Review of EMF Test Reports/Results

Mineral House, George Street, Brisbane

Dr Tee Tang

Faculty of Built Environment and Engineering
Queensland University of Technology (QUT), Brisbane, Australia

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Preliminary: For consistency, the unit micro-tesla (μT) will be used in this report instead of milli-gauss (mG) for the magnetic flux density (often loosely referred to as magnetic field). 1 μT = 10 mG.

Contents

1. Introduction

QUT was commissioned by the Department of Public Works to review the EMF test reports for Mineral House, and to make comments/recommendations where appropriate, particularly in the technical areas. It was agreed that epidemiological assessment is not part of this review.

At the time of commissioning this review, four reports were available. A new report tabling the results of EMF measurements at 19 government buildings was finalised on 17 September 2008.[10] This new report is used only as a reference to compare the levels at Mineral House with the other buildings.

2. Reports on EMF measurements at Mineral House

The following four reports contain the results of EMF measurements carried out at Mineral House in 2008, 2000 and 1999. Major findings of the reports, particularly the measured levels and conclusions, are summarized here, together with my comments.

2.1 Report #1

Queensland Health, "Queensland Health investigation into concerns regarding cases of cancer in staff on the ground floor of Mineral House, George Street, Brisbane", Report, May 2008.

This report consists of two parts: (a) epidemiological assessment, and (b) radiation level survey (including both radiofrequency power flux density and 50Hz magnetic flux density).

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The measured radiofrequency power flux density levels were 0.001 W/m2 or less, well below the ARPANSA exposure limits of 2W/m2.

The *maximum* magnetic flux density level was 1.5 μT directly above the substation. Three locations (L7, L67 and L68) had higher levels at 1.7, 2.3 and 6.3 μT. These locations were identified to be near electronic equipment, cables and switchboard.

The report concluded that 1.5 μT is below the NHMRC limits, but noted that it was above the *expected normal exposure* for office works of 0.06-0.2 μT. Readings at Levels 1-5 were between 0.02 μT and 0.15 μT.

Comments:

a) The magnetic flux density levels close to electrical/electronic equipment, switchboards, electrical cables, etc, are usually higher than ambient. Figures of around 10 μT at 30 cm distance have been reported. [eg, ARPANSA 2005[4]] This type of EMF field tends to decrease rapidly with distance. The three "hot-spots" are typical of this type of situation.

(b) The measured maximum magnetic flux density level of 1.5 μT agrees well with the reading of 1.9 μT measured early in 2000 after shielding was implemented. [Report #2]

(c) The "*expected normal exposure*" range of 0.06-0.2 μT was confirmed to be based on the practical experience of the officer who made the report. It is not found in the public literature.

(d) "Walk-through" spot magnetic field measurements at more than 30 locations on the ground level of Mineral House were conducted by Tee Tang and Michael Ball on 6 August 2008, using a calibrated Enertech EMDEX II meter. The measured levels were consistent with this report, with a maximum reading of 1.3 μT. Levels at the three "hot-spots" (L7, L67 and L68) were found to be 1.7, 0.14 and 1.32 μT respectively. These readings were consistent with the report.

(e) In the 17 September 2008 measurement report*, the 1.5 μT maximum level at Mineral House sits in the range of 0.1 to 2.9 μT of the other buildings where measurements were not taken near electrical installations. At locations where nearby electrical installations exist, the readings were reported to be as high as 7.0 μT.

*"Measurement of ELF magnetic fields report, various sites", Project Services, Queensland Government, 17 September 2008.

2.2 Report #2

"Mineral House (Ground Floor) Electromagnetic Field Testing Results – Post Shielding Works", test results by Project Services in 2000.

In 2000 after shielding was implemented, Project Services re-measured the spot magnetic field levels at workstations which had high readings during the pre-shielding measurement in 1999. The maximum post-shielding reading was 1.9 μT at a location directly above the sub-station.

