

**Update and Review of Research on Radiofrequencies:
Implications for a Prudent Avoidance Policy in Toronto**

Technical Report

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EXECUTIVE SUMMARY

This report is an update to a 1999 Toronto Public Health (TPH) review summarizing research on exposure and health effects from radiofrequency (RF) emissions. The recent literature on RFs leads TPH to conclude that many of the uncertainties in the science identified in the 1999 review remain. Despite limitations in the body of research to date, the possibility of harmful health effects from RF exposures cannot be ruled out.

Current safety standards for RF exposure are based on avoiding tissue damage from heating effects. The standards do not account for the effects that may occur at exposure levels that do not involve tissue heating. The public and some scientists have concerns about the potential for cumulative, whole-body exposure to RFs from their widespread use and presence in the environment.

There is agreement that biological (i.e. non-thermal) effects from radiofrequencies are evident from research with animals, cell cultures and in humans. Continued research into these effects, including potential mechanisms of action and the significance of these effects for long-term human health, is warranted.

A great deal of the new research on human health effects from RFs has come from studying those who use cell phones. Some recent studies suggest that low-level, long-term exposure to RFs may be linked to leukemia and certain brain cancers, among long-term cell phone users. Studies of the impacts on children from cell phone RFs, while limited in number, do not rule out the possibility that children require greater protection from RF exposure.

Research in populations near cell phone base stations in Europe indicates that some people living within about 300 metres of a base station are more likely to experience symptoms, such as headache, memory changes, dizziness, tremors, depression and sleep disturbance, that are similar to a condition known as “microwave sickness”. Such studies are limited and have not yet been conducted in North America. Some scientists conclude there is need to ensure that RFs are kept as low as possible to protect people living close to cell phone towers.

It is commonly agreed that the cellular and wireless technologies relying on RFs have not been in use long enough to adequately assess the potential for all long-term health effects.

The expanding network of cell phone towers, antennas and wireless communication technologies and installations in Toronto, together with the increasing use of the associated devices by the public, likely translate to increasing rather than decreasing exposure of the public over time. Current data on RF levels measured in Toronto indicate that with few exceptions, levels of RFs are typically many times below the Health Canada exposure guidelines.

Despite diverse views on whether exposure limits are adequately health protective, a number of jurisdictions have moved to adopt more stringent exposure standards. The Prudent Avoidance Policy previously endorsed by the Board of Health in 1999 requests that applicants who wish to install new antennas or modified antennas demonstrate that radio frequency (RF) exposures in areas where people normally spend time, (that is,

workplaces, residences or areas where the public has unrestricted access) will be at least 100 times below those currently recommended by Health Canada's limits for public exposure, known as Safety Code 6.

The approach of the TPH Prudent Avoidance Policy has been applied successfully already to cell tower and wireless antenna sitings and has not placed undue burden on staff time or on the industry's ability to comply.

Health Canada has not revised its guidelines to address the concerns raised in 1999. This review indicates that, in the face of uncertain risks, prudent avoidance is still the best approach to minimize public exposure from the new and increasing number of RF sources in Toronto. The Medical Officer of Health recommends that the City continue with a prudent avoidance approach in siting new telecommunication towers and antennas in the City. Initial consultations can be used to collect data from cell phone carriers on predicted RF levels of proposed towers and antennas. This will allow the City to monitor the potential impact of proposed telecommunications facilities in Toronto and to encourage voluntary adoption of the Prudent Avoidance Policy.

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1.0 INTRODUCTION

1.1 History of the Issue

In November 1999, the Toronto Board of Health adopted a policy of prudent avoidance respecting decisions of where to situate cellular telephone base stations in the city. This policy recommends that consideration be given to keeping public exposures to radiofrequency (RF) emissions (measured in power density) from these installations 100 times below the current federal guideline (referred to as *Safety Code 6*) in order to provide a greater level of protection against potential health effects (TPH, 1999a). This decision was supported by a review and assessment of the scientific research (TPH, 1999b). That review highlighted uncertainties in the science and the need to account for the likely increasing sources of RF exposure to the population in Toronto.

1.2 Reasons for this Review

Since 1999, there has been a steadily expanding network of cellular phone towers and other wireless telecommunication devices throughout Toronto. The increasing concentration of telecommunication towers in certain locations may have the effect of increasing the level of RFs to which the public in the immediate vicinity may be exposed. Residents in some areas of Toronto have expressed concerns related to the potential health effects that may be associated with exposure to the radio waves used with this technology. As well, there has been attention to the expanding Wireless Fidelity (WiFi) Internet service and other sources of radiofrequencies (from cellular, wireless or cordless technologies), which contribute to the environmental levels of, and exposure to RFs in Toronto.

At its meeting of May 15th, 2006, the Board of Health moved that the Medical Officer of Health, in collaboration with the Chief Planner and Executive Director, City Planning, report on the incorporation of the Prudent Avoidance Policy into the City of Toronto Protocol for Telecommunication Towers and Antennas which is under revision by City Planning.

(See: <http://www.toronto.ca/legdocs/2006/minutes/committees/hl/hl060515.pdf>)

1.3 Scope of this Report

Because the research on exposure and health effects related to RFs has expanded substantially, with many hundreds of papers and reviews having been published since 1999, an updated review of the scientific literature by Toronto Public Health was warranted. The Board of Health specifically directed that this report also address any health risks arising from the concentration of telecommunication towers, denoting the concerns with recent siting decisions that have led to multiple mobile telecommunication towers and antennae being installed on top of individual buildings in some areas of the city.

This report therefore summarizes recent research on RF exposure and effects, including what is known about newer sources of RFs. As well, the report updates the actions taken by other jurisdictions regarding exposure guidelines and policies. The conclusions from

this science and policy summary inform a re-assessment of the 1999 Prudent Avoidance Policy for Toronto.

2.0 UNDERSTANDING ELECTROMAGNETIC WAVES

2.1 Introduction

Radiofrequencies (RFs) are a form of energy that belongs to the electromagnetic spectrum. Electromagnetic waves include a wide range of types of radiant energy that differ in terms of their frequency (or number of cycles per second), which is measured in units called hertz (Hz). One Hz is one cycle per second, whereas a kilo hertz (kHz) is 1,000, a megahertz (mHz) is 1 million and a gigahertz is 1 billion cycles per second. RF waves span the range between 3 kHz and 300 GHz, or from 3,000 to 300 billion hertz. They also differ in their wavelength, or the distance they travel in one cycle, which is measured in metres. RFs are in the band that is described as “non-ionizing radiation” that also includes infrared and visible light.¹

Although many associate “EMFs” as describing only waves generated from electrical power lines, the term includes fields generated from electricity, magnetic, radiofrequency or microwave radiation. Extremely low frequency (ELFs) waves is the term used specifically to describe fields generated from electrical power lines whereas, RFs refer to higher frequency waves that include radio waves and micro waves and are mainly used in telecommunications.

2.2 Sources of Radiofrequencies

RFs come specifically from television and AM and FM radio transmissions, cell phones, cell phone towers (also known as masts or base stations) and are also used for pager systems, emergency communication systems (e.g. TETRA, or Terrestrial Trunked Radio), cordless phones, baby monitors, air traffic control radar and global positioning systems, among other uses. Wireless technologies such as WiFi and WiMAX (Worldwide Interoperability for Microwave Access), that allow internet access by devices such as laptop computers and Personal Digital Assistants (PDAs), also operate using radio waves.

RF waves have been used in many technologies for a long time but in recent years the increasing expansion and prevalence of cellular and wireless technologies has become a source of media attention and public concern. This report will focus on describing the available science on health effects and exposure from RFs linked to cell phones, cellular base stations and WiFi, recognizing that there is in fact a broad range of sources of RFs in the environment, and that for WiFi in particular, the information on exposure and health effects is notably lacking.

¹ The term “non-ionizing” means that these waves do not have sufficient energy to ionize, that is, to remove electrons from atoms or molecules to create a charged ion. They do not break chemical bonds and therefore, are different in terms of the ability to cause biological effects, compared to forms of ionizing radiation, such as x-rays.

The frequencies that are used for cellular and wireless communications in Canada range from 824 MHz to 2.4 GHz (RSC, 1999; Health Canada, 2003). These are slightly higher frequencies than those used for radio and television and similar to the frequencies used for some radar, remote sensing, and microwave ovens.

2.3 How do Cell Phone Base Stations Work?

A number of terms used in cellular telecommunications help in understanding the elements of this technology. Cell phone antennas are the element that radiates RF waves and are often mounted on structures called “masts”. The term base station refers to the entire unit of an antenna, plus support structure, as well as the “communication electronics and their housing structure” (DCMNR, 2007: 4).

Base stations are needed to support cellular phone communication. They act similar to two-way radios since their antenna receives and transmits radio signals when people make calls using their mobile phones (McLaughlin Centre for Population Health Risk Assessment, undated). The cell phone gets its name because the area of coverage by the RFs from any base station antenna is called a “cell”. Where there is a high volume of cell phone users, there is a need for more base stations, placed closer together and therefore, there are more and smaller cells (also known as “micro-“ or “pico cells”).

For optimal functioning, base stations must be high above the ground and are typically mounted on top of metal towers some 20 to 30 metres high or, they are commonly mounted on shorter supports that sit on the roof of a tall building. The base station antenna sends out a radio wave signal that is directed into a narrow, horizontal beam. The beam is relatively narrow in the vertical plane (likened to a flat pancake with side lobules) and extends horizontally about one-third of the way around the tower. The beam is slanted downwards at an angle of between 5 to 10 degrees. The beam reaches ground level typically at 50 to 200 or 300 metres from the base of the tower (see Figure 1 below) (DCMNR, 2007).

