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Health Risks of Cellular Telephones: The Myth and the Reality

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CONTENTS

Executive Summary

The issue of exposure to electromagnetic radiation is rising in public consciousness and as such is a topic with which public health professionals will undoubtedly become more familiar in the future. Among the numerous sources of exposure to such radiation are cell phones and base stations. Though this paper specifically focuses on cell phones, the information presented must ultimately be considered through a much broader lens; one that includes the many, varied sources of exposure to electromagnetic radiation in our environment. This paper is intended to serve as a base from which the OPHA can further explore and become active on the issue of exposure to radio frequencies (RF). The focus of this paper is strictly on the RF-fields emitted by hand held cell phones, we do not address any other type of RF-fields which will be addressed separately in future reports. Another source of exposure to RF-fields closely associated with cell phones is "cell towers" emission. The emission by telephone towers will not be addressed here either as it was the subject of an in-depth report by *Toronto Public Health in 1999*.

Cell phones have become a ubiquitous means of communication. The 'mobile' phone has obvious advantages over a fixed line: it offers extraordinary accessibility and security. Businesses and individuals are increasingly dependent on this relatively new communication tool which is here to stay.

Due to their wide-spread use, and fueled by numerous (frequently conflicting) media reports about the biological and possible adverse health effects of the radio-frequencies emitted by cell phones, there has been public concern about the safety of this relatively young technology, particularly with respect to cancer and potential neurological effects. This paper addresses the safety of cell phone use and attempts to summarize the potential risks to health reported in the peer-reviewed literature.

Exposure to RF-fields in the frequency-range emitted by cell phones elicit a host of biological responses and therefore *do* represent an unnatural stressor to the biological system no matter how small. On the other hand, the majority of the *reported* adverse effects are associated with the heating of the tissues exposed to the RF-fields, effects that requires field strengths that are orders of magnitudes stronger than those emitted by a single cell phone antenna. While a conclusive link between a specific health risk and the long term use of hand cell phones has not been unambiguously established,, organizations such as the Royal Society of Canada have concluded that insufficient research has been done to conclude that radio frequencies do not present long-term health concerns (RSC, 1999). One particular deficiency in most epidemiological studies published to date is that they do not cover periods of time that are long enough to demonstrate chronic impacts that may be associated with long term-use (since the wide-spread use of the cell phone is relatively recent). Research results, while contradictory, have demonstrated impacts that could prove significant from a public health perspective, because of the widespread nature of exposure. For example, there are suggestions that radio frequencies could promote cancer by stimulating an enzyme that is related to cell growth and development (TPH, 1999). This, in conjunction with the very fact that a host of biological effects can be induced by the RF-fields of a cell phone, suggests that the best approach is to use cell

phones with caution until 'proven' safe. There is a need for more research on the possible role of RF-fields as cancer promoters, and on the possibility of harmful synergistic effects between RF-fields and other factors. Such a synergy may be another reason for caution.

We present a number of recommendations in line with the precautionary principle (PP). These recommendations can be classified in three broad branches:

1. Recommendations about the dissemination of information to the public about the risks to health from the use of cell phones.
2. Recommendations about enforcing existing *Health Canada* standards, Safety Code 6 (SC6), on cell phone antenna emission specifications and regulating certain facets of cell phone use.
3. Support for *Toronto Public Health*'s "prudent avoidance" principle and for their recommendation of drastic reduction in exposure limits set forward in SC6, the current Canadian guidelines.
4. Recommendations for further research.

Disclaimer

1. The information in this paper is to be used within the context and spirit in which is it presented only. It is intended to support a precautionary approach toward human exposure to non-ionizing radiation, particularly with respect to cellular phones and the equipment associated with them.

2. Any reference to brand names or products is only for illustrative purpose. It does not imply in any way the endorsement of either OPHA or the authors for that particular commercial product.

3. Any error or mistake is the sole responsibility of the authors. No such responsibility falls on any other person or organization mentioned in this paper including the "Acknowledgements" section.

