, with fields in the new home. These fields are usually quite similar. Often the field strength between the house and the power line will pass through a minimum value. This provides further reassurance. There have been only a handful of cases where a caller decides not to progress the purchase of a new home on the basis of its proximity to overhead powerlines.

Phone Masts

Mobile phone ownership in Ireland is growing at a rate of 40% a year. Likewise the number of cell sites is growing at a comparable rate. The popularity of the phones is equalled only by the dislike of the base station transmission towers which are springing up everywhere. Opposition to these towers is widespread. The main fear is that the towers will cause cancer among those who live nearby. The risk to children's health is often advanced by objectors to these developments. The Dept. of Public Enterprise can receive as many as a dozen calls in one day from concerned members of the public over the risks posed by the fields from the phone towers. It is however rare to have anyone express concern about the phones themselves which expose their users to fields 1000 times stronger.

Because of the inadequacy of the public telephone system outside the major cities there are powerful social, economic, and security reasons for having a first class mobile phone service. The government has licensed two carriers to provide a service on the 900 MHz band and a third carrier is in the process of being awarded a licence for an 1800 MHz service. However, the development of these services is being frustrated by public opposition, orchestrated by environmental activists. These groups apply pressure on elected representatives and senior officials at county level to have the

planning applications for towers refused. Needless to say it is in those parts of Ireland most in need of a mobile telephone service that the problems are greatest and the development of the service most delayed. We have launched a number of initiatives with the objective of assisting the planning authorities and informing the public.

In July 1996 our Department of the Environment with the co-operation of the Departments of Health and Public Enterprise produced guidelines concerning the siting of phone towers (Environment, 1996). Among the recommendations was one that new towers should be located in residential areas only as a last resort or where there were strong technical reasons which ruled out an alternative site. Today, however, it is common for a county council to refuse planning permission on the grounds that the proposed development is in a residential area and so contravenes the official guidelines. The county councils who must give a reason for rejecting a planning application have chosen to elevate a guideline to a mandatory requirement and ignore the qualifications associated with the original guideline.

In March 1998 the same three government departments organised an international conference specifically to address the phone mast-health issue (Public Enterprise, 1998). Our list of speakers read like a Who's Who of EMF. Our capacity audience of around 350 comprised all shades of opinion from phone mast objectors groups to the phone companies themselves. It included over 40 elected representatives (politicians) and officials from nearly every planning authority in the country. By the end of the conference it was felt the health issue had been put on the back burner and into a realistic perspective. However it was very clear there was major public antipathy towards the phone companies themselves, who were seen as arrogant, uncommunicative, and eager to exploit every loophole in the planning laws to erect towers with a minimum of public consultation.

In the months that followed the March 1998 conference the Parliamentary Joint Committee on Transport and Public Enterprise - this is analogous to a Congressional Sub-Committee in the US - held two meetings on the mobile phone tower issue. At these meetings the Secretarys General of Public Enterprise, Health, and Environment; the chief executives of the phone companies; the Director of Telecommunications

Regulation, and many other senior officials were all closely questioned. Representatives of a dozen anti-phone tower groups were also given an opportunity to put their concerns to the Joint Committee. The Committee's report is in preparation (Joint Committee, 1998), but I believe it will make recommendations concerning the strengthening of our Siting Guidelines document and encourage greater sharing of towers by the phone companies for their antennae. It is also likely they will call for improvements in the monitoring of field strength levels around base station towers.

In June 1998 the Telecommunications Regulator published the results of the first nation-wide survey of radiofrequency emissions (ODTR, 1998). The survey involved visiting a sample of 30 broadcasting antennae. The sample included mobile phone transmitters, radio transmitters, television transmitters and microwave communication transmitters. At each site a search was made for the location at ground level where the public had access and where signals were strongest. Signal strengths were then measured and the measurements compared to the ICNIRP guidelines. Apart from two medium wave radio transmitters which were inadequately fenced all measurements fell within the ICNIRP guidelines by orders of magnitude.

However despite all of these efforts many Irish planning authorities, bowing to public protest, continue to refuse planning consent to new phone towers. It could be asked where are we going wrong?

In our handling of phone mast enquiries to the Department of Public Enterprise our approach is similar in some respects to that described for new houses near pylons. We discuss the problem, answer the questions, send out a standard letter that reflects the Department's current view, and include a selection of recent literature and publications on the subject. However there is one thing we are unable to do. We cannot offer a monitoring service as a matter of routine as we are able to do with powerlines. If we wish to carry out a survey we must engage consultants and pay for them ourselves at a cost of approx. $1500/survey. Our limited budget restricts us to no more than three or four such surveys per year. The kind of RF survey we commission is different from that undertaken by the Telecommunications Regulator. We will go the caller's home and measure all signals in the frequency range 30 MHz to 1000 MHz. We will extend

the frequency range to 3000 MHz in future surveys when new equipment becomes available.

Typically a survey will identify some 50 or so strong signals. These are ones that can be readily picked up on a good radio or TV set. The signals of course include those broadcast from the analogue and GSM phone towers. We then identify the sources of the main signals and express them in order of strength in units of milliwatts per square metre. We don't use decibels. The survey compares the signal strengths from phone towers to those from VHF radio and UHF television transmitters. From this data it becomes quite clear to the householder that the signals from the phone tower are similar in strength to those coming from their favourite radio and TV stations and often much weaker. We do, of course, relate the measured signals to the ICNIRP guidelines, but it is the comparison among the actual signals themselves that provides the greater reassurance to the householder.

The Department has held discussions with the phone companies with a view to setting up this kind of monitoring as a routine service but have so far failed to convince them of its merit.

Electro-sensitive Individuals

There are not many electro-sensitive people in Ireland, but they are quite vocal and have their own pressure group. Generally the symptoms they experience include unexplained rashes and skin troubles. Many also suffer chronic fatigue syndrome. They are certainly not inventing their problems. They are genuinely suffering. They have usually exhausted the resources and patience of conventional medicine and have then sought help from alternative medicine. When the solutions proffered by alternative medicine have also failed, their problems must therefore be due to the only thing left to blame - electromagnetic fields - which is where the Dept. of Public Enterprise comes in.

We listen sympathetically. We remind callers that despite the huge advances in medicine the medical profession can still only diagnose about half the illnesses presented to them. Fortunately most of us get better on our own. A few unfortunate people never get better. This nostrum does

not always help. People demand good health as a right. One lady I spoke to stated, and I quote:

> *"It is the governments' responsibility to find out what's making me ill and to stop it."*

The remit of the Department of Public Enterprise covers gas, electricity, oil, solid fuel, renewable energy, public transport, telecommunications, and ionizing radiation. We will send teams round to check for gas leaks, carbon monoxide, electricity faults, radon concentrations, and EMF levels at both ELF and radio frequencies. Usually everything is perfectly normal. We will check the water for lead if we are in an older part of town. We will direct the electro-sensitive to a self-help group started in Sweden. Should we be told there is a cluster of similar illness in the neighbourhood and this can be substantiated we will contact the local Health Authority who will send public health specialists to talk to the people concerned.

Why do we get involved? Why do we bother? It's not entirely altruism. The electro-sensitive are well organised and have good political contacts. In many respects Ireland is still like a large village. Parliamentary time can be taken up by an elected member enquiring of a Minister why Mrs. Murphy didn't get her pension last week. Parliamentary questions generate action. Likewise do letters to Ministers, especially letters from opposition members writing on behalf of individuals who claim electromagnetic fields are damaging their health and accusing the government of doing nothing about it. We at least enable our Minister to respond that she has or is taking action.

So far we have failed to identify any abnormal electromagnetic field strengths in the environment of the electro-sensitive. Sometimes we might even be thanked for at least listening and doing something. But most remain totally convinced of the cause of their problem and it is not uncommon for them to be invited to promote their views on radio talk shows. We have had a few successes. Once we 'cured' someone who was electro-sensitive. This was when we had a gas leak repaired, had proper ventilation installed - at the state's expense, and persuaded a volunteer group to give the house its first real clean in ten years.

Prudent Avoidance

Now it is time to say something about prudent avoidance.