Simulated Flux Density Distribution w.r.t. Health Canada SC6 Limit Typical PCS & Cellular Site with Adjacent Building

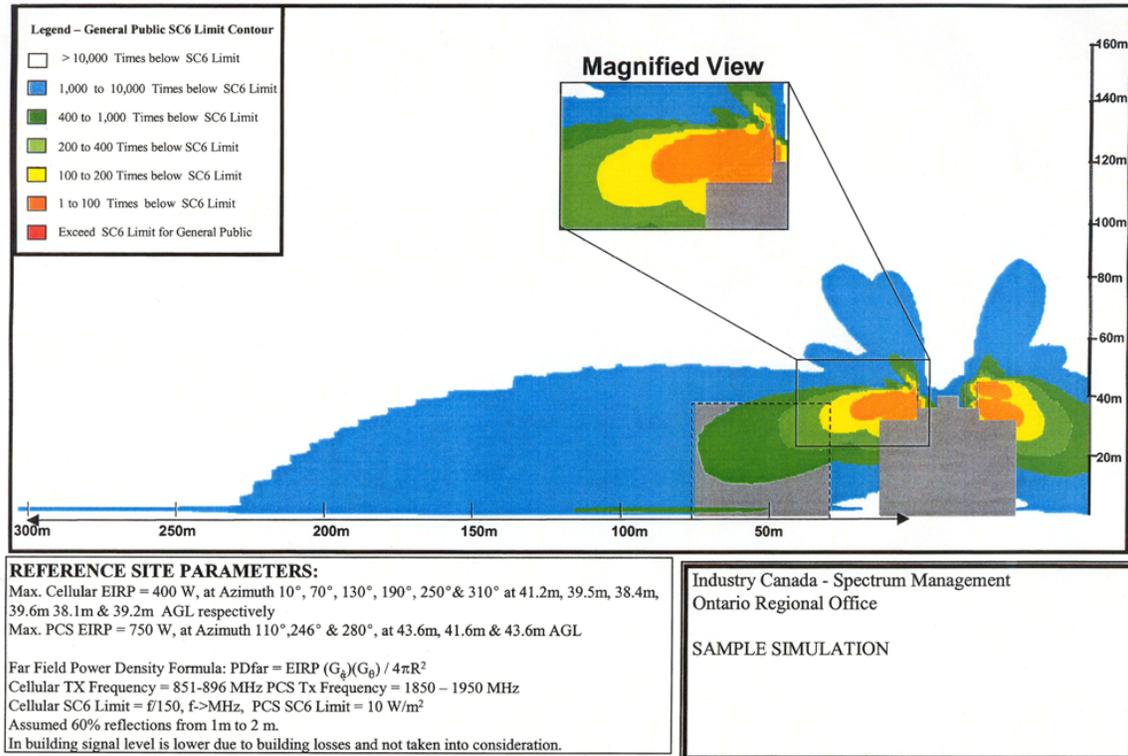


Figure 1. Modelled depiction of RF emission patterns from cell phone antennas on top of a building. [Industry Canada (for TPH), 2006]

Although actual power output varies depending on the type of antenna and the volume of cellular calls (or “traffic”), the typical power output of a cellular base station at its maximum is 60 watts. This is about 1000 times lower than the power output of a television antenna (which also emits RF waves) (McLaughlin Centre for Population Health Risk Assessment, undated). Table 1 below indicates the maximum power output according to the cellular or wireless antenna type.

Table 1. Frequency band and maximum power output for various cellular or wireless antennas.

Antenna or Device (Cellular or Wireless) type	Frequency Band	Maximum (watts)
omnidirectional collinear antenna	VHF	50 - 100
ground plane antenna	VHF	30
exposed dipole array	VHF	80 - 125
exposed dipole array	UHF	250
“dish” or “drum” (do not radiate backwards)	UHF, SHF	1000 - 1778
cellular & PCS of various styles		variable

Adapted from BC Centre for Disease Control. Radiation Protection Services, No date. Ross RN, Philips B. “Antenna Awareness”. <http://www.bccdc.org/downloads/pdf/rps/reports/antenna.pdf>

2.4 How does WiFi Work?

Wireless local area networks (WLANs) use wireless fidelity (usually called “WiFi”), the trademark name for one wireless communication technology. This is a more recent technology compared to that for cellular telecommunication. WiFi also operates using

RF waves. WiMAX is another newer technology supporting wireless connection to the internet but is not as widely used at this time.

These wireless technologies operate on similar principles to those for cellular telephones. WiFi-based devices, that is, laptops or Personal Digital Assistants (PDAs), contain an internal antenna, also called a “client card”, which transmits RFs to and from a central antenna (also called an access point) within a WiFi cell. These central antennas are small apparatuses that are usually mounted near the ceiling or on a wall, or for home users, they may be placed on or near a desk. The central antenna distributes RFs over a small radius or cell. Generally their maximum output power is very much lower (about 100 milliW) compared to cellular base station antennas (Foster, 2007).

In Toronto, as in many other cities around the world, wireless access points are often found randomly in cafes, restaurants, hotels, airports, train stations and other public buildings. In 2006, Toronto Hydro Telecomm activated One Zone™, which is present in the downtown core. This service allows for broader, more consistent internet connectivity through antenna installed on existing street light poles (Toronto Hydro Telecom, 2006).

3.0 HUMAN EXPOSURE POTENTIAL

3.1 Introduction

Exposure to RF fields from a base station is measured as power density, which is a measure of power per unit area. The power density is often expressed in watts per square metre (W/m^2) or microwatts per square centimetre ($\mu W/cm^2$).

The amount and site of RF exposure differs when using a cell phone compared to being near a base station. Overall, RF wave exposure from using a cell phone is many times greater than from a base station, but it is localized to a small region of a person’s head and occurs over a relatively short time span. Cell phone use is also different because it is voluntary or under the control of the individual. By comparison, people receive a whole-body, longer-term or chronic exposure to the RFs emitted from base stations and it is an involuntary exposure.

3.2 Current Canadian Exposure Standards

The regulation of telecommunication installations and devices is under federal jurisdiction. Industry Canada is the federal agency responsible for overseeing this regulatory function. It is the policy of Industry Canada to consider environmental effects, safety requirements, and consultation with land-use authorities before issuing an approval for siting a telecommunication antenna. While it is not a regulatory requirement, Industry Canada also encourages applicants to address the concerns of the community.

The measure of RF energy dose from a cell phone, or amount that is absorbed by the body, is known as the Specific Absorption Rate or SAR. The SAR is expressed in units of watts per kilogram (W/kg) or milliwatts per gram (mW/g). Cell phone manufacturers

must also comply with regulatory standards that specify that cell phones must not deliver a SAR above certain levels when they are in use, as described in Table 2 below. These are in agreement with federal regulations that mandate allowable environmental exposure to the public.

Table 2. SAR Limits for Devices used by the General Public (Industry Canada, 2005)

Body Region	Average SAR (W/kg)	Averaging time (minutes)	Mass Average (g)
Whole Body	0.08	6	Whole Body
Localized Head and trunk	1.6	6	1
Localized Limbs	4	6	10

Health Canada's Radiation Protection Bureau has established Canadian guidelines for environmental exposure to RFs. The guidelines, set out in the document, "Limits of Exposure to Radiofrequency Fields at Frequencies from 3 kHz - 300 GHz" are also called *Safety Code 6* (Health Canada, 1999).

The International Commission for Non-Ionizing Radiation Protection (ICNIRP) set out the current global guidelines upon which most countries (including Canada) base their public exposure limits for RFs in 1998. These standards for RF are based on a threshold SAR of 4 W/kg in humans. Both ICNIRP and Safety Code 6 guidelines are based on preventing damage to human tissues due to the well-understood heating effects of RF. Health Canada and ICNIRP incorporate a 50-fold safety factor to the threshold for thermal effects to account primarily for inter-individual differences in susceptibility for heating effects because of age or health status (ICNIRP, 2002; Bailey & Erdreich, 2007). ICNIRP and other agencies assert that below this threshold harmful effects are not known to occur. Safety Code 6 specifies that, a whole-body, environmental RF exposure for the general public must be limited to power densities² ranging from 2 to 10 W/m² depending on the frequency of transmission³. Safety Code 6 guidelines are similar to those from ICNIRP.

3.3 Factors that Affect Exposure

In urban areas there is near ubiquitous presence of RF radiation. A large source of that exposure comes from radio and television broadcast transmitters. Researchers in Italy measured background levels of RFs in the town of Torino which has 330 cellular base stations. In their measurements, broadcasting sources contributed the most to total RF fields except in areas very close to the antenna itself which are usually not accessible to the public (Anglesio et al, 2001). A 2002 Industry Canada study to measure RFs in Toronto concluded that from 44% to 71% of the total measured levels were contributed by radio and television broadcast services.

Around cellular base stations, the highest levels are found at ground level between 50 and 250 metres. A number of factors influence exposure to RFs around a base station such as: the type of cellular phone service being supported, type of antenna, the antenna's height

² Since it is difficult to measure the SAR outside of a laboratory (where it is typically done using a phantom or computer model), exposure limits are given in terms of power densities as well as SAR.

³ The Health Canada exposure guidelines differ depending on the frequency of transmission: for example, for 900 MHz the standard is 6 W/m² and for 1800 MHz it is 10 W/m².

above ground, its tilt and orientation, the number of other antennas located nearby, the number of users in the area, and structures or buildings that may reflect or absorb the radio waves.

Newer cell phone service systems (since the early 1990s) are predominantly digital which operate at higher frequencies and use different modulation techniques compared to the earlier analog systems.

The number of cell phone users will influence the volume of cell phone calls at any given time. RF field strength varies considerably across the day depending on volume of calls. As field research readily indicates, there are large variations in the RF radiation from base stations measured throughout the day (Silvi et al, 2001; Keow & Radiman, 2006).

Measurements taken by Italian researchers in apartments in the immediate vicinity of base stations show that across the day, the maximum RF field strength varies and shows lowest levels at night and two clear daytime peaks correlating with the largest volume of cell phone call traffic (Silvi et al, 2001). A late morning peak (10:00am to 1:00 pm), reflective of business use is clear, as well as an evening peak (6:00 pm to 10:00 pm).

In general, emissions of RF from cellular base stations decrease with increasing distance from the source. In terms of areas to which the public has access, RFs are generally greatest in the range of 50 to about 300 metres away at ground level. Studies with actual measurements taken over space, however, indicate that human exposure is better evaluated with monitoring data rather than relying on models that correlate distance with power density (Zmyslony et al, 2006). For example, a Health Canada (2003) study measured ground level emissions near cellular base-station installations in the Regional Municipality of Ottawa. The study showed that power densities are generally stronger as you get nearer a base station but that they vary in a haphazard, unpredictable way. Two closely spaced points can have significantly different power densities, differing by a factor of 10 or more (Health Canada, 2003).