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Purpose

Mobile telephones have become an essential communication tool in the global modern society. According to the *Australian Mobile Telecommunication Association* (AMTA),[1] mobile phone use world-wide approached 500 million in 2001,(through Ref.[2]) and will exceed one billion users by the year 2005.[3] In Canada, mobile phone use has seen a similar explosive growth from 100,000 in 1987 to over 9.5 million users in 2001.[4] Mobile phones are gaining unprecedented popularity and their widespread use brings with it the issue of their potential impact on health. This matter attracts much media and public attention with a flood of often conflicting reports and inconclusive results. Adding to the confusion, some sources of information are interested parties, for example some manufacturers. There exists significant confusion about this topic, both in the general public and among public health professionals. We feel that it is important to establish a basis for understanding the scientific information available, to sort out what is factual and what constitutes merely opinion about the safety of mobile phones.
Our goal is not to duplicate existing reviews,[1] but rather to use information gathered from a number of reliable sources[2] to lay out, in non-technical language, what is known and what is still controversial. The purpose of this position paper is, therefore, to:

1. Define the issue of potential health hazards associated with cell phone use and briefly re-visit the possible biological effects and possible health risks to humans.
2. Review some of the regulatory aspects recommended by national and international bodies and their applicability to mobile phone usage in Ontario.
3. Suggest strategies for the public dissemination of knowledge on the topic.
4. Suggest further research aimed at pinning down the potential hazards and at identifying the safer modes of utilization.

Exposure to non-ionizing electromagnetic radiation of the radio-frequency (RF) range is a very broad subject, however, this paper is limited to the health hazards of RF emitted by cellular phones (as opposed, for example, to wireless/cordless phones).

[1] See for example Refs.[3-5,7,19,39,40] and references therein.

[2] By "reliable source" we mean a publication in a peer-reviewed main stream journal, a view expressed by a panel of experts, by national or international health organizations or regulatory agencies, or by an official affiliated with such bodies.

Introduction

The electromagnetic radiation at frequencies below the visible range do not have enough energy to ionize molecules and are referred to as *non-ionizing radiation*. It is important to clearly distinguish exposure to these types of radiation from exposures to much higher frequencies (higher than frequencies of visible light). Radiation with frequencies higher than the visible light (such as ultra violet, x- and (-radiation) are known as *ionizing radiation*. They interfere with the biological system primarily by ionizing water and biological molecules, breaking chemical bonds, and producing highly chemically reactive free radicals. This paper addresses non-ionizing radiation only.

Non-ionizing radiation represents a continuum that can be broken down into distinct regions. This review concentrates on the narrow range emitted by a typical cell phone antenna (800-900 and around 1800 MHz).[5] Cellular base stations, required to relay messages in the form of directed modulated electromagnetic waves, also emit within the same range.[5] These frequencies fall in the wider range of the so-called ultra high frequency (UHF) range of the spectrum (0.3 to 3 GHz).[6] An extensive review of the potential health impacts of cellular-base stations can be found in the 1999 Toronto Public Health report *'Health Concerns of Radio Frequency Fields Near Base Telephone Transmission Towers'*. [7] It is hoped that this paper will complement and provide further support for this report by focussing on the hand held set itself.

To elicit a biological response, RF fields must directly influence the molecules and ions of a biological system. RF fields affect molecules and ions: their relative orientation in space, their distributions of electronic charges, and their various motions. (See for example [8]). For these effects to have observable consequences however, they must overcome the random statistical thermal noise to which molecules are constantly exposed. This implies that there should exist a threshold for RF field power below which no biological effect would be observed. On the other hand, molecules do not respond instantaneously to an external perturbation; they need time to re-orient in space as the field changes its direction (as it changes during its periodic cycles). Therefore, there should also exist a cutoff frequency above which no response would be observed.[3] The inability to observe a biological effect does not necessarily imply that such effect or/and adverse health effect(s) are not present.

The adsorbed energy depends on the length of exposure, the proximity of the antenna to the tissues, the geometry of the antenna, the direction of the emitted beam, in addition to the emitting power of the antenna itself.