The merits and demerits of prudent avoidance have raged since Granger Morgan (1988) first proposed the policy ten years ago. Prudent avoidance essentially involves accepting the principle that while there is no firm evidence to conclude electromagnetic fields present a health risk under normal circumstances, one should reduce one's exposure to these fields if this can be done with a minimum of effort and expense. Prudent avoidance in the home, for example, can involve moving an electric clock to the far side of a bedroom. To some, prudent avoidance is akin to walking around a ladder rather than under it. It is superstition not science.

There is also an important ethical question associated with prudent avoidance. Resources are finite and in allocating limited resources to public health, governments must always consider the greater good for society. It could be argued that it is hardly ethical to commit resources to avoid a theoretical health effect when governments lack the funds to tackle real actual health problems.

On the other hand governments are continually faced with decisions they have to make and actions they have to take in the absence of all the facts and before science has provided a definitive answer. In such cases the policy adopted will often be "The policy of least regret". The policy of least regret can be expressed as the choice of two alternatives:

1. What is the possible penalty if we do nothing and the worst happens?

2. How much money will be wasted if we take some action and the problem never arises?

It's the same question most of us face each year when our home insurance policy comes up for renewal. Prudent avoidance sits well with the policy of least regret. One country that has adopted the policy of prudent avoidance and supports it with an excellent rationale is Australia.

The Gibbs (1991) report from New South Wales in 1991 stated:

"It has not been established that electric fields or magnetic fields of power frequency are harmful to human health, but since there is some evidence they may do harm, a policy of prudent avoidance is recommended."

Two years later the Peach Panel report to the Victorian government (Peach, 1993) added its endorsement of prudent avoidance which it saw as a means of:

"... looking systematically for strategies which can restrict field exposure and adopting these strategies which seem to be prudent investments, given their costs and the level of scientific understanding about possible risks."

In reaching this conclusion the Panel recognized:

"... that a policy of prudent avoidance is not a health-based policy, and that the implementation of the policy cannot be seen as necessarily being of benefit to public health, and to any individual."

.....which is a polite way of saying it might all be a waste of time and money.

In December 1995 an Australian Senate Committee (Australia, 1995) again endorsed current Australian policy concerning prudent avoidance:

"The Committee agrees that, as a minimum policy, or until evidence suggests otherwise, the concept of 'prudent avoidance' should continue to be practised by government and power authorities [and] in the case of [the powerline project] prudent avoidance should mean siting the line as far as possible from houses, outbuildings and other farm facilities."

In Ireland new electric powerlines are routed in accordance with similar principles. Double-circuit lines are asymmetrically phased to

minimise magnetic field strengths. The electrical utility and the Dept. of Public Enterprise also provide public information on minimizing personal exposure to electromagnetic fields.

In the case of mobile telephone communications, public exposure to the radio frequency field is an essential element of the technology. There are no appropriate or relevant prudent avoidance measures available to the public even if they were considered necessary or prudent. The popularity of the mobile phone is increasing the number of new cells required. More cells in operation leads directly to a reduction in signal strengths from both the base station transmitter and from the mobile phone. When eventually everyone has a mobile phone, public exposure to the associated radiofrequency fields will be at a minimum.

The Future

Handling the EMF-health issue in Ireland is likely to become more difficult in the future. Three factors influencing this are:

- Affluence
- Litigation
- The forthcoming NIEHS report.

Affluence

Ireland is now an affluent country with a standard of living now above the European average. And affluence creates hypochondria. Affluent people feel entitled to good health as a right. Any threat to good health, however obscure, remote or unlikely, will generate loud demands that the authorities do something about it. *"Convince us that this technology will do no harm!"* say the activists. *"You can't prove a negative."* answer the health professionals. I now see this familiar exchange being employed in reverse. If one accepts that you can't prove a negative then logically *anything might be true*. There is therefore scope

for quite outrageous and extreme claims to further strike fear among the public.

So why should people in Ireland and in the west generally who are among the healthiest and longest-lived in history be so concerned about their health? At a Harvard Club Conference (Harvard, 1991) on this topic the panic was attributed to:

- those promoting the concerns who are moved by self-interest rather than facts,
- the presentation of problems by a media that is less interested in science than in sensationalist sound bites for the public,
- the real difficulties of dealing with the concept of risk.

Another factor is that we now live in an age where many feel that the secret of everlasting life on earth is just around the corner or at least the prospects of a greatly improved and vigorous life-expectancy. In these circumstances one shouldn't be surprised to find the public anxious to avoid any exposure that might prevent them being around when the anti-ageing pill comes on the market.

For those in the front line, dealing with the public on EMF issues will not become easier. I recently came across a reference to the opening of the first international air service from London to Paris in 1920. One of the main fears of the public at the time was the risk to life of standing up on open-topped buses. One can only wonder if, in 70 years time, some present concerns over electromagnetic fields will seem just as bizarre.

Litigation

A feature of civil actions under US Law is that the loser does not have to pay the winner's costs. This, and the fact that the US system allows the plaintiff's lawyers to work on a contingency fee basis, provides lawyers with strong incentives to engage in speculative litigation.

In the United States it proves cheaper for a company like Dow-Corning to settle claims than defend itself, even though in the case in question - breast implants - there is no evidence that the incidence of ill-health among women with breast implants is greater than in the wider population. There is a danger that something similar could happen with mobile phone users or with people living near power lines.

A single lost or undefended EMF case in the United States would be exploited by anti-EMF groups in Ireland to seek enhanced exposure restrictions and to prevent the growth of the electricity and telecommunications industries.

Ireland's and possibly Europe's first case where an injunction was sought against the construction of a base station transmitter on the grounds of a serious and immediate hazard to health was heard in Dublin's High Court earlier this year. The request for the injunction was brought by under-age children, represented by their parents. Such an approach is aimed at generating public sympathy and discouraging the defendants from seeking costs should the action fail. Although the plaintiffs were supported by a huge weight of evidence (I speak in gravimetric terms) submitted by their technical experts, the judge (High Court, 1988) refused the request, saying:

> *"On the evidence before me, I have come to the conclusion that it is highly improbable at the very least that any injury will ensue to the children between now and the hearing of the action and I think that that is as far as I should go in terms of comment on the facts. In those circumstances, I do think that it would be just as far as the Defendant is concerned, as not only would it be prevented from going ahead with the Easkey project but in reality the injunction would have very considerable repercussive affects likely to damage the Defendant's highly competitive business throughout the country.*
>
> *For the reasons which I have indicated early on in this judgement, I am very reluctant to adopt the traditional language of "serious issue to be tried, balance of convenience*

and damages as an adequate remedy" and I believe that this is a case in which those categories are neither appropriate nor helpful. But in case I am wrong about that, I would still have to come down in favour of refusing an injunction. Having regard to the stringent requirement of probability before a quia timet injunction would be granted on a permanent basis, I am very doubtful that there is a serious issue to be tried here, but even if there is, I have no doubt that for the reasons I have indicated, the balance of convenience requires that I should refuse any temporary injunction pending the hearing of the case.

I therefore refuse the interlocutory relief sought."

A full hearing of this case is expected to take place next year. It is my belief that this will be the first of many such cases, especially if anti-EMF groups can win an action in the United States.

NIEHS report

Should the final NEIHS report to Congress declare powerline frequency fields to be a possible human carcinogen this conclusion can be expected to receive major media coverage in Ireland. In one respect NIEHS would simply be restating the position as it was prior to the RAPID Program, for had there been no possibility of EMF being a human carcinogen there would have been no need for RAPID or any other of the major research projects underway around the world. So what has changed?

My personal view is, that should NIEHS endorse the statement in its draft report (NIEHS, 1998), authorities may well conclude: "If we can't get a definitive answer to this question after spending $46 million on RAPID then we're never going to get a definitive answer. And we're certainly not going to put another $46 million into finding out!" Authorities will then be in their familiar position of making a decision on the basis of incomplete and uncertain information. My forecast is that they will lean towards recommending a policy of "prudent avoidance" and may set up committees to identify specific actions and requirements. Other countries would then consider whether to follow the US lead. I would also predict that EMF

lawyers would endeavour to show that their clients' illnesses were due to being exposed to fields from installations that did not meet these specific requirements.