A number of recently published studies from around the world have similarly focused on exposure to RFs of the public living around base stations. They indicate that despite large variability in power density, exposure around base stations is generally well below the international standards for exposure to the public. For example, exposure to RFs near base stations in Ottawa was found to be at most thousands of times below the limits recommended in Health Canada's Safety Code 6 (Health Canada, 2003). Similarly, the RF levels measured around 400 base stations in Ireland indicated that public exposure would be hundreds to thousands of times lower than the international standards and would rarely be above a value of 0.01 W/m^2 (ComReg, 2004, as cited in DCMNR, 2006: 10). A U.K. study showed that the power density values measured around 20 base stations ranged from 0.002% to 2%⁴, with a maximum of 8.6% of the ICNIRP exposure guidelines. RF data from daytime, weekday measures of 60 base stations in five cities in Australia showed that more than 90% of sites measured were less than one thousandth of the ICNIRP guidelines (Henderson & Bangey, 2006). The highest level measured was on

⁴ Note that exposure standards are set so that no harm (based on thermal effects) will occur even if exposure is at 100% of the guideline.

a cellular tower in Perth supporting 3 services which, at 0.0078 W/m^2 , this is equivalent to 0.2% of the Health Canada exposure standards.

Power densities inside buildings are typically much lower than outside since the walls and ceilings absorb some of the energy. Researchers from the University of Vienna measured power density indoors (in the bedroom) in 365 homes close to one of 10 base stations in urban and rural Austria (Hutter et al, 2006). RF levels ranged from 0.0002 to 1.4 mW/m^2 ($= 0.0000002$ to 0.0014 W/m^2) for all frequencies between 80MHz and 2GHz. In this study, 5% of the estimated maximum exposure levels were greater than 1 mW/m^2 , which is equivalent to 0.001 W/m^2 or a value several thousand times below the ICNIRP guidelines (Hutter et al, 2006). Similarly in their study in a Spanish town, Navarro and colleagues (2003) measured RFs in the bedrooms of over 100 inhabitants living near a cellular phone base station. Daytime RF levels measured were all below $0.2 \mu\text{W/cm}^2$ which is equal to 0.0000002 W/cm^2 , several thousand times below the ICNIRP exposure guidelines (for RFs in the 900 MHz frequency range). Navarro et al (2003) also showed there was about a tenfold average difference in exposure depending on distance of the home from the base station, with average power density of $0.11 (\pm 0.19) \mu\text{W/cm}^2$ for those living less than 150 metres and $0.01 (\pm 0.04) \mu\text{W/cm}^2$ for those living greater than 250 metres from the base station.

Even in buildings where there is a rooftop or side-mounted antenna, the RF values tend to be lower indoors although they can vary according to the floors within a building, being higher in upper versus lower floors (Anglesio et al, 2001).

3.4 Exposure to WiFi

There is very little published research investigating exposure to RF waves from WiFi antennas and devices (Foster, 2007).⁵ A recent study measured RF fields from wireless local area networks (WLANs) at 55 sites including private residences, commercial spaces (e.g. coffee shops or hotels), public institutions (e.g. hospitals or university buildings) and other public spaces in the U.S., France, Germany and Sweden (Foster 2007).

Measurements were taken at two points so as to estimate exposure for a bystander. One set of measurements was taken close to a central antenna, and a second set, about 1 metre from a laptop while it was uploading or downloading files from the internet (Foster, 2007).⁶ This study showed that RF signals at each of the sites came from a number of different sources. They determined the contribution from the WLAN by calculating the power in the frequency band from 2.4 to 2.48 GHz, which, because it is the range typically used by wireless installations, would be a good approximation.⁷ The median and maximum power densities for this frequency band, for the two measurement conditions are shown in Table 3 below.

⁵ The RF energy (measured as SAR) emitted from various wireless devices are typically lower than for cell phones and have been documented as follows (Kuhn et al, 2005): DECT (cordless phone technology): 0.019 W/kg to 0.052 W/kg , WiFi: 0.06 W/kg to 0.81 W/kg , Bluetooth (communication protocol for connecting wireless devices via personal area network) 0.005 W/kg to 0.466 W/kg .

⁶ This is done to be representative of field strength in the far field.

⁷ However, they did note that other devices, such as a nearby microwave oven at one site and a cordless phone at another, contributed noticeably to RF energy in the WLAN frequency band (Foster, 2007).

Table 3. Median and maximum measures of RFs from WiFi (Data from Foster, 2007)

	Median WiFi Power density (W/m²)	Maximum WiFi Power density (W/m²)
Laptop not communicating with WLAN	1.2×10^{-6}	7×10^{-3}
1m from laptop while up/down loading files	1.6×10^{-5}	1×10^{-3}

Evidently, bystander exposure to RF from WLAN installations and devices is in the range of 1000 times or more below the ICNIRP guidelines and typically “below other RF signals that are present in the same environments” (Foster, 2007: 285). The study findings indicate also that exposure will increase by a factor of 10 when the devices are actively communicating with the WLAN, such as when they are downloading or uploading files or with video streaming (Foster, 2007).

Exposure to the individual using the particular devices can be higher than is indicated from this study, particularly if they get close to the internal antenna, therefore experiencing exposure in the “near field” (Foster, 2007). For example, putting a wireless laptop directly on one’s lap while data is being transmitted can increase absorbed power in the body (SAR) “comparable to that produced by a mobile phone” (Foster, 2007: 287).

3.5 Radiofrequency Measures in Toronto

Industry Canada scientists measured RF levels at 61 locations in Toronto including residential, industrial and commercial areas, parks, schools and airports in 2000 to 2001 (Industry Canada, 2002). The study showed that all but one of these sites had RF levels well below the 1999 Board of Health’s recommendation of 100 times below Safety Code 6 (SC6). At one site in the area between Metro Hall and Roy Thompson Hall, RF levels were 16 times below SC6. The value is likely higher here than at other sites because it is close to a cluster of television and radio transmitters in the city’s core. Overall, RF levels were highest at commercial sites and in the downtown for similar reasons. This study found that, depending on the location, from 44% to 71% of total RF levels measured in Toronto were from broadcast services. RF levels in residential areas, schools and parks were more than 5000 thousand times below the levels in the SC6 guidelines, which is well within the recommended levels outlined in the prudent avoidance policy. Other local sources, beyond cell phone towers and broadcast services, which can contribute to local RF levels are pager systems, radio taxi and emergency communication systems, among others as discussed in section 2.2.

At Toronto Public Health’s request, Industry Canada assessed the level, pattern and distribution of RF waves outdoors from cell phone antennas mounted near the top of a high rise building in the north region of Toronto. Their simulation indicates that the RFs generally decrease with increasing distance away from the antenna. Exposure above the 1999 Board of Health’s recommended level is localized to lobes that extend horizontally out from each antenna to about 45 metres from the building top. These areas of RF dispersion are not accessible to people in the building, on the rooftop or on the street, and they do not extend to neighbouring high-rise buildings. When modelling RF from all

sources in the area, the only place where RF levels approached the Board's recommended levels was on the roof top of a building with a major transmitter.

3.6 Gaps and Limitations Re: Exposure

While the 2002 Industry Canada data provide some reassurance that public exposure outdoors to RFs in Toronto is likely to be well below current guidelines, it requires more recent monitoring data to confirm that levels are still below the levels recommended by the Board of Health, given the presumed increase in number of base stations and broader establishment of wireless networks across the downtown core and in many more public and commercial sites since that time.

It would also be helpful to have targeted monitoring data that looks specifically at RFs measured nearby cellular base stations, particularly inside buildings so as to more fully assess exposure to people living in Toronto. Given there is a lack of data worldwide on measures of exposure to WiFi, this represents another gap that suggests future monitoring work. In addition, there remains a great deal of uncertainty as to the effects, if any, on human exposure from the interaction of RFs emitted simultaneously by several devices. This is further support for monitoring that looks at real-world exposure to RFs from the variety of sources that exist in the environment, particularly the indoor environment.

4.0 HEALTH EFFECTS

4.1 Introduction

The 1999 TPH report provides a detailed summary of the range of impacts from RF wave exposures. Discussion of the health effects from exposure to RF waves has generally focused on whether non-thermal effects occur and if so, what they signify with respect to the potential for adverse health effects in humans. The focus in this report will be on new science which sheds light on the evidence for and implications of biological effects from animal studies. This section will also summarize the updated epidemiological evidence exploring cancer and other impacts on people who use cell phones, as well as the newer research exploring symptoms among people who live near cellular base stations.

4.2 Thermal Effects

Thermal, or heating effects occur when there is sufficient RF energy to cause a measurable increase in the temperature of the object or person (e.g., more than 1°C). The thermal effects of RF fields are well understood and include: changes in temperature regulation, endocrine function, cardiovascular function, reproductive capacity, immune response, nervous system activity and behaviour (RSC, 1999 and further discussed in TPH, 1999).

Behavioural responses are the most sensitive thermal effects with a threshold exposure level of 4 W/Kg identified in short-term behavioural studies in animals. Some researchers argue that the threshold may be lower in different species. Nonetheless, regulators have applied various safety factors to this value of 4 W/kg to derive levels of 0.4 W/Kg for

workers and 0.08 W/Kg for the public, which define the exposure guidelines, expressed as maximum specific absorption rates, used in Canada and elsewhere (RSC, 1999).

4.3 Non-Thermal Effects

Reviews of the health effects from RFs have generally continued to describe heating effects as the only known adverse effect (Ahlbom et al, 2004). Nonetheless, effects that occur with exposure below levels that cause heating (i.e. non-thermal effects), have been the focus of a large number of animal studies and a substantial focus of the debate on whether current exposure guidelines are adequate to protect human health.

4.3.1 Biological Effects

The effects of RF waves on many health endpoints continue to be evaluated through animal, tissue/cell culture and human volunteer studies. These studies have focused on evaluating the potential for biological effects or for toxicological effects. Biological effects can include any change in structure, metabolism, physiology or morphology that is found at the level of a molecule, a component of a cell or in a living biological system after exposure to an agent (Meltz, 2003). Biological effects may or may not lead to changes or responses at other levels, but in theory, any biological changes can be neutral, negative (i.e. harmful) or positive (i.e. beneficial). Examples of biological impacts found in studies of RFs include changes in the enzyme ornithine decarboxylase (ODC), calcium ion efflux (or flow out of cells), melatonin secretion, cell proliferation and permeability of the blood brain barrier, among others. For toxicological impacts, there have been many studies assessing DNA damage (genotoxicity), mutations, cancer, cognitive, reproductive and other adverse impacts.