Exposure and its Measurement

Exposure, and hence the potential adverse effects, depend on the amount of radiation energy deposited in tissues. Exposure to RF fields is broadly categorized into two qualitatively different types:[6]

1. **Near-field (or reactive field) exposure:** Exposure in close proximity to the emitter.

2. **Far-field exposure:** Exposure to a field emitted from a distant source.

There is no sharp boundary between near- and far- fields, but a rule of thumb is that the boundary between them can be taken as the greater of the two quantities, 8 and $2L^2/8$, where 8 is the radiation wavelength and L is the length of the antenna.[6] (This relation applies for antennas shorter than the wavelengths they emit as is the case with most cell phones on the market nowadays). As an example, a cell phone with a 10 cm antenna emitting at 8 = 35 cm, these two quantities are: 35 and $2\%10^2/35=5$, and therefore exposures that are less than 35 cm from the antenna are near-field.

Near-fields are very non-uniform and regulation of their emitting power must define maximum limits for both the electric and the magnetic components separately (unlike far-fields where the ratio of there two quantities is constant, the impedance, and thus measuring or regulating one component suffices).

The extent of RF field exposure depends on the field strength, expressed as the 'power density', i.e. the power passing through a unit area (watts per meter squared (W/m^2)). Power density can be estimated from measurements of either the electric field strength or the magnetic field strength for the far-field, but both measurements are required to characterize near-fields. The power density, while important in characterizing hardware, does not reflect the amount of energy deposited in the tissues. Because biological impact depends largely on the amount of energy deposited in tissues, another measure must be introduced, namely the *specific absorption rate* or SAR. SAR measures the rate of energy deposition in tissue regions, i.e. the amount of energy absorbed per unit time per unit mass of tissue and is expressed in W/kg. It is possible to estimate cumulative absorbed dose from the product of SAR and the exposure time (in seconds), but most guidelines limit themselves to power densities and SAR.

There is evidence that exposure within a closed (or partially closed) metallic environment may increase exposure due to the reflection of the RF-fields on the metallic walls. Such a situation may present itself upon using a cell phone within a vehicle. Thus, besides the increased (four-fold) risk of collision when using a cell phone while driving,[9] there is a possibility of reinforcing the exposure from the reflected signals[10] on the inner metallic surfaces of the car.[11] Simulation studies do show such reinforcement and reflection, however no study (to our knowledge) specifically address this question. The field and SAR characteristics of a cell phone within a closed metallic environment such as a car remain largely unexplored. While not directly inked to the biological risks of cell phone,

mortality and injury due to distraction caused by the use of cell phone by motorists is definitely another (and established) *health risk* of cell phones. We take this opportunity to also support the recommendation of the WHO [3] and others [12] (based on the increased risk of accident) to take action to restrict the use of cell phones on the road. A large scale recent study has proven that the introduction of legislation restricting the drivers' use of cell phones has a strong effect on behavior, cutting by more than half the use on the road, however the long-term compliance has yet to be proven.[13]

Biological Effects and Health Hazards from Exposure to Cell Phones RF Fields

It is important to distinguish between 'biological effect' and 'health hazard' - not every observable biological effect of the fields is necessarily *known* to be harmful to health. A biological effect triggered by an external perturbation is, by its very definition, unnatural and therefore potentially harmful. As mentioned in the introduction, the mechanism of action of mobile phones RF fields is not ionization. The mobile phone RF fields fall within the broader range (300 MHz to several GHz), a range characterized by non-uniform (significantly local) absorption by the tissues.[3]

The biological effects of the RF fields of interest can be broadly grouped into

1. **Thermal effects:** due to local heat production just like the mechanism of a microwave oven,

2. **Athermal effects:** result from the absorption of enough energy to cause a temperature increase, but one largely compensated for by biological temperature-regulating mechanisms (therefore resulting in no observed increase in temperature),

3. **Non-thermal effects:** effects triggered by an amount of energy absorption too low to raise the temperature of the tissue and which is less than the normal biological temperature fluctuations.