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The application of prudent avoidance in EMF risk management

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Abstract

More than twenty years of international scientific research has not yet resolved the issue of whether or not exposure to power frequency (50/60 Hz) electric and magnetic fields causes adverse health effects such as cancer.

Scientific research is continuing, but it may be some time before the issue is resolved. In the meantime, governments, regulatory bodies and the electricity supply business must manage both the issue itself as well as the public perception of it.

In Australia, the electricity supply business has a long-standing policy of acting *prudently* in relation to the issue. Acting *prudently* includes practising *prudent avoidance* when building new transmission and distribution facilities. This policy position has been endorsed by Federal and State Governments and is an integral part of managing the issue.

This paper outlines the background to the adoption of the policy of *prudence* in Australia and gives practical guidance as to the way in which *prudent avoidance* may be applied by electricity supply organisations when designing and building new transmission and distribution systems. The paper argues that *prudent avoidance* should be an essential part of EMF risk management.

1. Introduction To EMF Health Issue

We are all aware of concerns amongst members of the general public regarding the possibility of adverse health effects such as cancer from exposure to power frequency electric and magnetic fields (EMFs). In recent years, scientific research has focussed on magnetic fields rather than electric fields, and the remainder of this paper reflects that focus.

Scientific discussion regarding the issue dates back to the late 1960's with the introduction of ultra high voltage transmission systems. Concerns were raised that the high electric fields associated with the operations of such systems might have health implications for electricity utility workers. In 1972, general health effects such as headache and fatigue were reported in switchyard workers exposed to high electric fields in the former Soviet Union. Subsequent studies attributed these symptoms to aspects of the work environment other than EMFs.

Public concern was heightened by an American study in 1979 which suggested a link between exposure to estimated magnetic fields from street distribution lines and transformers and childhood cancer. This was a turning point in the issue as it was the beginning of the transition from electric fields to magnetic fields as the source of concern. There has been much research since that time. The scientific literature is both complex and voluminous and covers a wide spectrum of science including epidemiology, in vitro and in vivo laboratory research, and engineering.

All of the research has been extensively reviewed by Australian and international inquiries and expert panels established for the purpose of trying to determine whether or not human exposure to EMFs is related to adverse health effects. There is scientific consensus that health effects have not been established, but that the possibility cannot be ruled out. Many scientists agree that there is a need for ongoing high quality scientific research in order to try and give better answers to the questions which have been raised.

2. The Gibbs Report

On 28 May 1990 the Minister for Minerals and Energy for the State of New South Wales ("the Minister") authorised former Chief Justice of Australia The Right Honourable Sir Harry Gibbs G.C.M.G., A.C., K.B.E. to conduct an inquiry into community needs and high voltage transmission line development in the State of New South Wales. On 3 July 1990 the Minister wrote to Sir Harry Gibbs a letter which included the following paragraph:

"Without in any way limiting or restricting the nature of the terms of reference of your Inquiry, I would like to request that you specifically include in your investigations the question of electromagnetic fields and their relationship to health." [1.1.4]

The Gibbs Report was delivered to the New South Wales Minister for Minerals and Energy in February 1991. In making findings relating to the state of science regarding the health issue, former Australian Chief Justice Sir Harry Gibbs was assisted by four Australian scientists. The Report concluded:

- *"It has not been scientifically established that electric fields or magnetic fields created by the electric power system in New South Wales (or by any electric fields or magnetic fields of extremely low frequency) initiate or promote cancer or have any other harmful effect on humans. However, it has not been scientifically established that such fields are not harmful".*[5.11.1]

- *"It would serve no useful purpose to review all of the numerous studies done "in vitro" or "in vivo" with a view to attempting to discover the effect of (the fields) on biology or health. It is quite apparent that the studies do no more than show that the fields can cause biological changes; they certainly do not enable it to be concluded that the fields are harmful to health."* [5.4.14]

- *"The epidemiological studies into the effects, if any, of electromagnetic fields at extremely low frequencies support the view*

that it is possible that exposure to those electromagnetic fields causes an increased risk of developing cancer in childhood and an increased risk in adults of developing leukaemia, lymphoma and brain tumours. The view that this is possible is particularly supported in the case of children by the residential studies and in the case of adults by both the residential and occupational studies. However, the findings are by no means conclusive and it cannot be said categorically either that it is probable that there is a risk, or that there is no risk." [5.5.6]

- *"If any risk is created by exposure to extremely low frequency electric fields or magnetic fields, there is no reason to suppose that it is created entirely, or even mainly, by exposure to the fields created by high voltage transmission lines. Electric fields and magnetic fields are produced also by distribution lines, by wiring in homes, shops, offices and schools, by return currents in underground gas pipes and water pipes and in the ground itself, and by the many appliances used in the home, at work, and in hospitals."* [5.11.3]

- *"The fact that evidence on the question whether exposure creates a risk to health is so inconclusive suggests that if a risk exists it is a comparatively small one....."* [5.11.5]

More research has been published since the Gibbs Report, and many reviews by other independent and authoritative panels have been undertaken. It is suggested that no more definite conclusions have been able to be drawn from this expanded body of literature, and that the various findings and conclusions reached in the Gibbs Report in 1991 are as relevant today as they were at the time they were published, and provide a sound basis for public policy decision making.

3. Emf Policy Issues

3.1 Background

Any policy or regulatory actions proposed regarding EMFs should be based on the totality of the science and not on the results of a single

research project or the opinion of any single scientist irrespective of his or her standing. The considered conclusions of independent authoritative reviews of the body of science by groups of expert scientists or official inquiries or panels established for the purpose are an essential guide for health authorities and other decision makers when dealing with the issue.

The uncertain state of the science regarding EMFs has presented significant challenges for decision-makers. As a Texas PUC Review put it:

> ***"Policy Issues and Options***
>
> *The current status of scientific evidence regarding EMF health effects is unclear. There is no definitive indication that EMF exposure can affect health, and there are no data that establish convincingly that it does not. In fact, as is often the case in situations involving very low probability cause/effect relationships, it may not ever be possible to prove an effect or the lack of an effect.*
>
> *With respect to the EMF health effects issue, state legislatures find themselves in a quandary. Acceptance of false positive conclusions may result in a significant expenditure of taxpayers' money and divert attention from efforts to seek the true source of any increased risk. By contrast, not acting on false negative conclusions is likely to be interpreted by the public as irresponsible disregard for citizens' safety. Therefore, it seems reasonable to expect legislatures to actively support efforts to resolve the conflict.*
>
> *Regulatory agencies normally address scientific uncertainty, such as the EMF health effects question, through procedural mechanisms similar to those used in the courts and legislatures. The details of the mechanisms vary considerably depending on the nature of the regulatory agency and its legislative charter. Political pressures to "do something" about the EMF issue may result directly or indirectly in the search for regulatory relief, especially if no action is achieved at the judicial or legislative levels.*

In at least 17 states, legislative or administrative agencies have formally considered the possibility of health effects as a result of EMF exposure. Responses range from dismissal of the question due to lack of evidence (Wyoming) to codification of formal EMF limits in transmission lines (Florida). Courts and legislatures are actively considering actions in several states.

Different responses and their rationales are tied to different views of what constitutes the key problem in the EMF debate. There have been at least four different ways to define the EMF "problem", each with distinctive views of the scientific evidence, of the proper role for science to play, and of the proper perception of risk. More importantly, each definition carries a policy prescription along with it. In the absence of a conclusive body of scientific findings that would provide a firm grounding for deciding which of the four ways of constructing the problem is the most appropriate, one is left to decide largely on the basis of pre-existing beliefs and values that each of us brings to the EMF issue.

In this instance, the values of experts alone may provide too narrow a basis for legitimating one definition of the problem over others. Recognizing this limitation, the Committee recommends that, until science can provide a clearer path, state officials should engage the public in open discussions of both the evidence to date and the public values that influence its interpretation."