Ornithine Decarboxylase

Ornithine decarboxylase (ODC) is an enzyme that is important in cell growth. Increase in its production has been viewed as a biomarker for tumour promotion. A number of experimental studies have shown increases in ODC level, while others have found no effects or decreases depending on the circumstances of the study. For example, Paulraj and Behari (2002) studied the effects in the developing rat brain of low level continuous wave RFs (2.45GHz). One group of rats received exposures of power density of 0.34 mW/cm² (SAR of 0.1 W/kg) for two hours each day for over a month. They found a significant increase in ODC activity in the exposed compared to the control young rats. Stagg et al (2001, as cited in RSC, 2004) exposed rats to pulse-modulated RF fields (1.6 GHZ) and found no difference in levels of ODC. Desta et al (2003) were unable to replicate results of increased ODC activity in skin fibroblast cells with exposure to RF from a cell phone (835 MHz). Hoyto et al (2007) found decreases in ODC in certain rat brain tumour cell types (primary astrocytes), but found no effects on other types of cells including mouse, rat and human.

Calcium Ion Activity

Calcium ion flow out of cells (or efflux) has been used as a marker for nervous system effects in laboratory cell culture experiments. This effect occurs at specific “windows” of conditions including frequency, power density, modulation and temperature. In their

study described above, Paulraj and Behari (2002) also found higher calcium ion efflux in the brain tissue of exposed developing rats. (In this study, the impact of RF appears to be to increase the release of membrane-bound calcium ion, rather than from the cytoplasm inside the cell.)

The Royal Society of Canada update report (2004) also notes a number of new studies shedding light on the ability of extremely low frequency (ELF) magnetic fields (e.g. from cell phone batteries) to impact on calcium ion flow and signaling. One hypothesis for a mechanism of non-thermal biological effects is that they happen because of ELF modulation of the RF field.

Cell Proliferation

Increases in cell proliferation are linked to the development of cancer. The influence of RF exposure on cell proliferation in laboratory cell cultures has been studied with mixed findings as well. Protein kinase is an enzyme that activates many cellular functions and plays an important role in controlling cell proliferation. Paulraj and Behari (2002) also found a significant decrease in protein kinase activity. The results are seen to "indicate that this type of radiation affects the membrane bound enzymes, which are associated with cell proliferation and differentiation, thereby pointing out its possible role as a tumor promoter" (Paulraj & Behari, 2002: 221).

Blood Brain Barrier

Some studies have examined alterations to the blood-brain barrier upon exposure to RFs at various exposure levels. The blood brain barrier allows passage of necessary substances, but prevents the crossing over of most toxic substances from the blood to the brain (via the cerebrospinal fluid). If exposure to an agent makes the blood-brain barrier more permeable, it may increase the potential for toxic effects on the brain and nervous system. A review of this issue concluded that while earlier studies suggest RFs made the blood-brain barrier more permeable, these results were only replicated with a high exposure (that is, above exposure guidelines) where there was brain tissue heating and increased blood flow (D'Andrea et al., 2003). The effects from low intensity RFs on the blood-brain barrier have been inconsistent overall therefore.

Melatonin

Several laboratory studies have looked at the effects of RFs on secretion of the hormone, melatonin. Melatonin is secreted from the pineal gland in the brain and is involved in regulation of sleep, puberty and ovarian cycles. Some suggest that one cancer promotion mechanism from RF exposure is via altered circadian rhythms of pineal activity and melatonin release (RSC, 2004). A few studies have shown decreased melatonin secretion at night. For example, Burch et al (2002) looked at melatonin secretion among male electric utility workers who used analogue cell phones. They concluded that cell phone use of 25 minutes or more per day may be associated with decreased nocturnal secretion of melatonin. Although the current studies are limited in number, a recent review concludes that "the existing data can only be interpreted as showing no effect" on the pineal gland from RFs (Black & Heynick, 2003: S193).

4.3.2 Toxicological Effects

The potential for RFs and other EMFs to cause cancer has been the most studied impact in the laboratory setting. Overview reports take the view that most animal studies indicate RFs are not genotoxic and are not tumour promoters. However, clearly the results from individual studies show conflicting findings. Highlights of newer studies are presented below.

Genotoxicity

Genotoxicity refers to damage to DNA. This may occur by an agent causing a break in DNA strands, by binding to DNA or by creating mutations through effects on enzymes involved in DNA replication. These mutations may or may not lead to cancer or birth defects (inheritable damage) or cell death. Because RF energy is much weaker than the energy needed to break chemical bonds, many conclude that RF fields do not directly damage DNA. However, some conclude that through the action of RF on other cellular constituents (e.g. free radicals), it is possible that RFs may affect DNA indirectly (EC-SCENIHR, 2006).

DNA studies are generally conducted on cell cultures, using either animal or human cell types. For the body of studies looking at impacts on DNA, some sources state that about half or better of the studies have reported DNA damage, DNA strand breaks, changes in DNA synthesis, micronuclei induction or chromosome and genome damage (BioInitiative Working Group, 2007). The REFLEX study, involving researchers from seven European countries exploring impacts of RFs in the lab, has reported DNA strand breaks in human fibroblasts and rat granulosa cells (Diem et al, 2005, as cited in EC-SCENIHR, 2006). Diem and co-workers found micronucleus formation and chromosomal aberrations in human fibroblasts as well. Some cell studies indicate that gene expression is changed with exposure to RF levels that are close to the guidelines (EC-SCENIHR, 2006).

Heat Shock Proteins

The release of a group of proteins known as heat shock proteins (Hsps) is part of the cellular response to stress. Although Hsps are important in many normal cellular responses, they are also released in response to several different environmental stressors including increased temperature, chemicals, heavy metals, oxidative factors, as well as ionizing and non-ionizing radiation. Hsps are often found attached to other proteins in their primary role as “molecular chaperones” to remove proteins that are damaged due to cellular stress. Therefore, their release and activity is associated with conferring protection against cellular stress. Research indicates however, that chronic release of Hsps induces or promotes cancer (French et al, 2001). French and colleagues (2001) hypothesize therefore, that “repeated exposure to mobile phone radiation acts as a repetitive stress leading to continuous expression of Hsps in exposed cells and tissues, which in turn affects their normal regulation, and cancer results” (2001: 93). While a number of studies have shown increased release of Hsps with exposure to RFs at low levels, many studies have found no effect on Hsp release. A recent review on the topic concluded that, given in vitro studies have not had comparable methodologies and that in vivo studies of this phenomenon are scant, “we are absolutely not presently in a position

to interpret the effects on Hsps, obtained in largely model in vitro systems, in terms of risks to human health” (Cotgreave, 2005: 239).

Cancer risks in animals

Research on RFs and cancer risks has focused on possible effects of RFs as cancer promoters or co-promoters. While some laboratory animal studies showed an increased incidence of lymphoma in genetically lymphoma-prone mice (Repacholi et al, 1997), these earlier findings of increased cancer risks in animals have not been replicated in more recent research (Ahlbom, et al, 2004). As well, studies investigating whether exposure to RF enhances the carcinogenic effects of other agents known to cause cancer (e.g. chemical carcinogens, X-rays or ultraviolet radiation) have not reported statistically significant increases in tumour incidence (EC-SCENIHR, 2006). There is also a sense, however, that the protocols for studying co-carcinogenicity in most of these studies may not be adequate for fully investigating these effects (EC-SCENIHR, 2006).

Reproductive risks

Impacts on reproductive capacity are known from laboratory studies with exposure to RFs at levels high enough to causes thermal effects (that is above exposure guidelines) (IEGMP, 2000). Reproductive impacts at exposures below guidelines have been reported but not consistently. For example, Dasdag and colleagues (1999) exposed rats to 915 MHz from a cell phone at average SAR of 0.141 W/kg, for two hours per day for one month. They found subsequent changes in the rats’ testicular function, such as, non-significantly decreased sperm count and narrower seminiferous tubules. However, these findings were accompanied by an increase in rectal temperature, which may be the cause of the observed changes (Dasdag et al, 1999). In a more recent study, this same team exposed rats to 900 MHz from a cellular phone for 20 minutes per day for one month, with whole body average SAR equal to 0.52 W/kg (Dasdag et al, 2003) but did not find the same changes in testicular function.

Reduced reproductive capacity of fruit flies (*Drosophila melanogaster*) was found after exposure to a 900 MHz digital cell phone for 6 minutes per day over 5 days (Panagopoulos et al, 2004). Exposed adult flies had significantly fewer pupae than non-exposed which they propose may be explained by a decrease in cytosolic calcium ion concentration affecting DNA, RNA, and protein synthesis (Panagopoulos et al, 2004). In a more recent study, these researchers indicate that the 900 MHz exposure may have greater impacts on reproduction compared to exposure to 1800 MHz frequency RFs (Panagopoulos et al, 2007).

4.3.3 Mechanisms of Action

Although biological effects, in both humans and animals, are reported from laboratory research, the mechanisms of action (except in the case of thermal effects) are unclear. This is particularly so in the case of the potential for causing cancer. It is generally acknowledged that RF waves do not have sufficient energy to ionize atoms or break chemical bonds, therefore, any effects must occur by other mechanisms of action. A number of recent reviews refer to the most current hypotheses proposed for how RFs might elicit effects on biological systems. In most cases, the scientific evidence is

lacking to support one proposal over another as being the most plausible explanation for how biological effects might occur from low level exposure to RFs.

The most commonly discussed hypothesis is that oxidative stress and DNA damage may occur from free radical reactions⁸ (BioInitiative Working Group, 2007). Some experimental research indicates that the concentration of free radicals is increased by exposure to low intensity, low frequency (80 MHz) RF fields (Woodward et al., 2001 as cited by Challis, 2005). It is not clear, however, whether exposure to higher frequency RF fields also increases the free radical concentration (Challis, 2005). Research to investigate free radical reactions as a possible mechanism continues in light of the importance of free radicals in human disease processes.

Another hypothesis proposes that that RF modulation⁹ may be biologically active and that *pulsed* RF signals from mobile phones might interact differently with biological tissues compared to continuous wave RF. Blackman (2007) suggests that modulation signals may interfere with normal, non-linear biological functions. In particular, there is concern that pulsed RF signals could stimulate disease related processes, such as increased cell proliferation in precancerous lesions. Some studies indicate the importance of pulse modulation. For example, Regel et al, (2007) found that exposure to pulse-modulated RFs reduced reaction speed and increased accuracy in a working-memory task among 24 young men whereas exposure to continuous wave RFs produced no effects. Tumorigenicity studies in animals (reviewed by Elder, personal communication as cited in Valberg et al, 2006) however, suggest exposure to modulated RF does not increase risk of tumour development. Although firm conclusions are not yet possible, ongoing research should contribute to a better understanding of the possible modulation related effects from RFs.