Comments:

Compared with the pre-shielding reading of 5.8 μT, shielding appeared to have attenuated the magnetic field by a factor of 3.05 (or 9.7 dB). The attenuation factors at five other nearby locations varied from approximately 1.4 to 3.3 (or 3 to 10 dB), as shown in Table 1. This is reasonably expected as the two sets of readings were taken at two different instances. It was also revealed that the shielding design intentionally provide more attenuation to areas with higher readings.

Table 1. Attenuation provided by shielding

Location	Pre-shield (μT)	Post-shield (μT)	Attenuation (ratio)	Attenuation (dB)
1	5.80	1.90	3.05	9.7
2	3.96	1.20	3.30	10.4
3	1.90	0.70	2.71	8.7
4	1.20	0.63	1.90	5.6
5	1.34	0.88	1.52	3.7
6	0.96	0.68	1.41	3.0

2.3 Report #3

David Simpson, "EMF Measurements of Ground Floor – Mineral House", Energex Network Investigations Department, Report No. 99/27, 9 April 1999.

The power frequency magnetic field levels were measured on Thursday 11 March 1999 during the morning working hours. More than 100 points were measured on a matrix grid. The highest spot reading was 5.8 μT at floor level directly above the substation. It was 4.2 μT at desk height at the same location. The readings decreased away from the substation. The average level was reported as 1.84 μT.

This report also referred to the 1989 Australian NHMRC exposure limit guidelines of 100 μT (for general public with 24-hour exposure) and 500 μT (for occupational exposure during whole working day). The report concluded that measured levels were well within the NHMRC limits.

Comments:

It should be noted that the NHMRC guidelines are aimed at *preventing immediate health effects* resulting from exposure to the fields. NHMRC qualified that the above limits do not apply to the avoidance of cancer risk resulting from *chronic exposure* to 50 Hz magnetic fields.

2.4 Report #4

"Monitoring of 50 Hz magnetic fields, Mineral House, Brisbane, 19-20 June 2008", Report by Radiation Health, Environmental Health Unit, Queensland Health, June 2008.

While Reports 1–3 measured the instantaneous magnetic fields due to the large number of locations covered, this report measured the fields over a period of 24 hours at one location. It was shown that the daytime levels were between 0.7 to 1.0 μT (average around 0.9 μT). The nighttime levels were about half as much. The measure levels were consistent with Report 1 at locations L20–L23

Comments:

It is expected that the 50Hz magnetic field will vary with time-of-day due to variation in power usage. With a 24-hour log of the levels during a working day, this report gives a more informative picture of the situation compared with spot measurements. It also confirms that the spot measurements (during working hours) in Reports 1–3 are realistic representation of the actual situation.

3. National and international views on EMF

A vast pool of articles on EMF is available in the public domain from many different sources, including government agencies, research institutes, interest groups and commercial companies. While there are many views on the safety of EMF, there is *no definitive conclusion* on the threshold level above which it is considered *unsafe*.

There are a number of established bodies which set health standards and guidelines in radiation (both ionizing and non-ionizing). The more prominent ones are:

(a) International Agency for Research on Cancer (IARC), of World Health Organization (WHO),

(b) US National Institute of Environmental and Health Sciences (NIEHS),

(c) UK National Radiological Protection Board (NRPB), now part of UK Health Protection Agency,

(d) Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) – in the process of establishing new EMF exposure limits,

(e) National Health and Medical Research Council (NHMRC), Australia – published guidelines on EMF exposure limits in 1989.

The maximum exposure limits (100 μT for general public 24-hour exposure and 500 μT for occupational working hours) stated by these bodies are significantly higher than the levels (<1 μT) that a number of researchers used in their epidemiological studies. There was also common reference to a level of 0.4 μT (or 4 mG) which was the level used in a number of research studies. It is noted in an article that the Swedish government has established a safety ELF EMF limit of 0.25 μT (2.5 mG), and a VLF EMF limit of 0.025 μT (0.25 mG).

A number of extracts from materials published by a number of websites are collected in the attached **Appendix**. From this small collection of articles, it is hoped that a balanced view can be developed. There is currently no definitive conclusion that EMF can cause cancer, and much research is still being carried out.

