Submission to the Royal Society of Canada's Expert Panel Reviewing Safety Code 6
Title: Expert Panel Review *[redacted words]* Safety Code 6*
Limits of Human Exposure to Radiofrequency Electromagnetic Energy in the Frequency Range from 3 kHz to 300 GHz

Overview

This submission was written in the hope that it will be relevant to the Royal Society of Canada's deliberations regarding radiofrequency electromagnetic energy, as the parameters of this review (purpose, objectives, background, assumptions, scope and research questions] were redacted by Health Canada. I am an Ottawa researcher in environmental health and clinical epidemiology. Of interest to the Panel, I wrote the medical issues paper on environmental sensitivities that led to recognition of this condition (including electrosensitivity) as a disability under the Canadian Humans Rights Act, have worked on many systematic reviews, including of toxic exposures (with CIHR funding for a review of toxic elements), acted as a guest editor for medical journals, and was recognized as an expert in a recent hearing by the BC Utilities Commission. My university training in chemical engineering and applied chemistry included electricity, and mathematical modeling. This submission was prepared independently from the institutions with which I am affiliated (Children's Hospital of Eastern Ontario Research Institute, Ottawa Hospital Research Institute, University of Sherbrooke), and represents solely my thoughts.

This submission discusses:

- scientific standards for review of health effects of environmental factors, evidence synthesis and a framework for determination of "weight of evidence";
- the "evidence chain" for effects of low doses of electromagnetic energy, from chemical reactions, through cell culture, *in vivo* animal and human studies, indicating a need to minimize exposures to radiofrequency electromagnetic energy; and
- electrosensitivity in the context of environmental sensitivities .

Summary recommendations

That the RSC Panel:

- Disclose the purpose, objectives, background, assumptions, scope and research questions, to permit meaningful public participation and to ensure the "rigourous, transparent" review stipulated by Health Canada;
- Seek further public input once the public has been informed of the parameters of the review;
- Conduct comprehensive systematic reviews to answer research questions, including all types of scientific evidence (*in vitro* to human studies);
- Publish the review protocol(s), and conduct and report the work according to international best practices;
- Ensure the Panel has the mandate, capability and resources to validate and further update literature searches provided by Health Canada;

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* Title as indicated in contract between Health Canada and the Royal Society of Canada, obtained under *Access to Information Act* by Canadians for Safe Technology (C4ST)

- Adapt and adopt a framework such as that proposed by the US National Toxicology Program to formalize a "weight of evidence" framework to answer research questions;
- Revisit Safety Code 6 averaging provisions, and considerations regarding highly modulated signals;
- Recognize explicitly that biological effects occur at ubiquitous exposures, explore all plausible harms that may ensue, and in the end protect Canadians from biological effects, rather than only harms that have been proven to unduly onerous scientific standards;
- Recommend approaches to turn the tide of rapidly escalating exposures, with the objective to minimize exposure to radiofrequency energy;
- Provide recommendations and guidance regarding initial steps towards the goal of minimizing exposure, particularly of the most vulnerable such as children and the foetus (e.g. using only wired technologies in schools, daycares, etc.; restricting placement of radiating equipment; mandating wifi-free public spaces to permit safe access; research and development needs for safer technologies);
- Recommend adoption of much more protective permitted exposure levels, comparable to global best practices such as in Switzerland;

Systematic Review of Health Effects of Radiofrequency Electromagnetic Energy

When sufficient data is available, systematic review yields the strongest evidence for medical interventions and public health. The *Centre for Practice-Changing Research* in Ottawa is a world leader in systematic review methodology. Ottawa scientists, along with others the world over, have developed guidance and standards for conduct, reporting and synthesis of health related research, of various study designs (available at www.equator-network.org). Indeed, the 50th anniversary revision of the Declaration of Helsinki incorporates many elements of these standards.[1]

One key standard for a high quality review is to publish the protocol before carrying out the review; indeed a BioMedCentral journal is dedicated to this one purpose (www.biomedcentral.com/authors/protocols). Such a protocol would provide background, research questions, and the methods proposed to answer these questions. Methods would include literature search strategies, inclusion and exclusion criteria for identified studies, and methods to synthesize the data and ascertain the "weight of evidence."

In stark contrast, Canadians do not know the parameters and research questions of the Royal Society of Canada (RSC) Safety Code 6 review, let alone methodology. *Canadians for Safe Technology (C4ST)* kindly shared the contract between Health Canada and the RSC regarding Safety Code 6, obtained via a request for information (Appendix 1). As noted in the title of this present submission, even the title of the RSC review was partially redacted. All other key scientific aspects of the contract are also redacted, including the purpose, objectives, background, assumptions, scope and research questions:

- Front page, and E1.2 ... Establishing an Expert Panel of the Royal Society of Canada (RSC) to conduct an independent assessment *[remainder of paragraph redacted].*

- E1.3 Objectives of the Requirement
  In order to support a rigorous, transparent and independent review of Safety Code 6 (2013), *[remainder of sentence redacted].* ...
- [there is no E1.4]
- E1.5 Background, Assumptions and Specific Scope of the Requirement
  Public concerns have been raised regarding the potential negative health effects of RF electromagnetic energy devices, and there have been reports of a variety of symptoms being associated with exposure to electromagnetic fields (EMF), despite a lack of scientific evidence linking symptoms to exposure. *[further 2.5 lines redacted; remainder of section describes the RSC, and provides no further information regarding the review]*
- E2.1 ... The panel will be expected to answer the following questions in their report: *[all questions are redacted]*

Redaction of the review objectives in a sentence referring to "a rigorous, transparent and independent review" is particularly troubling. Transparency cannot be claimed for a review that is independent of public scrutiny.