Professor Granger Morgan of Carnegie Mellon University in the United States has written widely on the issue of public policy in the context of EMFs. As he wrote in an essay for a book (**Carpenter & Ayrapetyan, 1994**) on the issue:

"In the face of possible risk and incomplete evidence many (including myself) believe that the wise strategy is to exercise prudence. Search for low-cost steps that could get people out of fields, especially new fields, and then adopt them. At the

same time, do not go off the deep end. On a per capita basis, do not spend large amounts of money or incur great inconvenience until the evidence is clearer than it now is.

In our private lives when we face a possible but uncertain risk, we exercise such prudence all the time. For example, many of us eat a bit more fibre, broccoli, and cauliflower and a bit less fat and charbroiled meat than we once did. We know that these dietary changes offer no assurance of protection from cancer, but there is some evidence that they might help. The changes do not cost much. You can get used to them. So, it seems prudent to make some adjustments. In public life we have rather greater difficulty exercising prudence. Our regulatory and legal systems want to classify everything unambiguously as either safe or hazardous. Indeed, a U.S. Federal Appeals Court judge once told me, "no matter how incomplete the scientific evidence, present me with the case and I will decide".

Creating certainty by fiat in the face of serious scientific uncertainty is not a wise way to organize a society. Understanding this, a variety of groups and individuals have begun to develop strategies for exercising prudence on the subject of power-frequency fields."

The Gibbs Report dealt with these policy aspects of the EMF health issue as follows:

- *"It then becomes a question of policy what action should be taken to avert a possible risk to public health when it cannot be said either that it is probable that the risk exists or in what circumstances a risk, if one exists, arises. A suggestion has been made in the United States that a policy of prudent avoidance should be adopted."* [5.11.6]

- *"It would not be prudent, but foolish, to make radical or expensive changes to existing lines until further scientific studies have resolved the doubts. On the other hand, when new lines are being*

constructed, it may be prudent to do whatever can be done without undue inconvenience and at modest expense to avert the possible risk, remembering that if that is not done and future research establishes the existence of a real risk to health, serious problems may arise which can be remedied only at great cost." [5.11.9]

The policy recommendation contained in the Gibbs Report formed the basis of the policy subsequently adopted by the Australian electricity supply industry.

3.2 Adoption of policy *prudence* by ESAA

At a meeting in Sydney on 19 July 1991, the Board of Directors of ESAA adopted a formal policy in relation to electric and magnetic fields. The ESAA policy on EMF was adopted in the light of authoritative reviews having concluded that no adverse health effects from exposure to EMF had been established, but recognizing that there was, within the Australian community, some genuine public concern about the issue which had to be addressed by the industry. This policy is reviewed at each meeting of an EMF Policy Committee which normally meets at six monthly intervals.

The policy recommends to ESAA members, including distribution members, that they operate their electrical power systems ***prudently*** within Australian health guidelines, and closely monitor, and, where appropriate, sponsor high quality scientific research. The policy is attached to this paper as Appendix 1.

ESAA committed itself to ongoing public and workforce education on the issue. This has included the sharing of information and the undertaking of measurements by ESAA members where requested. The industry also became involved in supporting Australian EMF research. In November 1993, ESAA commissioned a $1 million laboratory study examining the role, if any, played by exposure to magnetic fields in the cancer process in mice. The results of this study were published in March 1998. The study results were negative. ESAA has also supported other EMF research.

In an accompanying Advice to its members, the ESAA Board clarified what it meant by acting *prudently* in this context. The document was amended by the Board in June 1992, November 1994 and again in March 1997. In ESAA's view, acting *prudently* means embracing a range of sensible actions having regard to the uncertain state of the science, and which take into account scientific research and community concerns. These actions are set out in the document, and include informing employees and the public about the issue, and practising *prudent avoidance* (as defined in the Gibbs Report) when designing and building new transmission and distribution facilities. Such actions can include considering the design of the new facilities with respect to the EMFs which may be produced, sharing information on EMFs with the community, and taking community views into account when siting new facilities.

In its formal parliamentary response to the December 1995 Senate Eastlink Report the Australian Federal Government endorsed a policy of *prudent avoidance* for the building of new transmission lines in Australia. In a document tabled in the Parliament in October 1996 the Federal Government expressed its support for ESAA's policy of *prudence* including the practice of *prudent avoidance*.

The Federal Government noted that, had the Eastlink project proceeded - it was cancelled in 1996 following a change of government - *prudent avoidance* would have been included as part of the normal operational procedures of the two transmission authorities Powerlink and TransGrid. This would have involved the transmission line being constructed well away from houses, schools and similar structures.

In its response the Federal Government noted that "*the potential health impacts of electric and magnetic fields (EMFs) have caused considerable concern within the communities potentially affected by the Eastlink proposal. This could reflect the situation that even with major continuing scientific research programs at the global level, a clear link between EMFs and health problems has been neither established nor disproved.*"

The Federal Government also acknowledged "*that the appropriateness of prudent avoidance as a national public health policy*

needs to be assessed on the basis of the understanding of potential health effects at any given time."

4. Prudent Avoidance Principles

In Australia there is broad consensus that a *prudent* approach should be taken in the design and siting of new transmission facilities. Although there is no precise definition of *prudent avoidance*, there is considerable discussion in the literature which provides guidance as to how it might be applied in practice. In particular, Sir Harry Gibbs described *prudent avoidance* as:

> "....doing whatever can be done at modest cost and without undue inconvenience to avoid the possible risk (to health)....."

This raises the question as to what might constitute "modest cost". In 1993, the California Public Utilities Commission in the United State of America published an order defining *prudent avoidance* as undertaking suitable activities up to 4% of the cost of a new electricity company installation project. In a guidance document produced subsequently by Southern California Edison Company, the recommended approach was to:

> "Implement reasonable no cost and low cost steps to build new electric utility lines and substations in ways that reduce magnetic fields."

The application of *prudent avoidance* in the design and construction of new electrical facilities is a process of assessing the extent to which people may be exposed to fields produced by them and considering what "low cost" and "no cost" measures might be taken to reduce such exposure within acceptable constraints. Other than in California we are not aware of any regulatory order or direction dealing with the quantum of cost.

In broad terms, the range of measures which may be available to reduce exposure to the magnetic fields generated by electricity supply business facilities come under two broad generic headings:

1. siting measures

2. design measures.

4.1 Siting Measures

The process of site selection of electricity supply business facilities is a complex one involving a multitude of considerations of which the possible adverse health effects of exposure to EMFs is but one. Other considerations include:

- the location of the power source and the load
- provision for future development
- the location of existing rights of way
- cost considerations
- the nature of terrain and other siting constraints such as dams
- residential areas
- airfields
- national parks
- sites of particular cultural or heritage value
- transport corridors and the like.

In the context of the siting of electricity supply business facilities, the issue of EMFs is rarely an overriding consideration but rather should be considered as one of several important factors.

Furthermore, because many of the factors which influence the siting of electricity supply business infrastructure are, at least to some extent, of a

sociological nature, an essential part of the siting process should be the engagement of the affected community in the process of siting. This requires the community to be informed of the proposed project at an early stage, acquainted with the range of factors which may be relevant to the siting decisions and, genuine input sought. In respect of EMFs, the community involvement process could include measures such as informing the community about the need for the facility and the various site selection constraints, providing educational material (preferably including material from independent sources on the issue of EMFs), providing factual information on the magnitude and extent of fields likely to be associated with the proposed facility, providing information regarding the magnitude and extent of EMFs in the general area and in typical everyday situations, eg. in the home, the street, etc.

The community should be informed at an early stage of the consultation process to be followed and the way in which their views can be fed into it. Community feedback should be factored into project planning, along with the various other factors, and a decision made. Experience in Australia with community consultation programs suggests that dwellings, schools, playgrounds and other locations, especially those frequented by children, are likely to be of most interest from the perspective of EMFs. Where these can be avoided at modest cost and minimum inconvenience it is *prudent* to do so.