RF-fields can produce a very wide range of measurable biological effects. In addition to what can be measured at the present stage of scientific investigation, it is likely that other completely unknown effects remain to be discovered. A review of the biological effects of RF-fields, and their implications for effects on human health far exceeds the scope of this paper and the reader is referred to the literature (see for example Refs. [3,5,10,14-19]). What follows is *only a sampling* of some studies (and potential health impacts) of interest. We list some here, but the interested reader is referred to the reviews [14] and the references to the original literature listed therein. Example of potentially harmful biological effects include:

1. **Effects on biological membrane permeability:** RF-fields alter the transport of cations through ion-channels located in biological membranes. The change in

ion-transport through the membrane can affect the membrane potential and nervous signal transduction.

2. **Effects on cell growth and proliferation**: RF-exposures of cells *in vitro* has been linked to changes in transcription and cell proliferation assayed by the incorporation of an RNA-precursor and a DNA-precursor, respectively. RF-exposure has also been linked to changes in cell cycle. (See review [19]).

3. **Cancer:** Most laboratory studies were unable to find a direct causal connection between exposure to RF-fields at athermal or non-thermal levels and the incidence of mutation or cancer. Most *in vitro* studies reporting DNA or chromosomal damage were conducted at exposure levels that resulted in thermal effects. In contrast, several *in vivo* studies in rodents indicate a direct effect of RF-fields on DNA. Increased incidence of cancer in controlled experiments is equivocal and could be linked to thermal effects. (See review [19]). Based on several epidemiological studies examining the incidence of cancer in populations exposed to RF fields in the 100 KHz to 300 GHz range (and in the narrower range specific to cell phones), it appears that there is no statistically-significant association between cancer and the exposure to cell phone fields. (See for example [3,17,20-22] and references therein). Evidence from in vitro studies to date is consistent with these epidemiological results. For example, a recent in vitro study reports no effects on the frequency of neoplastic transformation after exposure to cell phone RF-field (835MHz, and 848MHz) at 0.6 W/kg for 7 days in cell cultures.[21] It must be emphasized that cell phones have not been in use long enough to allow for a "comprehensive epidemiological assessment of their impact on health, and we cannot, at this stage, exclude the possibility of some association between mobile phone technology and cancer", as stated in a review by a *World Health Organization* (WHO) expert on the subject.[3] There is also a general lack of understanding of the mechanism by which tumours might be initiated or promoted by RF-fields. It seems that most biological effects reported in the literature occur under extreme conditions which are most likely to be accompanied with induced heating resulting in at least a 1ºC rise in body temperature, consistent with SAR which is above 1-2 W/kg.

   Despite the apparent lack of a statistical link to cancer, the suspicion of cancer-promoting effects is however, significant enough to be considered a potential risk to human health by the Swiss Agency for the Environment, Forests and Landscape in their 1999 *Ordinance Relating to Protection from Non-Ionizing Radiation,* which based it's conclusion on a June 1998 report published by the US National Institute of Environmental Health Sciences that recommended the classification of low-frequency RF-fields as "possibly carcinogenic".

4. **Effects on the immune system:** Some evidence of immune system response similar to those resulting from thermal stress are triggered by non-thermal exposure to RF-fields, however more research is needed. Adverse effects on the

immune system can indirectly predispose to infection and to cancer. (See review [5] and references therein).

5. **Effects on the nervous system:** Inconclusive results indicate a possible change in the blood-brain barrier permeability under the influence of RF-fields. Changes in the brain electrical activity, in the release of neurotransmitters, in melatonin secretion, and in the retina, iris, and corneal endothelium have been reported. The effects on the nervous system include (but are not limited to) well-documented behavioral, cognitive,[15] neurochemical,[23] and neurological [24] effects in humans and laboratory animals (see references cited in Refs. [2,15,23,25]). Some of these effects are significant enough that they have prompted more stringent regulations in Europe around RF-field exposure.[7] A recent report shows a significant change in rat brain electrical activity following low-level exposure to cell phone RF-field (continuous irradiation by 700 MHz field of 25-71 V/m for 5-15 min).[25] The study attributes these changes to the non-thermal effects since there was no significant rise in the temperature and as the effects could not be duplicated when a 1ºC rise in temperature was imposed.[25] Beason and Semm studied the effect of exposure to cell phone RF-field on the brain of anesthetized birds and found a marked rise in the neural activity by more than half of the brain cells under the effect of the field.[24] De Seze et al. found no significant effects of cell phone RF-field on the auditory brainstem or the endocrine system, but found a slight increase in the activity of the Q-EEG.[26]