It is highly unusual and awkward to be commenting on a scientific review, in complete ignorance of fundamental aspects of the review itself – i.e. the questions being asked, and how these questions are to be answered. Thus I must address hypothetical situations, in the sincere hope that this discussion will be of assistance to the RSC Panel.

Review of primary literature, or an update?

One important aspect of the current review is whether it is being carried out "afresh," examining the totality of the scientific evidence to date based on the original, primary research, or if the current work is an update of a previous review. Previous Canadian reviews were not conducted publicly, so may or may not constitute a complete, unbiased foundation for the present work. RSC panels have repeatedly examined Safety Code 6, so the concern is that like the whispering party game where the message gets distorted as it goes around the table, compilations of research compilations may perpetuate and magnify biases and misinterpretations. No previous Canadian review has been adequately reported according to international best practices, with explicit research questions, clear methods, lists of studies included and excluded (with reasons), evidence tables, grading of study quality, transparent evidence synthesis and weighing, etc. Thus we appear to have no strong foundation for a mere update. It is hoped that the RSC Panel will conduct a thorough review and ensure high quality reporting of their work.

An example of potential review shortcomings is a UK report prepared by a panel chaired by Professor A.J. Swerdlow.[2] He had a long involvement in the INTERPHONE study, authoring studies that consistently found no problems with cell phone radiation. The report appears to be comprehensive, with extensive evidence tables, but the discussion does not always reflect the tables' contents, and evidence synthesis is simply a narrative. An obvious bias is in the discussion of cancer and cell phones. Although published in December 2012, this report does not so much as mention the 2011 International Agency for Research on Cancer (IARC) finding that the associated radiation is a 2B (possible) carcinogen.[3] Instead the UK report dismisses the possibility that radiofrequency radiation may cause cancer, relying heavily upon the highly criticized, thoroughly discredited long term Danish cohort study (e.g. see comments on BMJ

website).[4] I sincerely hope that the Canadian panel will not exhibit such obvious bias, nor build upon previous work with comparable flaws.

Vested interests also create biases. Huss *et al.* reported in 2007 that industry-funded studies into health effects of radiofrequency radiation should take sponsorship into account, as although most studies (68%) reported significant biological effects, studies solely funded by the industry were almost ten times more likely to report no significant problems.[5] Funding bias had not changed substantially in 2010 when the group updated their systematic review; they also noted that many reports lacked conflict of interests statements, even when authors had industry affiliations.[6] The funding bias issue has been examined with systematic reviews of other topics, such as for statins (cholesterol-lowering drugs). Bero *et al*. reported that among statin trials receiving industry funding, studies supported by the test drug company were 20 times more likely to report positive results, and 35 times as likely to report positive conclusions.[7]

Dose Response

Increasing symptoms or effects with increasing exposure, a "dose-dependent response," is an indication to epidemiologists that the effect is likely to be related to the exposure. Of course, in order to determine a dose response, you first need an accurate measure of dose. This is a common weakness of many types of environmental health research; in no area more than effects of electromagnetic energy on health. Early difficulties were also experienced by biologists venturing into the physics of radiofrequency generation and dose determinations. McNamee and Bellier reviewed conflicting studies of cytotoxicity of radiofrequency radiation, critiquing study designs and recommending research for more definitive answers.[8] In human studies, dose has been estimated based upon inaccurate and only partially applicable surrogate measures, such as self-report of cell phone use, distance from a cell phone tower, or measurements at the head of the bed. Some studies used a dosimeter worn for a short period of time, that may or may not be representative of the years of the study. These inevitable dose uncertainties bias results towards the null (make it less likely that significant results will be observed, even if a true effect exists).

Regardless of dose uncertainties, researchers may investigate whether "more" is worse. On a basic level, since Paracelsus (1493-1591) first spoke of no substance being without toxic effect at a high enough dose, toxicology's mantra has been, "the dose makes the poison." The historical dose response model is that high dose responses reliably predict lower dose responses; i.e. that an effect (e.g. racing heart, headache, brain cancer) continually increases in probability and/or severity with increasing dose, and that at a low enough dose there is no effect. For Safety Code 6, a threshold has been presumed based on bulk tissue heating. Some chemicals and ionizing radiation are deemed to exert diminishing toxicity down to infinitesimal doses (no dose threshold), eliciting regulatory and public health goals to reduce exposures to levels as low as achievable. Even if heating by radiofrequency energy exhibits a simple, monotonic dose response, this effect does not predict other biological effects of radiofrequency radiation, at lower doses. There is no clear justification of the "safe" threshold based on gross tissue heating.

Although it may seem counter-intuitive, in environmental health non-monotonic dose responses occur for many reasons, including endocrine, epigenetic and other physiological effects. Such complex dose responses are possible for radiofrequency energy as well. Different biological effects may be observed at different doses depending upon adaptive responses, as well as when very low doses affect the endocrine system – the body's "chemical messaging" system. Hormones orchestrate every step of development, and regulate metabolism from gestation

through the entire lifespan. They also are responsible for the "flight or fight" response. Hormones act at exquisitely low concentrations in the body, and endocrine disrupting chemicals can have different, even opposite effects at higher doses. A recent review of 845 scientific papers showed evidence of endocrine-disrupting chemicals having adverse health impacts at very low doses in animals and humans.[9] Based on such science, Canada banned bisphenol-A from baby bottles.[10] Indeed, even the American Chemical Society has issued a Public Policy Statement, saying that omitting low dose testing undermines the validity of regulatory toxicological testing.[11] Radiofrequency radiation may affect levels of hormones such as estrogen and testosterone, stress hormones, sleep-regulating hormones such as melatonin, and others as described below. Importantly, inappropriate hormone levels during critical windows of development can cause permanent effects in children's lives, affecting their intelligence and behaviour, and making them more susceptible to infections, asthma, obesity, diabetes, reproductive failure, cardiovascular disease and cancers. For example, early life exposure to cell phone radiation was associated with behavioral disturbances in two studies of children,[12,13] and more recently with asthma (indicative of immune disturbance)[14] and obesity (metabolic/endocrine disturbances).[15] Furthermore, through epigenetic mechanisms, effects can pass from parent to offspring.