4.2 Design Measures

Most of the design measures that will be discussed in the remaining sections of this paper are presented in the EMF mitigation handbook written by G Melik in 1996 under contract to the Electricity Supply Association of Australia Limited.

The following design measures for reducing magnetic fields may be applied to power lines of all voltages:

- Increasing the (vertical) distance of the line from sensitive receptors
- Configuring the conductors to minimise the magnetic field

- Arranging the phases to minimise the magnetic field
- Using more than one conductor per phase (split phase) and arranging them to minimise the magnetic field
- Reducing the current
- Shielding or active cancellation
- Locating the lines underground (in some cases this can increase the ground level magnetic field but the field strength will diminish more rapidly with distance).

The option selected should neither jeopardise the reliability nor downgrade the operating characteristics of the electricity system. Nor should it create a hazard to maintenance personnel or to the public in general.

5. Prudent Avoidance - Transmission

The following sections describe the detailed options for *prudent avoidance* mentioned in principle in Section 4 which may be applied to transmission facilities.

5.1 Transmission Lines

5.1.1 Distance

The most common method of reducing peoples' exposure to EMFs is by selecting line routes (i.e. siting) to avoid population centres or areas where people gather. Particular attention should be paid to schools, child care centres and other areas where children congregate. Increased separation also needs to be considered when new residential development is proposed adjacent to existing transmission lines. Cost is a component of *prudence*, and in considering the feasibility of alternative routes or sacrificing land with significant development potential, regard should be had to the additional cost which may be involved.

Raising the height of supporting structures or towers, and thus the height of the conductors, can also reduce the magnetic field strength below the line and may also decrease the fields away from the line. The cost associated with the increased structure height may limit this technique to selected portions of a line. The approach may be more practical for wood pole lines than for steel tower lines, due to the cost factor. In some cases, raising height can increase the field strength at some distance from the line, and, accordingly it is necessary to treat each case on its merits.

5.1.2 Conductor Configuration

Different arrangements of phasing can produce different magnetic field strengths for the same line current. In general, triangular arrangements tend to provide more field cancellation than horizontal arrangements, with lower resultant field strengths.

5.1.3 Phase Arrangement

For double circuit lines, it is possible to arrange each three phase circuit with a different vertical phase arrangement in space, such that some cancellation of magnetic fields occurs. This is usually a relatively low cost option in the case of an existing line, and often a no cost option for a new line.

Selection of the proper phasing arrangement is usually the most effective way to reduce magnetic fields for two circuits on the same structure or two or more circuits on the same easement for minimal cost, if re-routing is not possible.

5.1.4 Split Phasing

A single circuit line can be constructed as two parallel circuits with a phase arrangement designed to achieve maximum field cancellation. This is known as the split-phase technique and may be considered if only one circuit exists on a route. Although this form of construction is significantly more expensive than conventional single-circuit construction, it could be used for short sections of a line where it is desirable to reduce fields within a cost limitation.

5.1.5 Current Reduction

A reduction in electrical current will generally reduce magnetic field strengths. The reduction in field strength is approximately proportional to the reduction in current. Transmission line currents (and voltages) are usually based on system stability and required load transfer considerations. The only practical way to achieve this option is to move to split phasing for a single circuit line, or a second line in the case of a double circuit line.

5.1.6 Shielding and Cancellation Loops

Shielding is the erection of a barrier between source and subject to reduce the field strength at the subject. Shielding can substantially reduce **electric fields** from transmission lines but has little effect on magnetic fields. Any object between the source (line) and the point of interest will provide shielding or distortion of the electric field. Common examples are buildings, trees or any other structure.

For all practical purposes there are no means to significantly reduce or screen **magnetic fields** from overhead lines. In special applications, screening of individual pieces of equipment is possible using structures or enclosures made from special metals, but these are expensive and limited in application.

5.1.7 Undergrounding

Because undergrounding is usually far more expensive than overhead construction, it does not often fall into the category of *prudent avoidance*, with its "modest cost/minimum inconvenience" criteria. There will be occasions, however, when partial undergrounding may be consistent with *prudent avoidance* on a total cost basis, and therefore this option is considered here.

In underground cables, phase conductors are insulated from earth and from each other by a relatively thin layer of solid insulation as compared to a much larger dimension of air insulation in the case of overhead lines. Accordingly, underground phase conductors can be placed much closer together, providing a more effective field cancellation effect.

On the other hand, underground cables are normally buried one metre or less below ground and can be closer to people than an equivalent overhead line. Nevertheless, due to the cancellation effect, the use of underground cables usually reduces the effective level of the magnetic field at the point of interest. An exception to this might be the situation of cables in a street area where the point of interest is the footpath or roadway immediately above the buried cable where the field strength is still significant.

When considering undergrounding, it should be noted that, contrary to popular belief, earth has no magnetic field shielding property and plays no part in further field reduction.

A three phase underground cable in one sheath will produce a lower magnetic field than the same capacity line constructed from three single-core cables because the conductors are closer together and provide more effective field cancellation than three single-core cables, especially if they are in flat formation.

A very effective method of reducing magnetic fields from cables can be applied to a three phase cable constructed from three single core cables. This method of shielding utilises the principle of longitudinal electromagnetic induction where a longitudinal voltage is induced in a non-energised conductor that is in parallel with the current carrying conductor.

If each insulated phase of a three phase cable is laid inside a conductive conduit such as copper, aluminium or steel pipe and the pipes are electrically bonded together at each end, then each pipe will carry an induced current in the opposite direction to the phase current and hence provide some cancellation of the magnetic field. The effectiveness of this method is heavily influenced by the contact resistance of the bonds.

Practical experience shows that up to a 20 fold reduction of magnetic field can be expected from this measure. When applying this method of shielding it is important to de-rate the cable due to its reduced heat dissipation. This method is usually a high cost alternative due to the cost of encasing the cables in conductive conduit, and also because of the de-rating effect.

5.2 Transmission Substations

The magnetic fields produced by transmission substations result largely from the outgoing and incoming overhead transmission lines, especially where they come together at entries to busbar arrangements. Consequently, most of the *prudent avoidance* options available for transmission substations are those detailed above. Particular opportunities may arise where multiple circuits parallel one another as they converge on their substation. Also, there is sometimes an opportunity in the siting of the substation, or even in the fencing of the substation equipment (often part of the whole site) to keep minimised magnetic field strengths in areas accessible to the public.

5.3 Land Development

Land development adjacent to transmission lines often occurs after the transmission line has been built. In such cases, the application of *prudent avoidance* principles should become the responsibility of the developer. A developer should be expected to spend some money in reducing people's exposure to magnetic fields, although detailed discussion of land development issues is beyond the scope of this paper. It is noted that the prospect of future land subdivision and development may create an argument for utilities adopting wider easements in the first place. In his 1991 Report, Sir Harry Gibbs found no support for such a move, which would alienate additional land and increase costs to the community. Gibbs said:

> ".. it would be particularly undesirable at the present time to prescribe standards or guidelines with regard to exposure to the fields created by transmission lines or the width of easements acquired or used for such lines."

All transmission line easements would be affected while any potential benefit would be restricted to a few isolated developments.

6. Prudent Avoidance - Distribution

6.1 Distribution Lines

6.1.1 Siting

Due to the need to provide electricity supply to customers, the options available to designers in siting distribution infrastructure are limited. Distribution lines by their very nature and function are normally located in road reserves to provide supply to customers on both sides of the road, although some instances, they are located at the rear boundary of residential properties.

Where practicable:

- distribution lines should be located on the opposite side of the road from areas such as:
- schools
- kindergartens
- child-care centres
- distribution lines should be sited away from the walls of multi-storey buildings or areas where children congregate
- distribution lines should be located on the side of the road bordered by open spaces where applicable
- substations should be located at the electrical centre of their low voltage network, i.e. current flows in all directions should be balanced.