6. **Oxidative stress:** In healthy organisms there is a constant production of the so-called reactive oxygen and nitrogen species (ROS and RNS, respectively). The ROS and RNS are very reactive and can attack a host of critical cellular organelles and molecules, including DNA. In healthy aerobic organisms the production of the harmful ROS and RNS species is balanced by antioxidant defense systems and repair mechanisms. If this balance is disturbed, the result is an increase in the likelihood of cell injury and damage which can lead to cancer or cell death.[27] A recent study on 12 human volunteers exposed to continuous cell phone emission for up to 4 hours showed a slight (but statistically-significant) oxidative stress response and a consistent rise in plasma-levels of lipid peroxidases with the duration of exposure.[28] At the same time levels of antioxidases in the erythrocytes decreased.[28] Oxidative stress is typically induced by ionizing radiation through direct homolysis of chemical bonds. In the case of non-ionizing radiation such as RF-fields, another mechanism must be involved, e.g. by stabilizing the reactive species or by destabilizing the parent molecule.

Most research conducted to date has looked at thermal effects. There is however, concern as well as scientific uncertainty about the non-thermal effects of RF-fields. A mechanism recently proposed for the non-thermal effects of pulsed RF-fields is protein conformational changes (denaturing of the proteins) brought on by a transient change in local temperature.[29] A "local" heat-shock response is postulated as a possible

mechanism for cancer induction by chronic low-level exposures to cell-phone RF-fields.[30]

Other researchers highlight possible effects of extremely low frequencies emitted from rechargeable batteries of cell phones,[2] a topic largely unexplored in the literature. This adds another dimension of uncertainty to the process of establishing exposure limits with respect to non-ionizing radiation.

In conclusion, there exists evidence that links a very wide variety of biological effects to RF-field levels emitted by a cell phone antenna. What is uncertain is the magnitude and nature of the health hazard associated with biological effects brought on by typical exposure levels and patterns.

Risk-Reduction Measures and Regulations

1. Regulations of the Field Strength and Power Density

In Canada, consumer exposure to radiation is regulated primarily under the *Federal Radiation Protection Act*, applied and enforced by Health Canada's *Radiation Protection Bureau*. Radio-communication equipment (including cell phones and base stations) is regulated by *Industry Canada*. There exists an agreement with the *United States Federal Communications Commission* (FCC), which essentially results in a North American standard with respect to equipment construction and radiation emission (though Canada's position with respect to radiation hazards is slightly more stringent than that of the U.S.). When developed, cell phone equipment must be tested by manufacturers and/or distributors to ensure compliance with regulations; compliance is monitored through occasional and random testing done by Industry Canada.[31]

Canadian exposure limits for non-ionizing electromagnetic radiation are set in accordance with guidelines established by Health Canada guidelines: *Safety Code 6 (SC6)*. These guidelines establish exposure limits to RF -frequencies in the 3kHz to 300 MHz range for both occupationally exposed workers and the general public.[32] For frequencies falling between 1500 MHz and 15000MHz, uniform non-frequency-dependent limits were put forward (see Table 1). (See Appendix I for details on calculation method for exposure limits).