Recent reports of the presence of biogenic magnetite¹⁰ in human brain tissue suggest that this may act as a transducer of RF fields (IET, 2006; Challis, 2005). The torque on magnetite particles from RF absorption may open ion channels, a mechanism that should be further explored given “tentative experimental support” (Challis, 2005: S105).

Finally, some propose that interaction between RF and ELF signals (the latter from cell phones batteries) may explain effects found in cell phone users.

4.3.3 Observational & Epidemiological Studies

Aside from experimental laboratory research, the understanding of biological impacts from RFs is also informed by observational studies. These include observations among wildlife or domestic animals. They also include observational studies among human populations, otherwise known as epidemiological research.

⁸ Free radicals are molecules that have an unpaired electron. Although they are involved in many important normal biological processes, these highly reactive molecules may also cause cell damage. They are known to play an important role in human diseases. For example, several cancers may be the result of free radical interaction with DNA, causing mutations which alter cell processes and lead to malignancy.

⁹ RFs are subjected to low-frequency modulation so that they can transmit information. Modulation refers to the changes in the parameters of a wave either in amplitude, frequency or in timing (pulse).

¹⁰ Magnetite is a magnetic mineral that is found in a number of organisms including some bacteria, honeybees, some migratory birds, salmon, bats and dolphins. It is important in allowing detection of changes in the earth’s magnetic field.

While the research is limited, there are some reports of impacts on domestic animals and bird populations possibly linked to exposure to RFs from cell phone base stations. These studies are not generally viewed as providing strong evidence because of their ecological design which means that they are unable to account for other potential exposure factors that might be influencing the biological systems under study.

Dairy cattle were reported to produce significantly less milk, have greater rates of spontaneous abortions and stillbirths and to become emaciated after a GSM mobile phone antenna was installed on a local radio and television antenna in Bavaria (Loscher & Kas, 1998). These effects appeared to resolve once cattle were moved to a farm 20 kilometers away, but returned with re-location of the cattle to their original pasture.

Researchers in Spain found that mean density of house sparrow populations declined significantly over a 4-year period, and there was a strong relation between lower bird density in areas where RF field strength was higher (Balmori & Hallberg, 2007). Balmori and Hallberg (2007) suggest that a proliferation of telecommunication masts may be one among several explanations for the declining house sparrow populations. Similarly, in a cross-sectional study, Everaert and Bauwens (2007) found that higher RF field strength was correlated with fewer male sparrows in six areas of Belgium.

Epidemiological Studies

Generally, observational or experimental studies in humans are considered the strongest evidence for weighing the potential for effects in humans from exposure to an agent. The scientific literature examining impacts in people from exposure to RFs is at an earlier stage and more limited compared to that for ELF (energy fields from power lines). Nevertheless, since 1999 there have been many more studies adding to the evidence base.

The 1999 TPH report reviewed evidence for human health effects that comes from studying those exposed to RFs from different sources through their work (such as in manufacturing dielectric heaters, wireless devices, police or military working with radar devices, among others). A 2003 review paper documents nine cohort studies with findings published between 1980 and 2002, which have explored health effects in worker cohorts (Breckenkamp et al, 2003). Most of the studies report increased occurrences for cancer in those exposed, but because the cancers occur in a variety of organs or body sites, these results are found to be inconsistent and described as weak evidence (Breckenkamp et al, 2003). As well, in all but one of these studies, past and current exposure was determined only indirectly using a proxy measure such as length of occupation. A case-control study by researchers in Germany concluded that those individuals who reported frequent use of radio sets or mobile phones in their work had significantly higher rates for uveal melanoma, a rare cancer of the eye (Stang et al, 2001). They speculate that RF radiation may act as a cancer promoter through its impact on production of melatonin in the eye. No additional studies have confirmed these effects. Overall, the occupational exposure studies provide limited evidence of health effects such as cancer in people exposed to RFs in a variety of types of work.

Epidemiological studies assessing impacts in communities near radio and television transmitters have provided a source of information on radiofrequency (RF) exposure and possible local population health effects. The power intensities from radio and T.V. towers are typically more constant and higher, whereas cellular phone transmission signals differ dramatically in amplitude from channel to channel, and through time (Navarro et al, 2003). These studies report increased rates of leukemias in children and adults (Dolk et al., 1997; Hocking et al., 1996; Maskarinec et al., 1994). Such studies of community exposures to RFs from radio and TV transmitters have been characterized, however, as providing only “a weak test of the possibility of a relation (between community RF exposure and cancers)” (Ahlbom et al, 2004: 1750) because they often have poor estimates of exposure (typically based on distance only) and are based on small numbers of cancer cases.

A recent large case-control study examining leukemia and brain cancer in children in South Korea, considered the impact of modelled exposure to RFs from local AM radio transmitters and antennas (Ha et al, 2007). Previous studies have only estimated exposure using distance from an installation as a proxy. Ha et al (2007) reported that children living within 2 km of an AM radio transmitter had more than double the rate of leukemia compared to children living more than 20 km away. While this finding did not show a clear dose-response relationship, the observed rates of lymphocytic leukemia, one specific leukemia type, did increase as the individual predicted exposure was higher (Ha et al, 2007). Childhood brain cancer rates and cancers in infants did not appear to be correlated with exposure to RF radiation in this study.

Studies of Cancer among Cell Phone Users

A great deal of the research on human health effects from RFs has come from studying those who use cell phones. The RF energy from cell phone use is localized to the head and can reach levels that approach ICNIRP guidelines. Brain tumours and other types of cancer in the head and neck have been most frequently studied. Case-control studies in Sweden and Finland reported increased rates for brain tumours on the same side of the head (or ipsilateral side) as for phone use, in those using analog but not digital technology phones (as discussed in a review by Ahlbom et al, 2004). On the other hand, U.S. case-control studies have shown no relation between cell phone use and occurrence of brain tumour (Ahlbom et al, 2004). A recent meta-analysis of nine case-control studies found that brain tumour occurrence was not correlated with cell phone use, however, the pooled data from five studies with subsamples of longterm phone users indicated there was a 25% greater rate of brain tumours in this subgroup (Kan et al, 2007). Further, a recent analysis of data from case-control studies by Hardell and co-workers indicates that there are strong associations for cell phone use of ten or more years and “a consistent pattern of an increased risk for acoustic neuroma and glioma” (2007: 632).

Acoustic neuroma, is a particularly rare, benign, slow-growing tumour of the auditory nerve in the brain that has been studied in connection with cell phone use. Hardell et al, (1999) were the first to report a higher but not statistically significant occurrence of acoustic neuroma in analog phone users in Sweden. Similarly, Lonn and co-workers (2004) also found acoustic neuroma rates to be higher among Swedes who had used cell

phones for longer than ten years. These results however, have not been found in other studies (Muscat et al, 2002; Inskip et al, 2001; Schlehofer et al, 2007). Methodological limitations may explain the subsequently negative results (described in detail by Kundi et al, 2004).

There have been large cohort studies conducted among U.S. and Danish cell phone users which report no increased risks for brain or nervous system cancers (Rothman et al, 1996; Dreyer et al, 1999 cited in Kundi et al, 2004; Johansen et al, 2001; Schuz et al, 2006). The Danish study followed more than 420,000 subjects with cell phone subscriptions between the years 1982 and 1995 and assessed cancer rates up to 2002 (Schuz et al, 2006). Schuz et al (2006) reported no associations between cell phone use and any tumour (including brain tumours, acoustic neuromas, salivary gland tumours, eye tumours or leukemias). They reported no differences according to whether use was long-term or short-term and in particular, among those using phones over 10 years, the occurrences of brain tumours or leukemias were not increased.

Researchers from the National Cancer Institute (NCI) in the U.S. have recently reported on their multi-centre, case-control study of risk factors for another type of cancer, non-Hodgkins lymphoma (Linet, et al, 2006). Existing research has found increased incidence and mortality of this type of cancer among amateur radio operators, military radar workers, and in genetically cancer-prone mice exposed to low level, pulsed RFs (Linet et al, 2006). Linet and colleagues (2006) reported no relationship between exposure to RFs from cell phones and occurrence of NHL for men or women (n = 551 cases)¹¹. They reported a higher but not statistically significant occurrence of unspecified NHL for men using cell phones for 8 or more years. However, they explain this as a chance finding. In spite of their negative findings, the authors conclude that it is “premature to dismiss a possible relationship out of hand, particularly given the low proportion of long-term or heavy users” in their sample of cases (Linet et al, 2006: 2386).

The evidence from epidemiological studies as a whole has not shown consistency for the occurrence of any other tumours or types of cancer in those using cell phones.

Review panels have frequently concluded that, overall, these studies do not allow us to say with certainty whether there are associations between using a cell phone and increased cancer risk. For example, experts representing ICNIRP concluded that “no single association has been consistently reported across multiple population-based studies... (therefore), current evidence is inconclusive regarding cancer risk after heavy RF exposure from mobile phones” (Ahlbom et al, 2004: 1752).

There are, however, important limitations with the existing epidemiological studies that reviewers frequently discuss. One important limitation is that existing studies typically have few study subjects who have used cell phones for a period long enough for one to detect adverse impacts, such as cancer, which typically take many years, and in the case

¹¹ NCI researchers asked subjects about their frequency of lifetime cell phone use (was it < 10 times, 10-100 times, or > 100 times?) and translated responses to weekly minutes or cumulative lifetime hours (or years, for the most frequent users).

of solid brain tumours, even decades, to appear (Moulder et al., 2005). Most studies of cell phone users are also limited in how accurately they are able to assess exposure in the individual. Exposure is usually determined based on self-reported use and can vary with each study. Relying on user recall can be affected by inaccuracy, particularly for reconstructing exposures that happened years in the past. Critics have called for more objective measures of exposure and some studies have begun to use cell service provider records, which improves accuracy but may not necessarily reflect use of a single study subject because phones may have more than one user.