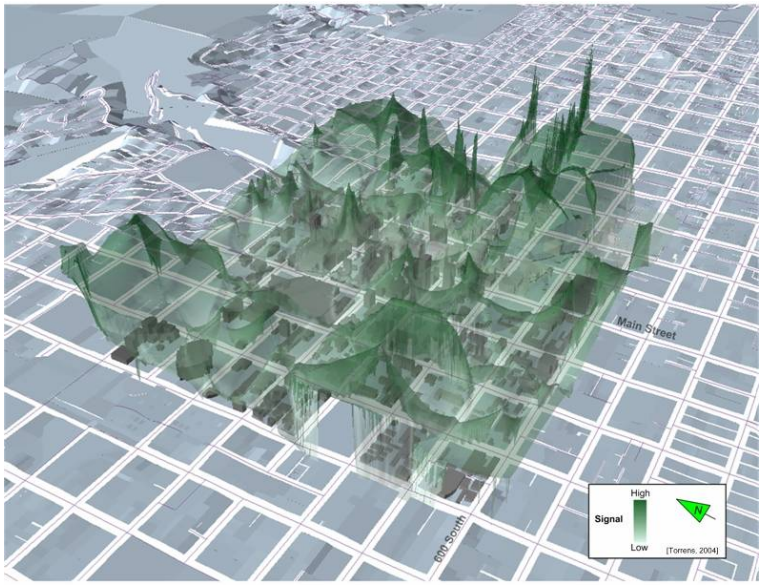
Time is another metric of radiofrequency radiation dose that may not yield monotonic results. Research findings would be more easily interpreted if effects were cumulative or at least persistent/consistent over lengthening exposure times. Unfortunately, research that shows an effect at an early time point, that does not persist and therefore is not replicated later on in the study/experiment, is often considered unreliable. In fact, such studies (that are often dismissed) should be considered a positive signal of concern. This data may actually be quite valid, because living organisms are marvelously adaptive. Responses over time may peak and subsequently fall off. Importantly, however, adaptive responses take a long-term toll on the organism.

Another aspect of time relates to averaging of modulated signals. Generally, regulation of hazards must be within appropriate time frames. Floodplains are not regulated on the basis of annual rainfall, nor are firearms restricted on the basis of the force exerted by a bullet averaged over a week. Similarly, important toxicological aspects of timing may be absent from Safety Code 6. If bulk heating was the only biological effect of radiofrequency emissions of concern, then the low average power of millisecond packets spread over six minutes might be reassuring. If, however, bursts of radiofrequency electromagnetic energy with complex wave forms have other biological effects, this averaging would be obscuring a hazard.

Very brief, high energy bursts of transmission may have different physiological effects, just as a small continuous force over a long period is very different from the impact of a bullet, even if the average energy imparted is the same. When modulated or discontinuous signals, such as cell phones that are transmitting speech, are compared with continuous radiation, effects are generally more pronounced with the irregular signals than with unmodulated radiation. There are many examples, but this was recently demonstrated in the form of more pronounced effects on slow-wave and rapid-eye-movement sleep in rats exposed to 900 MHz modulated signals, compared with unmodulated, or sham exposures [16] (Mohammed *et al*. also reviewed radiofrequency effects on sleep, and brain circulation and chemistry). For this reason, the Safety Code 6 averaging provisions should be revisited.

Finally, individuals are not exposed to single sources of radiofrequency electromagnetic energy;

rather we all experience diverse sources including ongoing communication signals from diverse household technologies that are touted to reduce energy use (e.g. remotely controlled thermostat and appliances), communication towers, "dirty electricity," etc. Amidst the complex inner city or urban structures, geographers have identified marked variations in energy levels, with hotspots commonly occurring.[17]



Modelling of signal strengths in Salt Lake City (Torrens et al.[17])

Data Analysis

Researchers expend great effort collecting data, but the conduct of statistical analyses has the potential to highlight or obscure effects of exposures. Assessment of evidence during a systematic review requires skill and knowledge both of the topic, and of epidemiology and statistics. Without belabouring a technical topic I'll provide an example.

Both epidemiology and experimental (e.g. provocation) research measures "outcomes" such as subjective feelings of pain, tingling, "brain fog" or headache, or objective findings such as analyses of blood or urine, electrocardiogram, electroencephalogram, etc. The study groups have ranges of baseline values, including day to day individual (intra-participant) variability due to diverse factors ranging from what they had for breakfast, to time of day, time of year, and exposures or anxiety in the research facility. Consider a provocation study examining effects of exposure to radiation from a cell phone. In order to discern differences between group averages under different exposure conditions, the observed change in average outcome measures would have to overwhelm the natural range of variations across the entire study group. On the other hand, if steps are taken to minimize individual variabilities, such as habituating the participant to the research facility and protocol and ensuring that no other exposures (e.g. background radiation, fragrances) are affecting individuals, and then results are presented as individual differences between outcome measures under sham and real exposures, then within the same dataset an effect might be detected. Type of data varies with study design, so intra-participant data may not be available. Research standards are desirable, to facilitate future pooling of data.