We calculated the exposure limits for the range of interest (800-900 MHz) and around 1800 MHz according to *Health Canada*'s Safety Code 6 guidelines for radiation exposure (See Appendix II: Table 1). We are not aware of a study that has established whether or not the average cell phone in Canada abides by these limits. Canada's exposure limits, as set out in SC6, are similar to those of most other national and international bodies. An equivalent set of exposure limits (slightly more stringent) was put forward by the *International Commission on Non-Ionizing Radiation Protection* (ICNIRP). The *Federal Communication Commission* of the United States (FCC) recommends the same limit on the power density for the general population (frequency/150) but does not explicitly give

the electric field and the magnetic field strengths. Instead, the FCC uses an averaging over 30 minutes.[33]

There are however, indications that these exposure limits may be too high. A consensus reached at the *International Conference on Cell Tower Siting* held in Austria three years ago implied that the numerical limits in SC6 were 100 times higher than the levels considered safe by an international panel of 21 world experts (with two abstentions).[34] The exposure limits for the public to cell phone base station antennas in Canada are higher than in several other countries, some limits are for example: 10 W/m^2 (Canada, at 1800MHz, see Table 1, Appendix II); 2 W/m^2 (Australia); 0.1 W/m^2 (China, Italy, Scotland).[34] *Toronto Public Health* has recommended revising SC6 to meet the recommendation of this panel of experts, i.e. to reduce the limits by a factor of 100.[34] To be consistent with the spirit of this recommendation, every entry in Table 1 (Appendix II), and of course the more comprehensive SC6 standards, ought to be divided by 100.

Though Canada's regulation of exposure to non-ionizing radiation is in line with the approach taken across much of the world, the fact that other developed countries, as well as one of the largest Canadian public health agencies, Toronto Public Health, have taken steps to promote and/or implement lower exposure limits, indicates a need to revisit existing exposure limits and to consider them through the lens of a more precautionary approach; one that considers the many uncertainties inherent in calculating exposures and risks, as well as the current limitations of the scientific research on the health effects of exposure to non-ionizing radiation.

2. Regulations involving the Specific Absorption Rate (SAR)

The Specific Absorption rate is a key element in the calculation of exposure limits. It is important to realize that SAR is a combined *property* of a specific tissue region exposed to a particular type of radiation; it is not strictly a measure exposure. Exposure can be estimated from SAR only when the duration of exposure is taken into account. Restrictions on SAR levels are subject to regulatory considerations to prevent harmful exposures within 'reasonable' periods of time. For example, a whole-body SAR of *ca.* 4 W/kg exposed for about 30 minutes would provoke biological and health effects consistent with a body temperature rise of more than 1ºC.[10] For example, ICNIRP as well as the FCC sets the limit for whole-body exposure for occupationally-exposed workers to 0.4 W/kg (the 10^{th} of the SAR necessary to raise the body temperature by 1ºC in 30 min) and for the general public, a further safety margin is recommended limiting the exposure to half of that allowed for RF-workers, i.e. 0.08 W/kg in the frequency range of 10 MHz to 10 GHz.[10]

Determination of both the SAR for body tissue regions (i.e. head, trunk, eye, etc…) and exposure levels considered acceptable, rely on quantitative risk assessment. This process combines available research data, models and expert opinion to come up with an estimate of risk from exposure to a substance or force of concern.[35] A valuable tool in decision-making and regulation, risk assessment is however, subject to a number of limitations, some of which may apply here. These include but are not limited to the following:

1. Gaps in scientific knowledge.
2. Exposure levels based on modeling as well as estimates of frequency of exposure may not include all possible sources of exposure.
3. Common lack of consideration of multigenerational effects.
4. Tremendous individual variation in risk for effects from specific hazards due to age, health status, genetic make-up, etc.
5. The impossibility of gauging the effect of concurrent exposure to the many substances and forces people are exposed to.

To compensate for uncertainty, safety factors are built into risk assessment calculations. These are however, also 'best guesses' based on the existing evidence. For non-ionizing radiation exposure for the general public, *Health Canada* has introduced a safety factor of 50, i.e. the acceptable exposure level is 50 times below the threshold of potential harm as determined by scientific consensus [35].