6.1.2 Design

Options which may be considered, subject to their economic viability, could include:

- use of aerial bundled conductor (ABC) for low voltage reticulation to provide more effective field cancellation
- use of offset construction to increase horizontal separation from point of interest
- use of underground cable in place of overhead conductors where economically justified
- use of 3 phase cable instead of 3 single phase cables
- balancing of load across all phases to reduce neutral currents
- use of insulated twisted service cable instead of open wire services to provide more effective field cancellation
- for new double circuit lines, adoption of RWB/BWR phasing when current flow in both circuits is in the same direction

When installing electrical facilities which involve both low voltage and high voltage, the following options apply:

- When overbuilding (or underbuilding) existing facilities, the phasing on the existing circuits should be determined and the new circuit or circuits phased to minimise the combined magnetic field strength.
- Where new or reworked subtransmission facilities are being considered on the same structure with distribution circuits, the most effective field reduction measures may be applied to the distribution circuits.

6.2 Distribution Substations

6.2.1 General Principles

Distribution and consumer substations are typically 22,000/415 V or 11,000 /415 V and can generally be classified as:

- free standing open type ground mounted
- free standing enclosed type ground mounted
- underground (pit)
- indoor
- pole mounted

The main sources of magnetic fields from substations are:

- incoming and outgoing lines and cables
- busbars
- switchgear (ie. isolators, switches, circuit breakers, fuses, etc)
- transformers
- earth connections/neutrals where these can form alternative earth paths

Underground metallic pipes and telecommunication cables with metallic screens, or even structural steel can also be significant sources of magnetic fields if they constitute a return path for a portion of the substation earth or neutral currents.

The compact design of gas insulated switchgear (GIS), as compared to open or enclosed air insulated switchgear substations, offers significantly

lower magnetic fields due to a substantial reduction of the phase separation distances. A degree of magnetic shielding is also afforded by the gas filled enclosures. The LV side of the substation has higher associated levels of magnetic field due to the higher currents compared to the HV side.

Metal-clad substations, where mild steel is usually used for fabrication of enclosures, are afforded a modest level of shielding by the enclosure. Also, reinforced concrete slabs, walls and floor panels can provide some magnetic field shielding. It should be noted that unless cables, busbars and the like are fully surrounded, any shielding afforded by metallic enclosures becomes less effective with increased distance from the source. Building materials such as brick, stone, plaster, wallboards and wood have no shielding properties for magnetic fields.

The following basic magnetic field management techniques can be applied in the design of substations:

- increasing the distance from source of magnetic field
- reducing the conductor or busbar spacing
- selecting an appropriate phase configuration
- balancing load between phases to reduce the neutral current

Magnetic field levels in excess of about 12 mG may cause interference to conventional computer monitors and the following recommendations for *prudent avoidance* can also serve to mitigate this effect.

6.2.2 Specific Measures

In designing distribution substations in situations where *prudent avoidance* is required, the following design measures may be considered. Some measures are more appropriate for high rise office situations, and some for outdoor substations near domestic dwellings.

In the case of high rise office buildings:

- locating substations away from normally occupied areas such as offices, lunchrooms, etc;
- planning the substation layout so that the LV side is further away from adjacent offices, computer rooms, etc than the HV side;
- locating transformers, LV busbars, disconnector switches and other potentially large sources of magnetic field within the area of the substation as far away as possible from adjacent offices, etc;
- if the floor above the substation is used as office space, avoiding where possible, direct ceiling mounting of heavy current cables, open type busbars or disconnector switches;
- locating all cable trays as far as possible from the substation ceiling and walls that separate it from adjacent offices, etc;
- avoiding the laying of heavy current cable directly on the floor of the substation if the floor below the substation is used for office space;
- designing busbars to minimise separation between phases and between phases and the neutral bus;
- if practicable, orienting transformers and other sources that have uneven field patterns so that their highest field strength side is turned away from the field sensitive area;
- where possible using three phase cables in preference to three single phase cables;
- using a trefoil arrangement of cables when using three single core cables in a three phase configuration. In such cases, if the neutral conductor is a separate single core cable, placing it, where practicable, in the centre of the trefoil formation of phases;

- selecting the substation equipment considering, among other important electrical parameters, its low magnetic field design, ie 11,000/415 V distribution transformers in steel housings, compact metal-clad busbars;

- avoiding phase by phase grouping of single core cables in parallel circuits;

- distributing all large single phase loads and all constant current load such as lighting and office equipment equally between three phases of the LV supply.

In the case of outdoor substations:

- positioning the secondary side of the transformer so that barriers such as landscaping, fencing or block walls inhibit normal access to that side of the substation;

- locating substations away from normally occupied areas such as bedrooms, offices, playgrounds etc;

7. Miscellaneous

Whilst the primary focus of this paper is on electricity supply business installations, sources within customers' installations can also make a significant contribution to the overall magnetic field. Accordingly, a brief selection of considerations relevant to customer installations are provided in the following sections. Supply conditions may vary from utility to utility and, if inconsistencies are evident, these conditions should take precedence.

7.1 Commercial/Industrial Switchboards

In the case of large commercial/industrial switchboards, the busbars inside the switchboard can have an effect on field levels outside the switchboard. The following *prudent avoidance* measures may be available:

- Keeping the incoming line and associated meter panel and/or busbars away from heavy use areas. This will also help avoid computer interference problems.

- Avoiding the use of separate conductor trays for the energised and neutral wires. If separate trays are necessary, it is best to place them adjacent to low/no use areas.

- Locating switchboards away from high use office areas if possible

- Locating workstations away from switchboards when laying out new or reorganised office areas. A distance of 4 to 5 metres is suggested to provide the additional benefit of avoiding computer VDU interference.

- Use energy efficient lift motors, air conditioning equipment and industrial motors and manufacturing equipment.

7.2 Domestic Meters and Wiring

Generally, the principal source of magnetic fields associated with domestic meter boxes is the wires leading to the meter box. Accordingly, *prudent avoidance* measures associated with meter boxes generally focus on the wiring rather than on the box itself. The following options may be available:

- In general, for new constructions, the layout of meters, switchboard and wiring may be planned in advance, giving consideration to the magnetic fields that they would produce.

- Locating the meter box in an area that is not adjacent to high use areas. Good locations would be at the garage, a closet, storage room or at the back of a wardrobe. Bedroom and living room walls are better avoided to reduce fields in active use areas. Many authorities recommend the placement of meters and switchboard in a back-to-back arrangement, with meters outside and switchboard inside the home for security of home and occupants. This arrangement usually

places the switchboard in low-use areas (for the sake of appearance), and is consistent with *prudent avoidance.*

- Locating the main connecting wiring away from high use areas in cases where meter location and switchboard location are separated by a significant distance, e.g. where meters are installed at the fence and the switchboard is located at (or in) the house. The connecting wiring should be run with phases and neutral grouped together, and in a ceiling space rather than a wall space, for example.

- Using service wires of insulated twisted construction, as they produce significantly weaker fields than open wire (bare conductor) construction.

- Minimizing or avoiding situations where heavy current wiring, especially that of stoves and air-conditioning is placed in wall cavities within the house. This type of wiring is best located and grouped together in the ceiling. Close proximity of the phase wires and neutral helps to cancel the magnetic fields.

- In the case of two-way switches, running the neutral wire along the same path as the twin active wire connecting the two switches to provide a cancelling effect on the magnetic fields.

- Using energy efficient equipment which will use less electricity and save money, as well as reducing the electrical load on the switchboard, thereby reducing magnetic fields. Large white goods such as refrigerators, dishwashers, washing machines and dryers are often sold with energy efficient model alternatives.

7.3 Earth Connections

The Multiple Earthed Neutral (MEN) system is commonly used to connect a utility's neutral at a customer's switchboard. This neutral is earthed at the switchboard, sometimes via a metallic earth stake, and sometimes via a metallic water pipe. Depending on the condition of these earth connections, some fraction, or indeed, the majority of the neutral

current may flow through a path other than via the utility's neutral. If this happens, then an earth connection or water pipe can itself become a substantial source of magnetic field. The supply wiring also becomes a source of significant magnetic field as the magnitudes of the active and neutral currents are not equal.

When considering options for earth connections, it is the responsibility of the owner/electrician to identify and implement appropriate actions as follows:

- If metallic water pipes are a source of magnetic fields, install a plastic joint at the entrance to the building's water system to prevent current from adjacent earths travelling along the pipe. In this case, the installation of a separate earth stake is mandatory for electrical safety considerations.