Epidemiologists discuss issues like this at great length – another example would be appropriate statistical methods to account for co-variables versus confounding variables.

Evidence synthesis and "weight of evidence"

Whatever the research questions are, it is expected that answers will hinge upon synthesis of a variety of research, from *in vitro* and *in vivo*, to human studies of various design. This is typical of environmental health research. Thousands of scientific studies examine effects of electromagnetic phenomena on various systems and creatures. Every study has strengths and weaknesses that are inherent to study design, arise from resource limitations, may be simply poor reporting of the research, or perhaps reflect ineptitude. It is not simple to apply all of these studies to real life complexities of human exposure to radiofrequency radiation; there is no single, perfect method to synthesize such diverse medical evidence. The US National Toxicology Program (NTP) has invested considerable effort into formulating how to synthesize such an "apples and oranges" basket of research results encountered in environmental health.[18] The RSC Panel will need to adapt and adopt such a framework to assist in formalizing a "weight of evidence" method to answer research questions.

Threshold for actions

How sure do you have to be that harmful effects are occurring from a particular exposure, before taking actions to avoid them? This is a normative question, to be answered by the public – it involves value judgements. The answer is a complex weighing and balancing of perceived risks, benefits, alternatives, certainties, social norms, and other factors. An interesting overlay to the present radiofrequency exposures discussion will be privacy considerations. Of course, public discourse of this nature is unfortunately highly vulnerable to being influenced by vested interests, and there is a long and ongoing history of public health disasters from lead, asbestos, tobacco smoke, pesticides, and so on, while the scientific, medical, public health and other communities mustered the evidence and wherewithal to counter the misinformation/disinformation, lobbying, slick advertising and other shenanigans of vested interests.

A common claim is that "there is no evidence of harm," that is then spun as "evidence of no harm." This situation arises alongside insurmountable scientific requirements of proof, demanded by industry representatives. The feasibility of research must be kept in mind, as harmful exposures should not continue because unethical research was not conducted to "prove" harm. For example, long term human controlled-exposure studies are not feasible, so observational studies showing, for instance, perturbed development of children's neurological,[12,13] immune [14] and endocrine[15] systems, with higher exposures to radiation *in utero*, in prospective observational studies, must be graded as higher-quality studies despite uncertainties regarding dosages, based upon feasibility of this type of research.

The NTP has also identified biological effects of radiofrequency radiation as an important research priority.[19]

As further information accrues, do we "stay the course" with rapidly escalating exposures from diverse, new applications of technologies, or do we take at least preliminary actions to be more prudent in deployment of technology utilizing radiofrequency radiation, seeking alternative

means to meet diverse, newly identified desirable ends? Canada should seize the moment for prudent avoidance, and become a world leader in wired technologies.

Plausibility of "low dose" or "non-thermal" biological effects

Thermal versus non-thermal effects?

According to Safety Code 6 (page 9), "For frequencies between 100 kHz and 300 GHz, the predominant health effect to be avoided is tissue heating." Health Canada further describes a thermal effect as, "a threshold effect for the occurrence of behavioural changes and alterations in core-body temperature of ~1.0^{o}C, at a whole-body average SAR of ~4 W/kg." Limits are thus set to restrict bulk or core body tissue heating, knowing that blood flow will serve to dissipate heat. (In this context, eyes are particularly sensitive to cataract formation from microwave radiation because transparent structures are not cooled by blood flow.[20])

Bulk heating has been a convenient experimental measurement as technology has been available to quantify temperature for decades; however bulk heating should actually be considered an end-stage, least-sensitive measure of molecular perturbations caused by radiofrequency energy.

Investigation of effects at exposure levels that do not induce bulk heating of tissue spawned extensive, diverse research into "non-thermal" biological effects of radiofrequency radiation. This gave rise to an interesting semantic evolution. As laboratory techniques, technologies and modelling improved, to examine smaller scale effects, more of the observed effects were ascribed to localized heating in smaller and smaller volumes (rather than being "non-thermal"). Indeed, since temperature is essentially a measure of molecular energy, one might argue that sub-microscopic effects on molecules such as DNA and enzymes could be described on the basis of local addition of energy (i.e. heating), in the absence of significant bulk heating.[21] Discontinuities such as cell junctions may also absorb disproportionately high amounts of energy, and elevated levels of heat shock protein are a common finding in this area of research even when the experimental sample or animal is not overtly heated.[22,23] Thus the concept of "non-thermal" effects has blurred as researchers have focused on specific biological effects, with or without concomitant expression of heat shock protein, while development of more protective regulation remained stalled. It is a logical non-sequitur to say that since Safety Code 6 addresses thermal effects, it must be protective for the heretofore "non-thermal" effects (now redefined as thermal effects) that occur at exposures lower than those that result in bulk heating. This terminology needs revision.

In the following sections, I provide a brief overview of some research indicating that radiofrequency energy, at levels that do not cause dramatic heating, have effects on simple, non-living systems, cells, animals, up to humans. Not all research studies are positive, and not all studies are rigorously designed and executed. It is unfortunately easy to design, execute and report a study that is likely to find no effect. This has been seen previously in many areas of environmental health (lead, tobacco, etc.), and makes the task of the RSC Panel, to discern the validity and value of the scientific literature, particularly difficult.