Health Canada has introduced more stringent regulations regarding the specific absorption rate (SAR), which according to SC6 now must be determined for all exposures that take place at 20 cm or less from the source [32] (and hence applies to cell phones). The SC6 guideline states that SAR limits should take precedence over the field strengths and power density measurements. Table 6 of SC6 sets these limits (for non-occupational exposure) as 0.08 W/kg for SAR averaged over the whole body; 1.6 W/kg for head, neck, trunk averaged over any one gram of tissue; and 4 W/kg for the limbs averaged over 10 grams. A maximum 0.2 W/kg for the eye, although this is not a formal requirement.

It is to be emphasized that the Health Canada SC6 guidelines suggests a "global" exposure limit when an individual is exposed to different fields simultaneously (see pages 12 and 13 of Ref.[32]). The limit to total exposure is such that **the sum** of the ratios (i.e. each field intensity divided by it's own exposure limit) does not exceed 1. Thus a cell phone user who is simultaneously exposed to other stray fields can be exposed to more than the recommended field density even if their cell phone complies with the SC6 guidelines (Table 1). The cumulative effect of other fields to which an individual cell phone user may be exposed should be a topic for further investigation. Additional indoor exposures can be microwave ovens, clothes washers, television video display terminal sets etc. while outdoors may include power lines, radar beams, etc. More study on the effect of simultaneous exposure to cell phones RF-fields and other stray fields is necessary.

3. RF-shields between the cell phone and the user?

Phone-shielding technologies, which redirect and control the near-field, exist. When an emitter is attached to the hand set then the exposure is of the near-field type. Since, in most cases, the cell phone is normally held very close to a user's body (especially the head), it is imperative to address the issue of near-field exposure. Several shielding fabrics, kits, and devices that can be fitted to a regular cell phone are commercially available. See for example Ref.[36]. These shielding devices would be most effective

when the phone is used outdoors, far from reflecting (particularly metallic) surfaces. Their effectiveness when the phone is operated inside a car, for example, is expected to be less due to reflection. A recent report by a WHO expert casts doubts on the effectiveness and even the need for RF *absorbing* device, however it is not clear if the author means the shields (which may partly act as *reflective* devices) that are the subject of this recommendation. The shields may have merit and the government of Canada is encouraged to examine these protective measures and promote them if proven effective. Though RF exposure from regular cell phones appears to deliver a very small amount of energy to tissue, and currently therefore appear generally harmless, it is prudent to further reduce exposure where possible. The effectiveness of shields in reducing exposures to cell phone RF fields is relatively unexplored (to our knowledge) and we would suggest this question for further scientific investigation.

Recommendations

The existing lack of clarity about the actual health hazards posed by cellular telephones, reinforced by differing recommendations for standards set by different regulatory agencies and authorities, extends to many public health professionals. It is therefore important that clear, accessible and meaningful information regarding this topic be made available. Quoting from the WHO's Fact Sheet No. 193: "*Given the immense numbers of users of mobile phones, even small adverse effects on health could have a major public health implications*".[37]

As reports about the safety of cellular phones are frequently conflicting, and in view of the wide range of possible biological effects (both known and yet to be discovered), the recommendations below reflect an approach based on the Precautionary Principle.[38] This principle, incorporated into law in a number of European countries and currently being explored by the Canadian government, dictates that a lack of scientific certainty is no excuse for inaction where there is a potential threat to human health or the environment.

The following recommendations are directed to the general public and to the Canadian health authorities and regulatory bodies:

1. **There is no cause for public alarm but there is no basis for public leniency either**
   At this point research has not established a definite link between the use of cell phones and the induction of serious health effects. However, a large body of evidence shows that the RF-fields emitted by a cell phone antenna do induce a plethora of biological effects, the long-term effects of which are not yet clear.

2. **Promote caution in the use of cell phones until they have been proven safe**
   As there is no definitive answer regarding the potential health risks or safety of long-term exposure to cell phone RF field, the public and regulating bodies should lean toward caution until use has been proven safe. We, thus, join Toronto Public Health in urging the public to adopt a prudent avoidance attitude with respect to RF-field exposure, in this case that from cell phones.