8. Conclusions

The concept of *prudent avoidance* has been recommended as the most appropriate public policy response to health concerns associated with magnetic fields. Because by its very nature it is not well defined in precise terms, historically it has been difficult to scope. Nevertheless, it is possible to adopt many specific measures which are consistent with the notion of doing what can be done at modest cost and without undue inconvenience to reduce people's exposure to magnetic fields. This paper has sought to discuss the concept of modest costs and to suggest a range of options or measures for transmission and distribution applications. This paper has also touched on a number of options which may be adopted by other stakeholders in this issue such as electricians and home and building owners.

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ADDENDUM

Policy Statement on Electric and Magnetic Fields (EMFs)
(Approved by the ESAA Board on 27 March 1997)

Background:

The Electricity Supply Association of Australia Limited (ESAA) is the national voice for members of the electricity supply business in

Australia. ESAA is committed to taking a leadership role on relevant environmental issues including power frequency electric and magnetic fields (EMFs). ESAA and its members are committed to the health and safety of the community including their own employees.

Adverse health effects from EMFs have not been established, but there remains a lack of scientific consensus about whether or not they can occur. Because of this lack of scientific consensus, the question of whether EMFs can cause adverse health effects such as cancer is important both for the Australian community and the electricity supply business. ESAA recognizes that there is concern within the Australian community about EMFs and is committed to addressing community concerns by the implementation of appropriate policies and practices.

ESAA is committed to a responsible resolution of the issue where government, the community and the electricity supply business have reached public policy consensus consistent with science.

Policy Statement:

1. ESAA recommends to its members that, within Australian health guidelines, they design and operate their electricity generation transmission and distribution systems ***prudently***[1].

2. ESAA will closely monitor engineering and scientific research including reviews by scientific panels, and overseas policy development.

3. ESAA will communicate openly with all stakeholders including assisting its members in conducting community and employee education programs, distributing information material including newsletters brochures booklets videos and the like, liaising with the media and responding to enquiries from members of the public.

4. ESAA will co-operate fully with any bodies established by governments in Australia to investigate and report about power frequency electric and magnetic fields.

The Politics of EMFs - An Activists Viewpoint

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Remarks to Public Viewpoint Panel

What is the public viewpoint on electromagnetic fields? From my perspective as an activist I see it as one of confusion. Confusion by reading about study after study pointing to a link between EMFs and health risks such as cancer and leukaemia and seeing contradictory statements from various agencies saying "there is no definitive proof" of such risks.

Why is the public subjected to this? It is because of the politics of EMFs. The politics of EMFs that sees reports linking EMFs and health suppressed by the White House. The politics of EMFs that sees agencies releasing reports with press releases that downplay or even contradict the findings of health links that are contained in the reports.

The latest piece of confusing information the public has been exposed to is the National Institute of Environmental Health Sciences panel finding that EMFs are a "possible" human carcinogen. What does that say to the public? Nothing! Bombarded with news stories about studies linking all sorts of things, including common foods, to cancer the typical public response is "So what - everything causes cancer these days."

However, if the truth be known, in my humble opinion, that is not the message the panel intended to convey. I believe they would not have examined the massive amount of reports and studies out there, and agonized over them just to say something as innocuous as that. I believe that they really want to convey the message that EMFs are PROBABLY, not possibly, a human carcinogen, but the politics of EMFs prevented them from going that far.

What the public deserves to hear is the truth. Not everyone exposed to EMFs is going to get cancer, indeed most won't. But there is now

overwhelming evidence that those who are exposed have a much greater risk of cancer, leukaemia and other health problems. Indeed the studies indicate that children, in particular, exposed to higher EMF levels, have two to three times the likelihood of getting cancer or leukaemia.

What the public wants to know is - What are we going to do about it? When are we going to do the research necessary to find out how EMFs are linked to health problems so we can find out what we need to do to reduce the risks? And when are we, as a society, going to start taking serious prudent avoidance measures?

We know we cannot eliminate the risk, just as we cannot eliminate the risks associated with driving automobiles, because no more are we going to ban electricity than we are going to ban cars. But we can take measures to reduce it, especially when children are concerned. For example, nobody would allow a 100 km/h highway beside a school. So why do we allow high voltage power lines beside schools?

So what is holding us back? It is the politics of EMFs. The public deserves better than to be subjected to the politics of EMFs.

Rapporteur's Report

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The seminar was opened by Dr. Elizabeth Nielsen of the Radiation Protection Bureau of Health Canada. She mentioned the wide range of interests represented among the participants and thanked each of the nine sponsoring organisations whose generosity had made the conference possible.

The chairman, Dr. Michael Repacholi of WHO, reminded the participants of the purpose of the meeting. As a key part of its International EMF project, WHO planned to publish a monograph on how the concepts of risk perception, risk communication and risk management can be applied to the EMF issue. The output of the two-day scientific programme was to discuss the main aspects of these issues and to contribute to the working group meetings which were to follow the seminar.

The keynote address was given by Dr. John Graham of the Harvard School of Public health. Professor Graham's talk was the kind you once gave up your lunch break for when you were a student. Although the title of his talk was "Making Sense of Risk", it soon became clear that the public and the media had a poor understanding of risk and especially in judging relative risks. The public judge risks by the ease with which it can imagine them while the media are driven by rarity, novelty and drama.

Dr. Graham discussed two kinds of bias. The first is the *optimism* bias where, for example, 80% of us believe we're better than average drivers. Then there is the *outrage* bias where in matters that are beyond our control, like nuclear power and chemical pesticides for example, the policy embraced is one of 'better safe than sorry'. Professor Graham felt that EMF was moving into outrage territory.

The public's lack of intuition for numbers is exposed in how it underestimates the likelihood of accidents that can arise from *disjunctive* events while it overestimates the risks from *conjunctive* events. Disjunctive events are those like car accidents where the risk due to one particular cause, like brake failure, is very small but the number of possible causes of accidents can be measured in thousands and so the overall risk of accident can be significant. Conjunctive events, on the other hand, are those where the accident or event only happens when a sequence of events, where each one of which might carry a measurable risk, all must all occur simultaneously or in a particular order.

Public perception, or should it be misperception of risk is illustrated by the fact that while Americans are healthier and living longer than ever some 75% believe life is riskier today than it was 30 years ago.

Attitudes to risk of a sample of 1019 lay people were compared to those of 264 members of the Institute for Medicine. Using the HCRA Confidence Scale it was found that while 40% of the lay group considered EMF a concern (where the HCRA score was 7 or more) only 15% of the medical group shared this view.

A profile of an EMF believer could be drawn:

- female, egalitarian, with children, living in the north-east United States.

The sceptic's profile was:

- well-off, highly educated, male, who understands actuarial mathematics.

So what can be done to change these misperceptions? Dr Graham recommended :

- Improved risk assessments; existing ones are not always reliable.
- The need to better explain the hazard and the magnitude of the risk .

- The need to rank risks in order of priority.

- That we remind the public that what reduces one risk can create a new one, (e.g. passenger side airbags in motor cars)

His final message was a plea for more scientists and engineers doing risk assessments for government agencies.

Following Professor Graham, Dr. Repacholi reviewed the objectives of the WHO's EMF Project and the framework within which its various outputs were being produced. He discussed the work of the International Advisory Committee which brings together all national authorities involved in the EMF - health issue. He discussed WHO's collaboration with IARC on matters such as electrical hyper-sensitivity and gave a timetable for the production by WHO and IARC of their respective assessments of the health effects of ELF and RF fields.

Dr. Repacholi then reviewed the basis for the ICNIRP guidelines for public and occupational exposure to ELF and RF fields and concluded by discussing the implications of the NIEHS Working Group's report on power - line frequency fields published in July 1998.