Biochemical effects

Radiofrequency radiation affects basic building blocks of living organisms, and effects are seen in the simplest models.

Microwave radiation has been extensively studied in biochemistry, as it may affect configuration and orientation of enzymes, and thereby modify biochemical reaction rates. For example Parker et al. found that in organic solvent with little water (water is a very polar molecule, highly affected by microwave irradiation), reaction rates were doubled with microwave irradiation at a given temperature, whereas irradiation with high water content in the reaction mixture slowed reaction rates.[24] Porcelli *et al*. found that irradiation with 10.4 GHz at non-thermal doses irreversibly inactivated two enzymes, probably by rearranging the molecular structure.[25]

Membranes act as gate-keepers for essential biochemicals and wastes moving into and out of cells and subcompartments; host enzymes to carry out chemical reactions; and are the backbone along which nerve impulses are carried. Lipids are a large, important part of membranes. A 2012 publication describes significantly decreased deformability and increased rigidity of liposomes (basically miniscule oily droplets in water), following 2 or 6 hours exposure to 950 MHz, at 2.5 mW/cm^2.[26]

Cellular effects

Hundreds of studies over decades have reported DNA damage, as well as other effects of various "non-thermal" electromagnetic exposures. With uncertainties in experimental and equipment design (poorly reported in publications) some findings were not replicated (often in ostensibly superior equipment), or ascribed to (micro-) thermal effects.[8] Nevertheless, there are strong signals of significant effects.

Cultured human HL-60 cells exposed to pulsed 2.45 GHz had altered expression of 221 genes after 2 hours exposure, and 759 genes after 6 hours.[27]

Bacterial cells exposed to microwave radiation develop pores in the membrane, that healed following discontinuing irradiation.[21] This was perhaps related to the effects seen in liposomes above, and/or related to calcium loss.[28]

DNA damage, measured as single-strand or double-strand breaks, or with assays such as comet assay, have clear implications for cancer. A recent review of this area identifies DNA as a "fractal antenna" that has potential to be the basis of new standards for radiation exposure.[29] Non-ionizing radiation may shift shared electrons along the structure, causing damage, and more frequently used regions of DNA may be more affected.

Voltage-gated calcium channels may plausibly be related to biological effects and symptoms of electromagnetic energy, as reviewed recently by Pall.[30]

In vivo experimental studies

Two hour exposure of rats to 915 MHz GMS phone radiation (2W; SAR 0.4 mW/g) changed DNA conformation, affecting expression of 11 genes including proteins for neurotransmitter regulation, blood-brain barrier and melatonin.[31]

Reduced sperm motility and clumping were observed following 3 hours daily cell phone exposure of rats, over 18 weeks.[32]

Litter size, and the numbers of egg follicles in female rat pups were significantly decreased with maternal exposure to cell phone radiation 15 minutes daily.[33]

An example of how effects are interconnected is a report of how altered cellular calcium homeostatis with cell phone irradiation (800 MHz, 1 hour per week for 4 months), is related to

lymphocyte infiltration and tumour induction in a mouse model.[28] This same group studied calcium homeostasis related to synergism of radiofrequency radiation with aluminum[34] and with iron,[35] causing increased cancer in lymphoma-prone mice. Other researchers indicate that calcium loss from membranes such as the blood brain barrier may decrease protection of the central nervous system from drugs and toxins, as well as decreasing important hormones such as melatonin.[36,37]

Cell phone radiation (call answering mode) caused inflammation in rat liver and pancreas, in a dose-response pattern.[38]

Human cancer

Further to the above discussion of cancer with respect to the UK review, Hardell et al. recently published reviews of brain tumour findings relied upon by IARC,[39,40] as well as another case-control study of brain tumours associated with phone use, demonstrating increasing risks with latency.[41] They also published a recent update of analysis of cancer research according to the Hill criteria, and concluded that the IARC determination should be upgraded such that radiofrequency electromagnetic energy is a group 1, known carcinogen.[40]

Today's high prevalence of cellular and cordless phone use has effectively closed the window of opportunity for case-control or cohort studies of phones and cancer. The spotlight of scrutiny regarding cancer is now turning to large tumour registries to detect increases in the general population. Reservations with this approach include limitations of tumour registries in capturing numbers and locations of specific tumour types (changes in diagnostic codes also complicates this), and how long it would take the fraction of attributable cancers to rise above the data limitations and statistical "noise." Data limitations abound; for example, the Public Health Agency of Canada online InfoBase (http://204.187.39.30/surveillance/) offers data for only a few years at a time for each ICD version, and lumps together all neurologically based tumours so those located in regions of highest exposure with phone use are not discernable. Without sound historical data, increases cannot be detected unless medical records are accessed directly for data not captured during surveillance.

The issue of cancer from phones is becoming an issue of liability, that may eventually reach many players in the industry and scientific community. In 2012, Italy's top court ruled that a worker's brain tumour was the result of heavy cell phone use for 12 years.[42]

Non-cancer human studies

Non-cancer studies may be more informative regarding electromagnetic hypersensitivity, although many studies suffer from shortcomings such as those described above.

Recent non-cancer studies have focused on the brain, reproductive organs exposed to phones carried in pockets, etc., heart rate variability (HRV), transcranial magnetic stimulation (TMS), electroencephalogram (EEG), glucose metabolism measured with positron emission tomography (PET), near-infrared spectroscopy (NIRS) to measure oxygenation of hemoglobin, and other outcomes such as biomarkers. The following are a few examples, indicating that the "no effect" hypothesis cannot be supported.