4. Precautionary Principle and Prudent Avoidance on EMF

In Reference [9], Kheifets from WHO states that "the precautionary principle is one of many guides society can use when deciding whether to take action to protect people from possible harm. It is essentially a *better safe than sorry* approach suggesting that action should be taken to avoid harm even when it is not certain to occur." Its application to the EMF issue involves many types of uncertainty, such as (a) is exposure associated with increased risk? (b) what is the magnitude and specificity of the risk? (c) which aspect of exposure might be harmful?

The paper summarizes that the absence of a clearly elucidated, robust and reproducible mechanism of interaction of EMF with biological systems makes avoidance strategies fall short of avoiding EMF exposure entirely (that is, eliminating electricity usage altogether), which is both difficulty to formulate and potentially counterproductive.

Various state and local authorities in the US have adopted **informal guidelines** for EMF limits for transmission lines ranging from 0.2 μT to 20 μT at the edge of right-of-way. In Australia, Energex requires its power lines to comply with the NHMRC exposure limits. [1]

Reference [9] also states that "**prudent avoidance** has been interpreted to mean everything from adopting the best available practices to implementing low-cost steps (e.g., <4% of a project budget in California) in constructing new lines…. Until stronger evidence changes this opinion, inexpensive and safe reductions in exposure should be encouraged."

As the precautionary principle is vague, additional decision rules for prudent avoidance should be established based on consideration of tradeoffs and cost-benefit analysis. It is vital to define the objectives of decision, and to prescribe certain criteria within the context of precautionary principle. For the case on Mineral House, the following objectives should be considered:

(a) to establish a work environment in which EMF is managed, and

(b) to mitigate staffs' concerns/fears of the biological effect of EMF.

Based on information available to date and current practice/guidelines by various authorities, the range of exposure levels was from 0.2 μT to 100 μT. Extensive practical measurements conducted recently by ARPANSA [4] and Dept of Public Works [10] showed that maximum magnetic field levels were as high as 0.99 μT in residential rooms [4] and more than 3 μT in a number of government buildings [10]. In order to establish a prudent avoidance practice, it would be unwise to suggest 0.2 μT or 0.4 μT as the maximum level as it would be impractical to implement. A range of **1 μT to 3 μT** appears to be a more practically achievable target, particularly for areas where people occupy continuously (e.g., staff offices, receptionist areas, etc.) during working hours.

It is probably preferred in the first instance to apply appropriate engineering control to situations which do not achieve the prudent avoidance target. Where there is difficulty in mitigating the situation technically, administrative control should be applied, such as re-designating the function of areas of high field readings, moving staff offices, etc.

Finally, cooperation between all parties concerned is essential in successfully implementing the prudent avoidance guidelines. It is also important that staff understand the aim of the prudent avoidance scheme, and are made aware of the due-diligence the department/employer is carrying out.

5. Conclusion and recommendation

The effects of electric and magnetic fields (EMF) have been vigorously debated worldwide because of claims by some researchers that exposure to EMF can cause disease. Since research on the matter has not been definitive, the practice of "prudent avoidance" is recommended. This means developing a set of guidelines to minimize human exposure to EMF. A hurdle to overcome in developing a prudent avoidance scheme in an organisation is the establishment of an acceptable exposure level. Any work needs to be taken through consultation and it is important to communicate any proposed prudent avoidance policy to affected parties, through means such as awareness educational programs and an open- approach to dealing with any violation of the prudent avoidance guidelines.

Appendix

ELF EMF Health Effect?

Human studies have consistently shown that there is no evidence that prolonged exposure to weak *electric* fields (such as those found in the home or in most workplaces), results in adverse health effects. Whether chronic exposure to weak *magnetic* fields is equally harmless remains an open question. There is no evidence that these fields cause immediate, permanent harm. [4]

Laboratory studies on animals and cell cultures have shown that weak magnetic fields can have effects on several biological processes. For example, they may alter hormone and enzyme levels and the rate of movement of some chemicals through living tissue. By themselves, these changes do not appear to constitute a health hazard. We do not know if, in the long term, they may have an effect on the incidence of cancer or other adverse health effects. While most studies have produced inconclusive results or no increased cancer incidence in laboratory animals following exposure to EMFs, a few studies have indicated an increased incidence.[4] Reference [6] is a recent (2006) example that used 6 Hz 10 mG magnetic field to investigate its effect on immune cells.