As the lengthy review by Kundi and colleagues (2004) points out, exposure misclassification largely biases the estimates of risk towards the null hypothesis, that is, towards not seeing an effect. In contrast to the conclusions of others, Kundi et al's review determines that, in fact, the evidence does not exclude an association between RF radiation and cancer as, “(e)pidemiological studies that approached reasonable latencies [time period between first exposure and diagnosis] consistently observed elevated risk for the development of neoplastic diseases” (2004:380).

There are currently no conclusions on the cancer impact from cell phones or from cell phone towers by the International Agency for Research on Cancer (IARC). IARC however, is currently coordinating an ongoing, 13-country collaborative case-control study, known as the Interphone study, to explore the relationship between mobile telephone use and brain cancer. Canadian researchers from the University of Ottawa, l'Université du Québec and the British Columbia Cancer Agency are sharing results with their colleagues in other countries (IARC, Interphone web page, 2001). This international cooperation allows pooling of data, thereby making this study statistically stronger than those from any single country. Recent results to date, reflecting pooled data from four country studies (Denmark, Sweden, UK, Germany), report no evidence for increased brain tumour occurrence from short or medium term use (IET, 2006). These findings, however, are not yet able to shed light on the risks with longer term phone use (that is, over 10 years). Judging by the recent meta-analysis showing increased associations between brain tumour occurrence in those using cell phones at least ten years, this is an important area of research (Kan et al, 2007). As mentioned earlier, while two independent Swedish studies found increased rates of acoustic neuroma (Hardell et al, 2006; Lonn et al, 2004), to date, findings for acoustic neuroma are negative in the pooled Interphone analyses (with data from 5 countries) (IET, 2006). IARC is expected to release its opinion on the carcinogenicity of RFs in 2008.

Studies of Neurological and Behavioural Effects

It is well established that neurobehavioral effects occur with high exposure to RFs that causes heating of tissues however, the evidence for neurobehavioural effects at lower exposures is not as clearly understood. There are reports of people who describe experiencing neurological symptoms such as headache, skin sensations, fatigue, memory and learning problems after using a cell phone or from living nearby a base station. Details of research in these contexts are given in later sections. Controlled laboratory studies have exposed volunteer subjects to short-term radiation from a cell phone to look at effects on sleep, brain electrical activity, or performance on tests of learning and

memory. Laboratory study has also examined the ability of cell phone RFs to produce symptoms in those who describe themselves as hypersensitive to RFs. This section describes the former set of studies, while studies among those with hypersensitivity to RFs are described in a separate section below.

Studies in animals exposed to low levels of RFs have found adverse impacts such as deficits in cognitive function and altered ability to adapt to changes in the environment such as, impaired ability to navigate through a spatial maze (Sienkiewicz, et al, 2005; Lai, 2007). No animal studies have reported impacts on learning (Lai, 2007). Some animal studies have also reported increased permeability of the blood brain barrier, small changes in EEG activity and in neurotransmitters in animals exposed to low levels of RFs (EC-SCENIHR, 2006; Sienkiewicz et al, 2005). Not all recent studies of animals however, have confirmed these findings of adverse impacts (Lai, 2007; Sienkiewicz, et al, 2005). While studies of neurological responses to RFs in animals are increasing, less work has been done to explore possible underlying mechanisms of action to explain the observed responses (Lai, 2007).

Few studies among adult human subjects have explored the relationship between exposure to RF from a cell phone and reported neurological symptoms under laboratory conditions. Most of these have found no differences in reported symptoms between RF exposures versus control conditions (EC-SCENIHR, 2006). A large epidemiological study conducted in Sweden and Norway found that users of digital cell phones were no more likely to report headache, feelings of warmth around or behind the ear or discomfort compared to analog cell phone users, as they had initially hypothesized (Sandstrom et al, 2001). However, Sandstrom and colleagues (2001) did report a statistically significant, positive trend for the occurrence of symptoms of headache, sensations of warmth and fatigue among all cell phone users with increasing calling time and number of calls per day.

Impacts of low-level RF exposure on human cognitive function have been examined through tests of attention, memory or reaction time among others. In a few cases, studies have found a lowered performance on such tests, whereas in others, there have been no effects (Krewski et al, 2007). In a number of studies, improvements in test performance with exposure to cell phone radiation have been documented (EC-SCENIHR, 2006; Lai, 2007; and as reviewed by Krewski et al, 2007). Interpretation of the influence of RF on cognitive function is therefore complex and unclear.

Reviewers of the research that looks at cognitive function have concluded that the marked inconsistency in the methods of individual studies make comparisons difficult. Results may vary depending on the ways in which tests are applied and how cognitive function is tested. For example, Lass et al (2002) administered a battery of visual tests of varying complexity to assess attention and short-term memory of 100 students randomly assigned to receive a low level RF or sham exposure. The RF-exposed students did exhibit more errors in performing complicated tasks and fewer errors in performing a simpler set of tasks, leading the authors to conclude that the effects of RF exposure differed depending on the complexity of the task (Lass et al, 2002). Results may vary

depending on the relative timing of exposure and assessment (Cook et al, 2005). In a recent review of studies examining RF exposure effects on physiology and cognitive function, Cook and colleagues note that most studies focus on assessing effects during or immediately after exposure. They note, however, that eleven such studies observed delayed effects, occurring after the exposure was stopped. Cook et al (2005) propose therefore, that future research must examine specifically whether behavioural or physiological effects are occurring later in the “washout” or post-exposure phase that are otherwise being missed.

Regarding sleep disturbance from exposure to RFs, early research in a Swiss community, around a short-wave radio broadcasting station, indicated that self-reported sleep disturbances were more common in exposed, than non-exposed subjects (Altpeter, 2000). Some subjects in two studies looking at symptom reporting among people who live near base stations reported sleep disturbances as discussed further below (Navarro et al, 2003; Huber et al, 2006). Controlled laboratory study of effects on sleep from exposure to RFs is somewhat limited and firm conclusions cannot yet be made based on the present level of knowledge. However, recent sleep studies in the lab suggest that low level RFs have a slight sleep promoting effect (that is, they reduce sleep onset latency) and that they alter the brain’s alpha wave activity measured on electroencephalograms (EEGs) during sleep (Mann & Röshke, 2004).

Recent reviews conclude that while some small neurophysiological effects have been observed, it is not clear what the mechanisms are by which these occur. Some authors suggest that they cannot rule out effects from temperature increase or local heating of tissues, especially if exposures are not consistent and comparable. As well, experts conclude that the observed effects do not clearly reflect long-term, irreversible harm. As discussed in the next section, an important research gap is reflected by the lack of study of neurological effects in the young.

Children’s Sensitivity to RFs

In May 2000, a report by the Independent Expert Group on Mobile Phones (IEGMP) in the U.K., chaired by Sir William Stewart, (also known as The Stewart Report), was instrumental in drawing greater attention to the possibly higher sensitivity of children to RF radiation from using cell phones (IEGMP, 2000). In 2004, the U.K. National Radiological Protection Board (NRPB) echoed the conclusions of the IEGMP and emphasized the importance of precautionary measures to protect children by recommending that parents not allow children under age eight to use mobile phones (NRPB, 2004). Others have recommended similar restrictions on use of cell phones by children (See e.g. Nordic authorities, 2004). Despite an abundance of research examining the impacts of RF waves on human health, however, very little of it has been devoted to examining the specific susceptibility, exposure to and responses of children (Martens, 2005; Schuz, 2005).

Work is underway, largely through several studies in Europe, to address the research gaps and help resolve unanswered questions identified by both the Stewart report and by experts convened at a World Health Organization (WHO) workshop in June 2004 (WHO,

2004; Martens, 2005; Schuz, 2005). The focus of study has been on assessing the potential for impacts on the developing brain and determining whether children absorb a greater dose of RF compared to adults for reasons of age-related changes in anatomy and biophysical or biochemical properties (Martens, 2005).

A number of anatomical features in the child, such as smaller head and brain size, thinner cranial bones and skin, thinner, more elastic ears, lower blood cell volume, as well as greater conductivity of nerve cells, have all been proposed as potentially contributing to greater absorption of RF in the child's head compared to the adult's (Martens, 2005). While some report greater absorption of RF energy in child-size models (e.g. Gandhi et al, 1996; Martinez-Burdalo et al, 2004; de Salles et al, 2006) others conclude that this does not appear to be related to head size (Christ & Kuster, 2005). The evidence is unclear, however, regarding the potential impacts from 1) ear thickness and elasticity on RF exposure (thinner ears mean the phone is closer to the head) and 2) the conductivity of tissues such as the blood and brain¹² (Christ & Kunder, 2005; Martens, 2005).

As discussed earlier, studies where animals were chronically exposed to RF radiation beginning at a young age, have not shown increases in tumours, cancer incidence or alterations in immunological factors (Martens, 2005). There have been no studies of cancer effects in children using cell phones largely because widespread use of cell phones by children is a relatively recent phenomenon. This therefore limits the span of exposure and makes it difficult to adequately assess the potential for impacts, such as cancer, that require a long latency period. The U.K.-based Link Mobile Telecommunications and Health Research Programme (MTHR), created to address research gaps identified by the IEGMP in the Stewart report (2000), is conducting research to explore cancer in children under five in relation to cellular base stations. The study however, is described as being "challenged by issues of exposure measurement" (IET, 2006: 4). Changes in the cellular technology (going from 3rd generation to TETRA systems) have meant changes in emissions/power density which means that different cohorts of children will not have had comparable levels of exposure.

Only a small number of studies have looked at the impacts on cognitive function or mental processing in children using mobile phones (Lin, 2006). In an experimental study conducted in the U.K., Preece et al (2005, as cited in Lin, 2006) examined the impacts on cognitive function among 18 children ages 10 to 12 years old exposed to RFs from a mobile phone handset mounted on a plastic headset. This study examined reaction time (in milliseconds) and accuracy (percent correct) as the main response measures. The experimental sessions (hence exposure) lasted about 30 minutes each. The study found a statistically non-significant trend to faster reaction time and increased accuracy during RF exposure compared to sham-exposure (Preece et al, 2005, as cited in Lin, 2006). A study of 32 children ages 10 to 14 years from Finland applied a battery of eight cognitive tests that assessed reaction time and short-term memory (Haarala et al, 2005, as cited in Lin, 2006). In this study the phone was secured to the left side of the head with an adjustable rubber cap and exposure duration was about 50 minutes. In contrast to the

¹² Changes in the dielectric properties of tissue from childhood to adolescence decrease conductivity which decreases exposure with age.

study above, there were no significant differences in reaction times or accuracy associated with differences in exposure condition (Haarala et al, 2005, as cited in Lin, 2006).