Older studies found various biomarkers, such as immune markers in skin samples of patients affected by video display terminals.[37]

An Italian group investigating effects of cell phone radiation on the human brain found modified brain excitability in male volunteers,[43] decreased cortical activity and decreased reaction times in healthy volunteers [44] and elderly compared with young volunteers,[45] and increased the coherence of temporal and frontal alpha rhythms measured by EEG in epileptic patients, that has potential to be clinically significant in contributing to seizure activity.[46]

A landmark study published in the Journal of the American Medical Association demonstrated increased glucose metabolism in the area of the brain exposed to cell phone radiation (receiving mode) for 50 minutes.[47]

The autonomic nervous system control of the heart is fundamental to health, and the heart is potentially sensitive to electrical disturbances. Heart rate variability (HRV) was affected adversely by mobile phone emissions.[48]

Associated with the autonomic nervous system, stress markers are reported in many studies. For example, saliva cortisol, alpha-amylase, and immunoglobulin A were modulated with exposure level from a 900 MHz antenna mounted outside the building.[49]

Near-infrared spectroscopy (NIRS) has been used in a small sample of volunteers, demonstrating statistically significant changes in oxygenation of hemoglobin within 80 seconds of exposure to a cell phone (maximum peak SAR exposures of 0.18 W/kg and 1.8 W/kg).[50] A transient increase in blood oxygenation in the brain was observed.

In a 2007 study of neurobehavioural effects of living close to cell phone antennae, significant deficits developed in close inhabitants versus participants living at a distance.[51] The authors discuss exhaustion of homeostasis.

In a 2012 review of cell phone radiation and male reproduction, la Vignera *et al*. summarize experimental and epidemiological studies pointing to decreased sperm concentration, motility and viability with increased exposure to cell phone radiation.[52] Oxidative stress leads to membrane lipid and DNA damage in sperm. Decreased testosterone production and increased expression of genes for adhesion molecules may be significant contributors. Merhi also reviewed research on cell phones and reproduction, highlighting diverse research methods and outcome measures, some demonstrating altered physiology; more research is necessary.[53]

A prospective study recently reported changes in neurotransmitters in Bavarian villagers following installation of a cell phone tower in the centre of the village.[54] Buchner and Eger found that initial significant changes in urine levels of neurotransmitters (catecholamines) dissipated somewhat over the 1.5 year duration of the study, but chronic low levels of the precursor phenylethylamine are interpreted to be indicative of physiological exhaustion (per Selye's model). Urine levels changed in a dose-dependent pattern, with exposure estimated from outside the dwelling. All participants were affected, and the beginning of recovery was delayed at power density levels greater than 1 $\mu W/cm^2$. Participants using wireless devices tended to be comparatively more severely affected, as were the children who exhibited attention deficit disorders. Increased numbers of participants reported sleep problems, headache, allergy, dizziness and concentration problems.[54]

As mentioned above, early life exposure to cell phone radiation was associated with behavioral disturbances in two reports on children,[12,13] and more recently with asthma (indicative of immune disturbance)[14] and obesity (metabolic/endocrine disturbances).[15]

The bottom line of the current research is that exposure to levels much lower than present guidelines can have biological effects on multiple systems. Furthermore, the young and those with co-morbidities are at heightened risk. As well, pulsed signals are not comparable to continuous wave signals in terms of adverse effects. The strongest consensus appears to be that more research is needed, but that should not be an excuse for inaction on the basis of what we presently know.

Electrosensitivity (Electromagnetic Hypersensitivity)

The only topic not redacted from the Health Canada contract has to do with hypersensitivity to radiofrequency energy. Rather than seriously addressing the issue and seeking a critical, systematic review of related literature, Health Canada concluded *a priori* that there is no research supporting this condition and is dismissing the topic out of hand. It would be reasonable to expect citizens claiming to experience this condition, and physicians treating these patients, to react with outrage, and a conviction that the present review of Safety Code 6 is a charade.

Symptoms of electromagnetic hypersensitivity include poor sleep, fatigue, pain, headache, nausea, dizziness, vertigo, tremors, spasms, heart palpitations, memory impairment, difficulty concentrating, metabolic disturbance, impaired immunity and skin rashes.

Background

Peoples' widely varying strengths and vulnerabilities arise from their genetic makeup; prenatal, childhood and ongoing nutrition; lifetime environmental exposures; and experiences and activities, to name a few determinants of health.[55] The broad range of physiology across the population translates into vastly different abilities to adapt to exposures. As our modern environment is changing, some individuals are unable to adapt sufficiently, and develop sensitivities and other chronic conditions.

The "General Adaptation Syndrome" model, a fundamental precept in medicine, describes how the body responds to "stressors," broadly defined to include injury, a traumatic event, noxious exposures, electromagnetic phenomena, etc.[56] If the stress is not lethal, there is an initial "flight/fight" response, then a period of adaptation and eventually resistance to the stressor. Extended periods or a sudden surge in any stress (related or unrelated to previous stressors) may exhaust adaptive mechanisms, bringing a generalized breakdown of body systems and non-specific illness, sometimes called "Toxicant-Induced Loss of Tolerance." TILT is treated in part by reducing stressors, including chemicals as well as electromagnetic phenomena.[57,58,59] This model may also describe electromagnetic hypersensitivity.