3. **Increase public awareness about possible sensationalization and inaccuracy of reports (especially by the media and by manufacturers) on possible health risks of cell phones.**

4. **Government control/regulation cell phone specifications in Canada**
   The federal government is urged to introduce strict governmental research, quality control and testing with regards to the specifications (power, frequency, beam characteristics, etc.) of cell phones available in Canada. The recommendation by Toronto Public Health to reduce the SC6 exposure limits by a factor of 100 has merit and deserves serious consideration by Health Canada.

5. **Raise awareness of possibility of concurrent exposure to other sources of RF-fields, in which case acceptable exposure limits to cell-phones should be lowered.**
   The likelihood of simultaneous exposure of a cell phone user to other stray fields may present another reason for concern about a cumulative exposure. More research is need to establish whether a synergistic effect between such stray fields an those emitted by a cell phone can increase the risk of exposure.

6. **Explore the utility and effectiveness of RF-shields between the cell phone and the user.**

7. **Promote the avoidance of cell phone use in partially closed metallic environments e.g. cars, buses, elevators, etc. until the reinforcement of the exposure from the reflected field is determined.**

8. **Re-emphasize to the public the 'common sense' basis for reducing exposure:**
   - Other factors equal, choose the cell phone with **lowest output** power.
   - **Maximize** the distance between the body and the transmitter.
   - **Minimize** the time spent in the RF field by limiting the use of cell phones to short communications and emergencies - avoid long conversations and frequent use.

9. **Promote more research on synergism between RF-fields and other environmental factors.**
   Effects of non-thermal long-term exposure should be further investigated. The effect (or lack thereof) of exposures to cell phone RF-fields on tumour initiation and promotion is needed. Epidemiological studies that can provide evidence of synergism of RF-fields with other factors such as gender and lifestyle factors should be considered. As there is some evidence of a possible oxidative stress from acute exposure to RF-fields of cell phones,[28] one area of interest would be to study the possible synergism between the RF-field and other oxidative stressors (or the antagonism between RF-fields and antioxidant intake).

10. **Promote research that explores the role of the rechargeable battery and other electrical components of the cell phone (other than the antenna) in emitting extremely low frequency RF-fields.**
    A recent report raised the possible effect of the battery in emitting in an entirely different region of the spectrum that may be more harmful than the antenna itself. These workers, as

mentioned in a previous section, attribute some of the changes in the electrical activity of the brain upon exposure to cell phone RF-fields to extremely low frequencies emitted from the battery.[2]

11. Consider the concept of second hand (environmental) exposure

It took decades for society and public health authorities to recognize the dangers of environmental tobacco smoke. Though it may seem far-fetched today, there does exist the possibility of environmental radiation exposure from cell phones. Therefore **until proven** safe we suggest consideration and exploration of the idea of second hand (environmental) exposure, particularly in metal-encased spaces such as a car or an elevator. Further research is needed to assess the risks of this type of exposure.

APPENDIX 1

Health Canada guidelines - *Safety Code 6 (SC6)*

For the general public, and in the range of interest (300-1,500 MHz), and ***in absence of any other exposure***, *Health Canada* recommends the following exposure limits averaged over 6 minutes of exposure:

1. Electric field strength in V/m = $1.585 \times \sqrt{\text{frequency in MHz}}$,
2. Magnetic field strength in A/m = $0.0042 \times \sqrt{\text{frequency in MHz}}$,
   (in milligauss = $0.0528 \times \sqrt{\text{frequency in MHz}}$),
3. Power density in W/m^2 = (frequency in MHz) / 150.

APPENDIX 2

Table 1. Exposure limits* to RF fields in the cell phone range (800-900 MHz) and around 1800 MHz according to the Safety Code 6 guidelines of Health Canada.

Frequency (MHz)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)	Power Density (W/m^2)
800	44.8	0.119	5.3
900	47.6	0.126	6.0
1500-15 000	61.4	0.016	10.0

* For persons not classed as RF and microwave exposed workers (including the general public).

While the above limits are for average field strengths and power densities, the SC6 guidelines also set maximal field strength limits that should never be exceeded even in instantaneous spikes of peaks. [32]

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