In summary, the existing evidence of exposure, absorption and greater impacts on children is very limited and does not clearly confirm that children are more susceptible (Lin, 2006). However, in light of the limitations, we cannot rule out the possibility that children require greater protection from RF exposure. The fact that mobile phones are in increasingly common use by children ages 10 to 19 years, however, is justification enough for continuing to direct messages to children, teens and parents that suggest cell phone use be limited so as to avoid unnecessary exposure (Schuz, 2005). Toronto Public Health's health promotion work with the Canadian Partnership for Children's Health and the Environment supports minimizing exposure to radiofrequencies by limiting the extended use of cell phones by young people (CPCHE, 2005).

Studies of Health Effects Reported from Base Stations

Several recent papers have reported findings from studying health effects in populations living near base stations. This area of research has been considerably expanded compared to what was available in the published literature and reviewed in the TPH 1999 report.

A French study of 530 subjects and controls explored the self-reports of 18 different non-specific health symptoms that typically describe "Microwave Sickness", also known as "Radiofrequency Syndrome". Among the symptoms explored were fatigue, irritability, headache, nausea, loss of appetite, insomnia, depression, discomfort, difficulties in concentration and memory loss, skin change, visual and auditory dysfunctions, dizziness, gait disturbance, and cardiovascular alterations (Santini et al, 2002, 2003). The control (considered non-exposed) subjects were those living greater than 300 metres from a base station. Santini et al (2002) reported that health complaints were significantly more common among the subjects living within 300 metres of a base station compared to controls. The symptoms that were most often reported included nausea, loss of appetite, visual disturbances and gait difficulties (Santini et al, 2002). In those living within 100 metres of a base station there was significantly greater prevalence of some symptoms including irritability, depression, difficulty concentrating, memory loss, vertigo and lowered libido (Santini et al, 2002). There was, however, no clear relationship between symptoms reported and distance from the base station which may reflect either the nature of human sensitivity to RFs or more likely, the adequacy of approximating exposure using only distance as an indicator. There were some sex-related differences in symptom reporting, with women appearing to have greater susceptibility to symptoms such as, headache, nausea, loss of appetite, depression, discomfort and visual disturbances (Santini et al, 2002). Santini et al (2003) also determined that age was a factor influencing symptom reporting with more marked effects among those over 60 years of age. In addition, the frequency of reported symptoms increased (up to a distance of 100m from the base station) among those closest to the "face" side of the base station, the side from which the beam from the antenna is directed. Santini and colleagues (2002)

conclude that in light of their findings, base stations should be sited minimally 300 metres away from populations as a precaution.

A study in Murcia, Spain recruited¹³ more than 100 local residents and, using a similar questionnaire, researchers asked subjects to rate the frequency with which they experienced 25 non-specific symptoms (Navarro et al, 2003). The study also included daytime measures of RF in the bedrooms of each respondent, as well as outside their homes. Close to one-quarter of the subjects were regular users of cell phones. More than 95% were estimated to have exposure to RFs from the base station (based on vicinity) of more than six hours each day. Measured RF levels were below $0.2 \mu\text{W}/\text{cm}^2$, a value several thousand times below the ICNIRP guidelines for exposure to RFs in the 900 MHz frequency range.

One subgroup (n=47), living less than 150 m from the base station, had higher exposure (averaging $0.11 \mu\text{W}/\text{cm}^2$) and greater severity of symptoms¹⁴. A second group (n=54) with average exposure ten times lower ($0.01 \mu\text{W}/\text{cm}^2$), living more than 250 m from the base station reported fewer severe symptoms, but also was less likely to have regularly used a cell phone or personal computer, which may have influenced symptoms. A large number of symptoms correlated significantly with the measured RF field or exposure intensity including discomfort, irritability, loss of appetite, fatigue, headache, concentration difficulties and sleep disturbances (Navarro et al, 2003). Navarro and colleagues conclude that “it is possible that cell sites are causing adverse health effects” (2003: 167) and they recommend that further, similar research be conducted in other locations.

A study of 85 subjects living near base stations in Egypt assessed individuals using a battery of tests for visuomotor speed, problem-solving, memory and attention (Abdel-Rassoul, 2007). Exposed subjects lived either in a building with a base station antenna on top or, opposite a base station and these were matched to 80 non-exposed controls. Similar to the findings from other studies, exposed subjects reported a significantly higher prevalence of symptoms such as headache, memory changes, dizziness, tremors, depression and sleep disturbance than controls. The exposed subjects performed poorer on one test of attention and short-term memory. Those opposite the station had lower performance in one problem-solving test compared to those living in a building with a base station on top. Some tests, on visuomotor speed and attention for example, were performed better by the exposed subjects, which agrees with the findings by Preece et al (2005) among children. Given that all available RF measurements indicated exposure was below the allowable guidelines, Abdel-Rassoul (2007) recommends that the standards be revised and that neurobehavioural testing be used to regularly assess and detect biological effects in residents around base stations.

¹³ Subjects were recruited by telling them that the aim of the study was to “evaluate the impact on the area of the cellular phone base stations” (Navarro et al, 2003: 163). This raises the question of self-selection bias among the study sample.

¹⁴ Severity was assessed by asking subjects to score the frequency with which they suffered from the symptoms as 0 = “never”, 1 = “sometimes”, 2 = “often”, 3 = “very often” (Navarro et al, 2003).

Finally, the study in Austria by Hutter and colleagues discussed earlier, recruited 365 subjects for a study described as investigating “the relationship between environmental factors and health” (2006: 308). More than 60% of subjects did not express strong concerns about adverse health effects of base stations. Subjects were asked to report on a range of symptoms. Sleeping problems were explored and cognitive performance was assessed using tests of memory, reaction and perceptual speed. There was an increased prevalence of certain symptoms with higher exposure, with headaches, cold hands or feet and difficulty concentrating being significantly elevated, whereas tremor, loss of appetite and exhaustion were non-significantly elevated (Hutter et al, 2006). There was some indication of poorer sleep but it was highly significant only among those expressing concerns about base stations. Of the neurobehavioural tests, only perceptual speed showed a trend (non-significant) to faster speed, but lower accuracy, in the more highly exposed subjects. Hutter and colleagues conclude that effects on health and well-being from very low but long-term exposure to RFs from base stations “cannot be ruled out” and that, “as a precautionary measure, siting of base stations should be such as to minimise exposure of neighbours” (2006: 312).

In summary, the number and quality of studies examining impacts in people living near base stations is highly variable and limited. There appears to be some consistency in finding a higher prevalence of symptoms reported by those living closest to base stations, although the pattern of symptoms is not entirely consistent. The few studies for which RF levels have been measured indicate that exposure is well below the international guidelines. At this very early stage in the research, it is not possible to say whether or not RF exposure plays a role in the symptoms reported in these subjects living near base stations.

Electromagnetic hypersensitivity studies

A substantial body of research has been devoted to exploring the nature of the condition called “Electromagnetic Hypersensitivity” (EHS), more recently described as “Idiopathic Environmental Intolerance with attribution to electromagnetic fields (IEIEMF)” to indicate that the condition has as yet no confirmed cause (Staudenmayer, 2006). EHS refers to the condition experienced by a percentage of individuals in the population who report that they are highly susceptible to adverse effects from exposure to EMFs, including RFs, at levels commonly encountered in the environment.

There is no consistent, objective clinical diagnosis or recognizable set of symptoms for EHS. Individuals often report that they experience symptoms in the skin (redness, tingling, burning sensation) or more generally, a variety of health complaints including, fatigue, memory problems, concentration difficulty, dizziness, nausea, depression, digestive disturbance and heart palpitations (DCMNR, 2006; Levallois, 2006). These symptoms occur when they are in the vicinity of devices that emit electric, magnetic or electromagnetic fields such as powerlines, household appliances, visual display units, cellular telephones and cellular base stations. Symptoms vary from person to person and in their severity (Levallois, 2006). While they do not appear to vary with intensity of exposure, symptoms commonly occur at levels that are well below the recommended exposure guidelines (Lin, 2005).

Some research from self-reported surveys indicates there may be a population prevalence of EHS of 2 to 3% but figures vary depending on country (Levallois, 2006). A study of a large sample of Swedish adults indicated about 1.5% prevalence of people reporting sensitivity to EMFs (Hillert et al, 2002, as cited in Levallois, 2006). Just over 3% of a sample of 2,000 Californians reported being sensitive to EMFs (Levallois, 2002b, as cited in Levallois, 2006). In both of these studies, a large percentage of individuals who reported electromagnetic hypersensitivities also reported other environmental illness (Levallois, 2006). A telephone survey of a random representative sample of the Swiss population determined that there was a 5% prevalence of EHS (Schreier et al, 2006). Finally, a recent survey in the UK reports that about 4% of a sample of adults declared sensitivity to RFs (Eltiti et al. 2007).

Some evidence suggests that there is a certain proportion of the general population that has significantly greater physiological sensitivity to EMFs (Lin 2005). This has been shown in one study of the variation in perception thresholds for electricity (that is, ELF) in a random population sample of 708 adults in Austria (Leitgeb & Schrottner, 2003). Leitgeb and Schrottner found that there was a distinct subgroup of individuals who were able to detect electrical currents at threshold levels that were many times¹⁵ below the means for other subjects. While this study shows that there are individuals with a markedly increased ability to perceive electric current densities, it does not conclude that this is a precursor to health effects from that increased sensitivity. One small study with 16 subjects did not confirm the greater sensitivity of EHS individuals to RF exposures in the laboratory setting (Raczek et al, 2000, as cited in Rubin et al., 2005). Whether there is a similar variability in sensitivity to (that is, ability to detect) RFs requires further investigation with similarly large sample sizes.

A number of independent case reports describe peripheral neurological effects from RFs after use of a cell phone or from base station antennas (Westerman & Hocking, 2004). Case subjects report symptoms of dysaesthesia such as burning or tingling sensations, numbness, pain, dull ache, visual symptoms and inability to think clearly after exposures to various sources of RFs (Westerman & Hocking, 2004). Effects can be transitory or long-lasting. Regular nerve conduction studies do not detect abnormalities, but more sensitive techniques (e.g. current perception threshold) have indicated that at low exposures there is not gross nerve injury, but functional change (Westerman & Hocking, 2004). Westerman and Hocking (2004) note similarly that not all people exposed to a RF source experience such symptoms, but that it may involve a specific sensitivity to RFs.