Another way to find out whether EMFs affect human health is to conduct relevant studies on human populations. [4] A study in 2007 based on Finnish job exposure matrix (FINJEM) consisting of more than 400 controlled and exposed samples. It did not find evidence of an association between glioma (a primary malignant brain tumour in adults) and occupational exposure to ELF. The highest mean EMF exposure level was 4.03 μT. [5]

Health Standards

Health standards are set by national and international health bodies such as the World Health Organization (WHO). They rely on detailed reviews of the results of epidemiology studies and laboratory experiments. They continually review the results of experiments from all over the world. Two major reviews of ELF-EMF have been carried out: (a) in 1999 by the US National Institute of Environmental and Health Sciences (NIEHS), and (b) in 2001 by the UK National Radiological Protection Board (NRPB), now part of the UK Health Protection Agency. [2]

NIEHS Review:

"The scientific evidence suggesting that ELF-EMF exposures pose any health risk is weak. The strongest evidence for health effects comes from associations observed in human populations with two forms of cancer, childhood leukemia and chronic lymphocytic leukemia in occupationally exposed adults. While the support from individual studies is weak, the epidemiological studies demonstrate for some methods of measuring exposure, a fairly consistent pattern of small increased risk with increasing exposure that is somewhat weaker for chronic lymphocytic leukemia than for childhood leukemia. In contrast, the mechanistic studies and the animal toxicology literature fail to demonstrate any consistent pattern across studies although sporadic findings of biological effects have been reported. The lack of connection between the human data (epidemiological) and the experimental data (animal and mechanistic) severely complicates the interpretation of the results." [2]

"The NIEHS concludes that ELF-EMF exposure cannot be recognised as entirely safe because of weak scientific evidence that exposure may pose a leukemia hazard." "Passive regulatory action is warranted such as a continued emphasis on educating both the public and the regulated community on means aimed at reducing exposures." [2]

NRPB Review:

The NRPB (National Radiation Protection Board - UK) Advisory Group on Non-ionising Radiation (AGNIR) headed by Sir Richard Doll produced a report titled, *ELF Electromagnetic Fields and the Risk of Cancer in March 2001. The report concluded that; unless ... further research indicates that the finding is due*

to chance or some currently unrecognised artefact, the possibility remains that intense and prolonged exposures to magnetic fields (from powerlines) can increase the risk of leukaemia in children. The inconclusive nature of this finding is due to the low relative risk and the lack of supporting evidence such as a biological mechanism or dose response curve etc. [3]

"Laboratory experiments have provided no good evidence that extremely low frequency (ELF) EMFs are capable of producing cancer, nor do human epidemiological studies suggest they cause cancer in general. There is, however, some epidemiological evidence that prolonged exposure to higher levels of power frequency magnetic fields is associated with a small risk of leukaemia in children", but goes on to say that "...the epidemiological evidence is not strong enough to justify a firm conclusion that such fields cause leukaemia in children." [2]

IARC Review:

In 2001, the International Agency for Research on Cancer (IARC), a part of the World Health Organization, classified power frequency magnetic fields as a "possible carcinogen", based on recent epidemiological study findings which associate childhood leukemia with higher levels of exposure to residential magnetic fields. It comments that no scientific explanation has been established for the observed association. [2]

ARPANSA Review:

In Australia, the relevant health authority is the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), an arm of the Commonwealth Department of Health. ARPANSA has some relevant information brochures available on its web site including: "Does Electricity Cause Cancer?", "Electricity and Health" and "The Controversy over Electromagnetic Fields and Possible Adverse Health Effects". The first is a direct response to the NRPB report from the CEO of ARPANSA. One quote is of particular interest:

"It is also important not to fixate on the location of external power lines, including high voltage transmission lines, as the prime cause of exposure. Exposure to ELF magnetic fields can arise from ground currents, internal household wiring and the use of electrical appliances as much as from exposure to external powerlines." The other two brochures contain more general information on the relationship between electricity, mainly EMF, and health. They broadly conclude: "On balance, the scientific evidence does not indicate that exposure to 50 Hz EMFs found around the home, the office or near power lines is a hazard to human health." [2]

Typical EMF Exposure Levels

Residential Exposures

Exposure levels to EMFs around the home are in the range of 0.01–0.25 μT (0.1–2.5 mG). For homes near powerlines, these levels may be as high as 0.5–1 μT (5–10 mG). Immediately under the powerline, magnetic field levels of 6–10 μT (60–100 mG) may be found. [3]

A recent ARPANSA survey of residential power frequency magnetic fields in Melbourne reported that, of the 26 homes, the average magnetic field levels were approximately 0.9 mG, with 10th and 90th percentiles of 0.2 mG and 5.1 mG, respectively. The maximum spot measurement levels were in the range of 5.0–11.6 mG. The pilot survey also identified situations where levels were likely to be above 4 mG, including inner suburban homes and homes near high-voltage transmission lines. Three of the residences, approximately 12% (95% CI = 1%–30%) had levels greater than 4 mG in the nominated youngest child's bedroom. This result was higher than expected (compared with approximately 1% in UK and 3% in US) although it cannot be taken to be indicative of the true population proportion due to the small sample size. [4]

The magnetic fields of some selected appliances were also measured at a nominal 30 cm separation. Their mean and maximum values are show below: [4]

APPLIANCE	Mean (mG)	Maximum (mG)
television	10.1	25.4
microwave oven	97.1	188.0
kettle	5.3	13.8
clock radio	4.8	9.6
hair dryer	25.3	99.0
computer	2.3	5.2

Workplace Exposures

The widespread use of electricity means that in all workplaces, there will be levels of magnetic fields that would be considered "normal". However, there are also localized sources of magnetic fields in the workplace such as electrical substations in the basement, power cables in the walls or floor and distribution lines close to the building. The field levels close to these sources will be relatively high and may cause computer screens to shimmer, for example. These levels may exceed the NHMRC limit. [3]

Official EMF Exposure Guidelines

Australia

There are currently no Australian standards regulating exposure to these fields. The National Health and Medical Research Council (NHMRC) has issued *Interim guidelines on limits of exposure to 50/60 Hz electric and magnetic fields*. These guidelines are aimed at preventing immediate health effects resulting from exposure to these fields. The recommended magnetic field exposure limit for members of the public (24 hour exposure) is 0.1 millitesla (1,000 mG - milligauss) and for occupational exposure (whole working day) is 0.5 millitesla (5,000 mG). It is important to note that the above NHMRC limits do not apply to the avoidance of cancer risk resulting from chronic exposure to 50 Hz magnetic fields. [3]

The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) is currently developing a standard for extremely low frequency (ELF) fields that will include protection limits for exposure to power-frequency magnetic fields. Although current epidemiological evidence does not provide a sound basis for the derivation of exposure limits, a precautionary strategy could be considered (Grandolfo and Vecchia, 1996). According to such a precautionary approach, it is important to have knowledge of the exposure potentially related to the possible risk. That is, one should know what proportion of the population, and in particular children, are exposed to time-averaged levels above 4 mG. [4]

Environmental Protection Agency (EPA)

The Environmental Protection Agency (EPA) reviewed 50 epidemiological studies and hundreds of biological studies and acknowledged that low level electromagnetic fields may increase the risk of cancer. A general recommendation is **"prudent avoidance"** of exposures. [7]

Swidish Government

It was reported that the Swedish government has established a safety ELF EMF limit of 0.2 μT (2 mG) for video display terminals (VDT). [8], [11]