A popular slogan post-World War II was "Better living through modern chemistry." People soon started reporting sensitivities to chemicals that had not previously been as common in personal and work environments. These sensitivities were reported variously as chemical allergies (a term now out of use as the field of immunology refined the definition of "allergy"), "sick building syndrome" (that emerged as indoor pollution escalated with decreased ventilation when buildings were sealed to save energy during the 1970s oil crisis), multiple chemical sensitivities and many other terms.[60,61] Many popular post-war chemicals such as the pesticides DDT and lindane, flame retardants such as PCBs, and more recently common plastics containing toxicants

such as bisphenol-A and vinyl chloride, were banned or increasingly restricted. Today major efforts focus on "green chemistry," to protect public health.[62]

Electronic wireless communication is still early in this evolution, as applications of innovative technologies have increased rapidly in the recent two decades. With increasing exposures it is anticipated that as with chemicals, adverse effects of radiofrequency radiation now seen in the most susceptible individuals will be experienced by increasing numbers.

An enormous literature, that is beset with the shortcomings described above (e.g. case definition, poor exposure characterization, lack of an unexposed control group, co-morbidities, etc.) addresses provocation and prevalence of symptoms of electromagnetic hypersensitivity in individuals self-identifying as so affected. Genuis and Lipp recently summarized medical aspects of electromagnetic hypersensitivity.[63] Earlier reports of sensitivities such as radio-wave sickness among workers exposed to radiofrequency radiation, have been followed in recent years by citizens' reports of sensitivities to electromagnetic exposures, and case reports of somatic reactions and physiological responses such as heart rate and heart rate variability. In addition, capillary blood flow and electric skin potentials may help to differentiate electromagnetic hypersensitive patients.[64]

Electrosensitivity is at best under-recognized (according to Gro Harlem Brundtland, past Prime Minister of Norway, and past head of the WHO, who experiences the condition herself), and at worst discounted out of hand, as by Health Canada. There are social and cognitive barriers to individuals recognizing it within themselves and others (indeed, the same is true for all environmental sensitivities, to perfumes, moulds, certain foods, pets, etc.). Research to "prove" existence of this condition requires attention to details of the condition.

Research into Electrosensitivity

Research into environmental sensitivities must ensure that comparison groups as well as exposures are well characterized and delineated, and confounding factors are eliminated to as great an extent possible. With no objective tests for electrosensitivity, and infrequent application of comprehensive screening methods (e.g. a lengthy questionnaire, and medical examination and testing to rule out other diagnoses), many researchers depend upon self-report for group allocation (hypersensitive versus normal). Joffres *et al*. described difficulties achieving reliable research results with patients experiencing sensitivities,[65] but their recommendations to ensure there are no background incitants, and to acclimatize participants to surroundings are rarely if ever described in protocols, leading to a lack of credible evidence rather than evidence of no harm.[66] Additionally, individuals with electromagnetic hypersensitivity often experience other sensitivities, so may well react to uncontrolled variables in the research facility, such as airborne chemicals as well as uncontrolled background electromagnetic energy.[63] Thus it is difficult to ensure a good baseline (subjects should not have recently been exposed to radiofrequency energy, or to substances that incite symptoms), and if subjects encounter both sham and test exposures during one session, the researcher must ensure that symptoms have completely resolved between exposures (notably, some people report taking hours or days to recover from exposures). In this light, most provocation research is highly flawed. There nevertheless are suggestions in the research of significant effects even among those who do not self-identify as being sensitive. For example, studying headache associated with using cell phones, Hillert *et al*. noted, "The higher prevalence of headache in the non-symptom group towards the end of RF exposure justifies further investigation of possible physiological correlates. The current study

indicates a need to better characterize study participants in mobile phone exposure studies and differences between symptom and non-symptom groups."[67] Importantly, continued exposures that initially elicit mild symptoms may eventually exhaust physiological adaptive capabilities and result in more severe sensitivities.

Epidemiological studies are unlikely to find a correlation between ongoing radiofrequency exposure and symptoms of electromagnetic hypersensitivity, because people with sensitivities avoid exposures that provoke symptoms. This happens both intentionally and instinctively. Indeed, due to such avoidance on the part of people with sensitivities, it would be unexpected to find a dose-related correlation in an ecological ("snapshot") study of avoidable exposures and symptoms attributed to electrosensitivity; yet this lack of correlation is noted as disproving the condition.[68]

The power of epidemiology is also inevitably limited by the evolving state of the world. As technologies and their use develop there is a shifting baseline of exposures. Today everyone in the world is exposed to anthropogenic radiofrequency energy, so comparisons are shades of grey, between more- and less- exposed individuals or groups. Sadly, refuges for those who experience adverse effects are fewer and further between, so these people may be cut off from society, isolated and spurned.

Environmental sensitivities diagnosis and treatment

Despite shortcomings with provocation experiments and epidemiological studies of this population described above, research into electromagnetic hypersensitivity progressed with efforts of Eltiti et al. to standardize measures such as a questionnaire.[69] Nevertheless the lack of a case definition and diagnostic criteria, and reliance upon self-report for case ascertainment still pose obstacles to research and care.[70]

According to Canadian expert physicians, diagnosis of environmental sensitivities involves thorough initial investigations to treat and rule out other possible explanations for the symptoms, then "ruling in" the sensitivities based upon the principles enunciated in the international consensus criteria originally devised for multiple chemical sensitivities, such as reproducibility of symptoms with exposure, chronicity, improvement with removal of incitants, and response to low levels of exposure (lower than previously or commonly tolerated).[71]

Indeed, it is somewhat common for people with electrosensitivity to have chemical sensitivities as well, or for chemical sensitivities to "spread" to electromagnetic exposures. Fortunately, addressing the entire load of stressors may bring improvements in this chronic condition.[63,59] The Austrian Medical Association also reviewed evidence for EMF-related health problems, and released guidelines for diagnosing (including many objective tests) and treating patients with "EMF syndrome."[72]

Tuengler et al. recently reviewed objective measures distinguishing electromagnetic hypersensitive participants from others, and recommends measuring HRV, capillary blood flow and electric skin potentials.[64]

Electromagnetic hypersensitivity recognition

Recognition of electrosensitivity as an important issue is reflected in many committed, hard working groups of individuals whose experiences have convinced them that this is an important issue, including some submitting to the RSC Panel. Although doubtless not a complete list, the following are some more examples.