Dr. Philip Gray was the first of two speakers from the Federal Research Centre at Juelich in Germany. Dr. Gray discussed the need for analysis and deliberation in improving risk management and risk communication. It was this paper that brought it home to the participants of how simple things used to be when there was only the triumvirate of science, industry and government to consider. Science came up with ideas, industry turned them into money, and government made the rules and collected the taxes. Now people - the public - have got in on the act and must be considered. So with people now involved in most decision-making processes Dr. Gray provided a host of good advice on how this new player should be handled:

- People should have input into risk decisions that affect them.

- Their risk perceptions can enrich expert analysis.

- Their perceptions reflect basic values.

The social dimension in dealing with the public is of prime importance. There is the importance of trust in mediating and interpreting scientific information for the public. The public were now more likely to promote what once might have been thought of as just some simple danger into a real actual risk.

Two risk management frameworks were discussed - *the analytic-deliberative framework* of NRC and the *risk management cycle* produced by the US Congress Committee on Risk Management. The latter framework lays greater emphasis on stakeholder collaboration and the US RAPID Program was seen as a good example of this.

Following Dr. Gray's paper, his colleague at the Federal Research Centre, Dr. Peter Wiedemann, continued the theme in a discussion of how one might deal with EMF risk perceptions. He began by reiterating many of the awkward questions the public ask about EMF and he discussed strategies that might be put in place to answer them. The problem is that while experts evaluate information by scientific methods, lay people use intuition. Dr. Wiedemann noted that the most difficult individuals to deal with are the electro-sensitive. He concluded his paper with a very useful and detailed guide on preparing for a public meeting on the EMF issue. Preparation and planning could not be over-emphasised. Some suggested techniques for handling and diverting 'loaded' questions were particularly well-received.

Mr Gerry Kruk of Gerry Kruk & Associates communications of Calgary was the next speaker. He reminded the audience of the good old bad old days.

In Calgary it was an energy company and the project was a sour gas well development. The company made little progress when at first it tried to browbeat the Energy Resources Conservation Board. Mr. Kruk's talk illustrated that you can't really go too far wrong when you treat the public as human beings living on the same planet. He took us through the various steps taken by the energy company once it had seen the light and changed

its approach. The changing nature of the newspaper headlines as the campaign proceeded made fascinating reading.

Ms. Judy Larkin of Regester Larkin (Consultants), London provided an excellent insight into public attitudes in the UK concerning the health risks of mobile phone use and what the phone companies are doing to counteract this threat to their business. As a result of the many health scares in the UK over such matters as BSE, *e-coli,* HRT, breast implants and Brent Spar, the public's regard for and trust in industry and government was at an all time low. In contrast activist groups were now dominating television coverage of the cellphone health issue. Even in the newspapers activists were getting 50% more coverage than industry spokesmen. Scientists working for environmental groups are now more trusted by the public than either government or industry scientists.

Ms. Larkin's conclusion was that industry must be proactive and more actively involved *as an expert.* Unless this happens there was a danger that the UK government might be forced into some action over cellphones, not in response to scientific findings but to a growing public anxiety. She concluded her talk by quoting Woody Allen: "The world is run by the people who show up".

Professor William Leiss of the School of Policy Studies at Queens University, Kingston, introduced his presentation with the largest number of boxes ever seen on a slide. It turned out to be a guide to the Internet around EMF and particularly the RF sub-category. Professor Leiss' paper came across as a warning to all those in the 'establishment' that the public were out there and that they could get all the information they needed within hours from the Internet. No longer had they to depend on what governments or Health Canada decided to tell them. Armed with this, information activist groups were now able to make life extremely difficult for those wanting to put up new phone towers, or hide old ones inside church steeples in Vancouver.

And as far as public outrage was concerned "We ain't seen nothing yet", was Dr. Leiss' view. Next year local multipoint broadband telecommunications systems are due to start operations in Canada. These loop systems will require even more antennae towers. Dr. Leiss' message

was "Be warned. Stop denying there is a risk. Stop claiming there are no biological effects. Because there are!"

The final paper of the first day was by M. Andre Beauchamp of Enviro-Sage in Montreal. He reviewed the history of Hydro-Quebec's dealings with the Quebec Dept. of Health, the Bureau d'Audience Publique sur l'Environment (BAPE), and the Quebec government over its various power line projects since 1983.

BAPE is an interesting idea for Anglo Saxon regulatory authorities, in that it provides a forum for public debate in advance of a decision by the authorities on a project. It seems however that the public doesn't get too much involved and that scientists from the Department of Health are the main source of critical contributions to BAPE on EMF issues.

It is interesting that following last winters' ice-storm Hydro-Quebec is proposing to build three new supply lines into Montreal and hopes to have construction underway before this coming winter. Because of the critical need for these lines the Quebec government has suspended the need for an environmental impact assessment and is adopting a streamlined approvals procedure. There are critics of this approach. M. Beauchamp sees the attitude to EMF risks in Quebec changing. Where once the risks were considered merely plausible, they are now regarded as uncertain, if not probable.

The second day's session commenced with an excellent paper by Dr. Bill Bailey of Bailey Research Associates. He invoked native American medicine men, Polynesian shamans, and his pet retriever to support the need to put risk communication at the start of any risk assessment process and not leave it as afterthought to be added like credits to the end of a movie.

In listing the qualities that make good risk assessment support good risk communication Dr. Bailey mentioned the importance of thorough documentation and a transparent evaluation of scientific data.

He also scored the INCIRP guidelines and the NIEHS report against his criteria for risk assessment. The probabilistic approach to establishing

the likely risk of a specific adverse health effect has much to commend it and could be looked into by standards setting authorities. There appears to be unnecessarily large margins of safety in the current standards.

Dr. Bailey was followed by Professor Daniel Wartenberg of the Robert Wood Johnson Medical School, New Jersey. He provided what was essentially a one-man seminar on the scientific approach to inferring risk. Weight of evidence, meta analysis and quantitative risk assessment are the three pillars on which this approach is based. It is easy to see why weight of evidence is used in the law courts. Meta-analysis appears to be a minefield. Meta-analysis should be able to survive the removal of any one particular study from the analysis.

He presented his own risk assessment of the NIEHS working group report data. From this Dr. Wartenberg concluded that with a risk ratio of around 1.3 about 6% or 100 to 200 childhood leukaemia cases may be associated with power lines.

Professor Wartenberg was followed by Dr. Chris Portier of NIEHS. Dr. Portier provided the inside story to the background and development of the NIEHS Working Group Report. The various votes of the 30 - person scientific committee and how these squared up against the IARC criteria gave a fascinating insight into the workings of the group.

The conclusion of the working group - that EMF is a possible carcinogen - has already received world-wide publicity. However it is important to note that the working group report is only one of seven separate inputs which Dr Portier must take into consideration when he and his colleagues prepare their final report to Congress. Dr Portier concluded his presentation by arguing that the findings of the National Academy of Science and the NIEHS Working Group are not in such disagreement as would appear at first sight.

The morning session was brought to an interesting close with a talk by Dr. Caron Chess of Rutgers University. She provided a stimulating assessment of the pros and cons of two of the 9 forms of public participation she listed - public meetings and Citizen's Advisory Committees. Many who dislike or fear public meetings find favour in the

Citizen's Advisory Committee idea. The bottom line from Dr. Chess's paper is that: "To be effective, public participation must be public participation based on research and not on accumulated wisdom".

In the final session of the seminar Dr. Tom McManus from Ireland was the penultimate speaker. He outlined how the EMF issue is handled in Ireland. In some areas - powerlines - some progress is being made. In other areas - mobile phone towers and dealing with the electrosensitive - lots of things have been done but the problems are growing, not diminishing.

The final presentation was delivered by Mr. Michael Dolan of the Electricity Supply Association of Australia. Mr. Dolan talked about prudent avoidance - a policy that Australians have warmly embraced. In 1991 the policy was proposed for New South Wales. It was then endorsed by the government of Victoria in 1993 and then by the Australian Federal Government in 1996. In its application, prudent avoidance measures continue to follow the guidelines set out by Sir Harry Gibbs in his 1991 report to the NSW government.

In its seven years experience of applying prudent avoidance in Australia and measured in the context of public acceptance ESAA believes it has proved to be a worthwhile common sense approach and the best policy option available.