Unofficial EMF Exposure Guidelines

Several epidemiological studies have reported an association between prolonged exposure to power frequency magnetic fields at levels above what is normally encountered (›4 mG) and an increased risk in childhood leukaemia, although other scientific evidence, including cell and animal studies, does not support this hypothesis. [Matthes R, McKinlay AF, Bernhardt JH, Vecchia P and Veyret B, (2003) "Exposure to Static and Low Frequency Electromagnetic Fields, Biological Effects and Health Consequences (0-100 kHz)", *International Commission on Non-Ionising Radiation Protection*. 2003]. [4]

Reduction of EMF Levels

The only remedies currently available to reduce these fields, and the resultant exposure, is a combination of shielding and relocating the source (both very costly), or relocating the employees (also potentially costly). The general aim of any field reduction program is to minimize the exposure level for all staff. However, particular situations may require particular solutions and the local electricity supplier or the Energy Networks Association should be consulted. [3]

Prudent Avoidance Practice

Even though there is no definitive conclusion to the human health effect of EMF, many organisations have introduced "prudent avoidance" practice in their working environment. Sound practical procedures were given to minimise human exposure to EMF. Examples can be found in the following websites:

State of Wisconsin:
http://dhs.wisconsin.gov/eh/Air/pdf/EMF.pdf

Hawaii Dept of Education:
http://fssb.k12.hi.us/emf.htm

Wisconsin Dept of Health Services:
http://dhs.wisconsin.gov/eh/Air/fs/EMF.htm

California Public Utilities Commission:
http://docs.cpuc.ca.gov/PUBLISHED/FINAL_DECISION/65273-14.htm

References

[1] Energex, “Electric and Magnetic Fields”, www.energex.com.au/network/emf/community_emf_info.html, accessed 25/11/2008.

[2] Energex, “Effects of EMF - Do EMFs Cause Adverse Health Effects?”, www.energex.com.au/network/emf/community_emf_approach.html, accessed 25/11/2008.

[3] ARPANSA, “Magnetic & Electric Fields from Power Lines”, www.arpansa.gov.au/radiationprotection/factsheets/is_emf.cfm, access 25/11/08.

[4] Ken K Karipidis and Lindsay J Martin , “Pilot Study of Residential Power Frequency Magnetic Fields in Melbourne”, ARPANSA Technical Report Series No.142, 2005, www.arpansa.gov.au/pubs/technicalreports/tr142.pdf, accessed 25/11/08.

[5] Ken K. Karipidis, Geza Benke, Malcolm R. Sim, Timo Kauppinen and Graham Giles, “Occupational exposure to ionizing and non-ionizing radiation and risk of glioma”, Occupational Medicine 2007;57:518–524, published online 29 August 2007, doi:10.1093/occmed/kqm078, http://occmed.oxfordjournals.org/cgi/reprint/57/7/518, accessed 25/11/08.

[6] H. WEI, N. ISHIMARU, T. ICHIKAWA and Y. HAYASHI, “Milligauss electromagnetic field influences immune cells”, Conference Paper 0863, 29 June 2006 Brisbane Convention & Exhibition Centre Exhibit Hall 1, http://iadr.confex.com/iadr/2006Brisb/techprogram/abstract_82197.htm, 25/11/08.

[7] www.healthgoods.com/shopping/Home_Test_Kits/Electromagnetic_Field_Testing.asp, accessed 25/11/08.

[8] “Are there any standards for EMF exposure?”, Less EMF Inc. www.lessemf.com/emf-news.html, accessed 07/09/08.

[9] Leeka I.Kheifets, “The Precautionary Principle and EMF”, accessed 29/11/08. This paper was based on the paper entitled: “Kheifets L.,. “The Precautionary Principle and EMF: Implementation and Evaluation,” *Journal of Risk Research*, 2001 4(2):113-125. (Dr Kehifets was with World Health Organisation.

[10] “Measurement of ELF Magnetic Fields Report – Various Sites”, Project Services, Dept of Public Works, Queensland Governement, 17 September 2008.

[11] National Institute of Environmental Health Sciences, (NIEHS), “EMF – Electric and Magentic Fields Associated with the Use of Electric Power”, National Institutes of Health, p.48, June 2002.