Electromagnetic hypersensitivity has obviously garnered much attention in terms of research publications, with dozens of publications listed in the US National Library of Medicine (www.pubmed.gov).

Within Canada, medical aspects of environmental sensitivities, including sensitivity to electromagnetic phenomena, were described in a report for the Canadian Human Rights Commission.[60] The CHRC has a policy regarding accommodation of individuals with environmental sensitivities, and urging least-toxic practices to prevent development of sensitivities in others.[73]

Physicians at the Women's College Hospital Environmental Health Clinic, who are academically affiliated with the University of Toronto, have summarized research into etiology, prevalence, diagnosis, treatment and primary prevention of environmental sensitivities / multiple chemical sensitivities, including electromagnetic hypersensitivity.[61] This group provides continuing medical education to physicians, and makes available materials such as a form to guide physicians in querying and recording a patient's Environmental History, including exposure to radiofrequency radiation sources.[74] They also convened a conference on electromagnetic hypersensitivity (Toronto, 2012).[75]

Dr. Magda Havas PhD at Trent University has conducted research, and popularized a lot of information about electromagnetic phenomena and health, particularly at low exposure levels. (www.magdahavas.com, www.magdahavas.org).

There are many international examples of recognition of the importance of sensitivity to electromagnetic phenomena; I will mention a few.

The US National Institute of Building Sciences and the Access Board recognize that Electromagnetic Fields may be a barrier or issue for access to public and work spaces, recommending minimizing exposure via design and personal actions.[76] The US Environmental Protection Agency took its advice in design of a large facility, seeking advice on electromagnetic fields.[77]

Sweden recognizes that electrohypersensitivity is a result of environmental exposures, and that citizens have a right to have their environment rectified.[37]

The Irish Doctors' Environmental Association "believes that a sub-group of the population are particularly sensitive to exposure to different types of electro-magnetic radiation." The Association discusses symptoms clearly related to electromagnetic radiation exposure, with recommendations for patient care and more restrictive regulation of technologies.[78]

The Austrian Medical Association reviewed evidence for EMF-related health problems, and released guidelines for diagnosing (including many objective tests) and treating patients with EMF syndrome.[72]

The International Association of Fire Fighters have a position that communication towers not be placed on fire stations, based upon a lengthy research document.[79]

Canada is among least protective nations

Health Canada's assessment paradigm, that biologically perturbing exposures are permissible unless and until harm is also conclusively proven, represents a scientific double hurdle. This approach is not shared by some other jurisdictions. For example, even if the effects are transitory

or there is an adaptive response, Russia considers that immunological effects of radiofrequencies (first observed many decades ago) were sufficiently concerning that regulatory exposures are a small fraction of those in Canada's Safety Code 6 (see Table 1, adapted from the Israel Ministry of Communications).[80]

Table 1. Comparison of Radiofrequency Power Density Permitted in various countries (after Mazdar)[81]

Country (most to least protective)	Permitted power density, compared with International Commission for Non-Ionizing Radiation Protection (ICNIRP) Standard
Switzerland	0.01
Italy	0.02-0.2
Poland	0.02
Luxembourg	0.05
China	0.08
Israel	0.1
Bulgaria	0.12
Italy	0.02-0.2
Russia	0.2
Belgium	0.25
Greece	0.8
Canada, USA, Japan	**1.33**

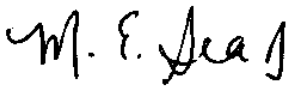
In conclusion, on January 23rd, 2013, the European Environment Agency published "Late Lessons From Early Warnings, Volume II," including a section on hazards of electromagnetic radiation.[82] Volumes I and II describe harms of delayed actions on known toxicants, the benefits of precaution, and the history of vested interests delaying important actions.

Society evolves, from enthusiastically embracing technological breakthroughs, to cautious concern, to recognition of harm, to restrictions of technology and more prudent uses. For example, X-ray machines ("fluoroscopes") were once used to fit shoes, but are now restricted to medical diagnostic imaging and cancer treatment, with considerable efforts to further limit exposures. Regulations and technologies need to be adjusted prudently, to limit exposures to the most important applications, where alternatives are not feasible. Indeed, considerable scientific evidence currently exists to justify curtailing and modifying our increasing reliance upon wireless communications, at every opportunity.

Canada has an unfortunate history of taking many decades to act upon important public health hazards. Sixty years passed between Europe and Canada acting on lead in paint, to the detriment of generations of children. Tobacco is an ongoing issue, we are very slow to act on asbestos and mercury, and we are impeding global actions on climate change. The RSC Panel has a rare opportunity to bring Canada from among the worst in the world, to the forefront of standards for exposure to radiofrequency energy, with concomitant innovation opportunities. Recommendations are summarized at the beginning of this submission.

Some of this material was drawn from writing for a hearing before the British Columbia Utilities Commission. I received no reimbursement for the present submission. I hope that the present discussion is helpful, and would be honoured to assist the Panel further in this important endeavour.

Respectfully submitted by



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