A number of studies have exposed self-described EHS subjects to RF fields in a laboratory setting. The double-blind provocation protocol, where neither the subjects nor test administrators knows whether a given test is a real or a sham exposure, is the best test of the ability of EHS subjects to assess impacts from controlled exposure to RF fields. Few studies have included EHS subjects and few have looked at exposures to base station signals as opposed to cell phone signals. One study in the Netherlands found that

¹⁵ Eight-fold lower for the most sensitive men and 15 times lower for the most sensitive women (Leitgeb & Schrottner, 2003: 393)

compared to placebo exposure, exposure to a universal mobile telecommunications system (UMTS) mobile phone base station signal resulted in effects on well-being¹⁶ in both EHS and control subjects (Zwamborn et al, 2003). The exposure to GSM signals, however, did not produce significant effects in either group of subjects.¹⁷ Objective tests of cognitive performance in this study also showed some impacts from UMTS signal exposures, however, there was no clear pattern depending on frequency of exposure and while some tests showed deficits from exposure, others showed improvements (Zwamborn et al, 2003, as cited in Rubin et al, 2005). Researchers in Switzerland found that in both EHS (n=33) and control (n=84) subjects, well-being and perceived field strength were not associated with exposure to UMTS base station-like signals (Regel et al, 2006). Similar to the Dutch study above, effects on cognition were not consistent and any positive effects were described as “marginal” (Regel et al, 2006). Finally, a recent study of EHS (n=56) and control (n=120) participants in the UK found no evidence that short-term exposure to either GSM and UMTS base station-like signals affected well being or physiological parameters in either group (Eltiti et al, 2007). While in open provocation studies EHS subjects reported lowered well being under RF compared to sham exposure conditions, with a double-blind test, there was no difference in reported effects in either control or EHS subjects.

While experimental studies such as these offer advantages over observational studies (e.g. as discussed below in base station health effects) because they improve assessment of exposure, they still rely often on subjective symptom reporting, they only consider acute, immediate effects and typically have small samples of study subjects (Seitz et al, 2005). A serious limitation of experimental studies is their inability to adequately study long-term or latent effects and effects from cumulative exposures. The limited numbers of studies reviewed in recent years have not been adequate for addressing causality between exposure and effect (Seitz et al, 2005).

In summary, while there is widespread acknowledgement of EHS as a real condition occurring among a proportion of the population, the few studies available have not been able to conclude that RFs or other agents are causally related to the symptoms experienced by these individuals.

Summary

Research to address the question of whether exposure to low-level RFs can adversely affect health continues to accumulate. A number of major research projects are underway internationally (for example, the Interphone study on cell phone use and cancer occurrence; the COST Action 281 research being conducted through the European Cooperation in the Field of Scientific and Technical Research; the Link Mobile Telecommunications and Health Research Programme (MTHR) in the U.K., among

¹⁶ EHS individuals scored higher levels of anxiety, somatic symptoms, inadequacy and hostility, whereas control subjects scored higher on inadequacy only with exposure to a UMTS-like exposure (as cited in Rubin et al, 2005).

¹⁷ Universal Mobile Telecommunications System (UMTS) is a third-generation (3G) cell phone technology, whereas Global System for Mobile communications (GSM) is a 2nd generation cell phone technology. Both are digitally based.

others). Efforts are focusing on the gaps in knowledge and priorities identified by experts and as identified in the WHO research agenda, as one example. At the same time, there are regular initiatives to review the ongoing published work from these studies and from independent researchers. Examples of review reports include the Royal Society of Canada report and updates (Krewski et al 2001; RSC, 2004; Krewski et al, 2007), in the UK, the Independent Expert Group on Mobile Phones, (IEGMP, 2000), National Radiation Protection Board Advisory Group on Non-ionizing Radiation (AGNIR), (2003); the annual reports of the Swedish Radiation Protection Authority, (SSI, 2007) and of the Institute of Engineering & Technology (IET, 2006). In addition, there have been recent reviews by the International Commission for Non-Ionizing Radiation Protection (ICNIRP) (Ahlbom et al, 2004), the World Health Organization (Valberg et al, 2006), the European Commission's Scientific Committee on Emerging and Newly Identified Health Risks (EC-SCENIHR, 2006) and finally, the scientists of the BioInitiative Working Group (2007).

Not all review come to identical conclusions, which reflects the inconsistencies in the science, methodological limitations of some studies and differing scientific opinion. WHO concludes that current scientific evidence is “consistent with the conclusion that public exposure to permissible RF levels from mobile telephony and base stations are not likely to adversely affect human health” (Valberg et al, 2006: 416). Other expert panels emphasize that while health effects have not been consistently shown at RF exposure below the international guidelines, the current body of studies are limited in terms of their methodology. The ICNIRP panel and others have concluded in addition, however, that current evidence is not adequate to rule out the possibility that there is an association between RF exposure and adverse health effects (Ahlbom et al, 2004: 1741; Feychting et al, 2005). There is also general agreement from these reports that, despite the low exposure levels from cell phones and their base stations, and the gaps from current studies, continued effort to improve research studies is indicated and that exposure guidelines should be updated as new information is generated (RSC, 2004; Krewski et al, 2007). The BioInitiative Working Group scientists conclude however, that the current science is indicative of impacts occurring below current exposure guidelines.

Toronto Public Health's review indicates that, as was apparent in 1999, there continue to be many scientific uncertainties around possible health impacts from RFs. TPH concludes therefore, that it continues to be prudent to keep RF exposure of the public to a minimum wherever possible. TPH will continue to monitor and assess the science as it evolves.

5.0 POLICY CONTEXT & APPROACHES

5.1 Introduction

This section will focus on the international policy context largely as it pertains to the exposure guidelines established to protect the public from RF waves. It will describe the measures taken by various jurisdictions, which aim to reduce public exposure beyond that

specified by international guidelines. It will also revisit the original rationale endorsed by the Board of Health for a Prudent Avoidance Policy in Toronto.

5.2 Regulating Radiofrequencies

Although individual countries have their own regulations in place to protect people from radiofrequency radiation, the current global standard upon which most countries base their public exposure limits is from the International Commission for Non-Ionizing Radiation Protection (ICNIRP). As described earlier, ICNIRP incorporates a 50-fold safety factor to prevent health effects resulting from RF exposure that causes tissue heating, or thermal impacts. ICNIRP guidelines range from 4.5 to 10 W/m² depending on the frequency of the radio waves. These guidelines have been accepted by over 30 countries, and are consistent with the maximum exposure limits for Canada, the United States, United Kingdom and Australia, among others.

5.3 Other Jurisdictions

An increasing number of countries have developed more stringent exposure guidelines in response to concerns regarding the adequacy of the permissible exposure levels. These stricter exposure guidelines are typically at least an order of magnitude lower than the ICNIRP values. The lower exposure limits are founded variously on the precautionary principle, technologically achievable limits or, they reflect exposure values determined from a different scientific database, as will be discussed further below (Roy & Martin, 2007).

A number of other countries, including Bulgaria, China, the Czech Republic, Hungary, Italy, Russia, Poland and Switzerland have all adopted stricter, legally enforceable exposure limits for the public. As well, several local jurisdictions have made exposure limits more protective, largely through voluntary agreements with industry. For example, Auckland, six municipalities in Australia, Brussels, Paris and Salzburg have all implemented stricter exposure limits through cooperative agreements with proponents. The exposure limits supported by the Toronto Board of Health in 1999 are comparable to those applied by a number of countries such as Bulgaria, China, Hungary, Italy, Russia and Switzerland.

Table 4 below provides detail on the standards for public RF exposure limits of various jurisdictions that have adopted exposure standards stricter than the ICNIRP standard.

Table 4. Comparison of national standards for public exposure limits to RFs

Agency/Jurisdiction	General Public Exposure Limit[#] (W/m²)	Comments
ICNIRP	9	Guideline
Canada	10	Acute, thermal effects prevented
Board of Health	0.10	Cooperative agreement, precautionary
Italy	0.10*	Regulatory precautionary
Switzerland	0.10*	Regulatory, precautionary
China	0.10	Regulatory, science-based
Russia	0.10*	Regulatory, science based
Paris	0.10*	Cooperative agreement, precautionary
Salzburg	0.001	Cooperative agreement, precautionary

#For RFs at a frequency of 1800 megaHertz

*approximate conversion from Volts per meter to Watts per meter squared

+Minimizing unknown risks, based partly on public concerns (as described by Roy & Martin, 2007)

The various exposure standards listed above reflect differences in the philosophy of protection, the scientific database used and the approach to deriving reference or “threshold” levels (Roy & Martin, 2007). The ICNIRP standard, used by most nations, applies two uncertainty factors to a reference exposure level that equates to known thermal effects from acute exposure. The western European nations with stricter limits base these on the precautionary principle or focus on keeping RF emissions as low as reasonably (or technologically) achievable. These jurisdictions have implemented precautionary standards that are lower than the ICNIRP values, to account for possible non-thermal impacts occurring below the existing guideline. For example, the Italian government decided that extra precaution was warranted in light of research indicating non-thermal effects (Giuliani, 2000). Similarly, the Swiss regulations to limit non-ionising radiation exposure such as from radiofrequencies are founded on a principle of preventing effects on both health and well being which goes farther than ICNIRP. Experts from the Swiss Ministry of Environment, Forests and Landscape concluded that there was a link between the transmissions from cell phone towers and sleep disturbances and impacts on well being reported by people living nearby (BUWAL, 1999: 7).

In the case of eastern European nations (including Bulgaria, the Czech Republic, Hungary, Poland, Russia) and China, the RF exposure standard is based on a different approach. Scientists in these jurisdictions put greater emphasis on the biological effects observed at exposures below the ICNIRP standards. These nations have set standards so as to protect from the non-thermal effects caused by chronic, low-level exposure. This approach is informed by an extensive, although less familiar, database of studies conducted by eastern scientists who report distinct functional changes in central nervous, endocrine and immune systems among workers exposed to RFs (Roy & Martin, 2007; Chiang, 2000). Some biological effects from these studies have been viewed as falling within the normal range of variation for physiological functioning, whereas others are described as being more significant (Roy & Martin, 2007).

In addition to differences among nations, there are also local jurisdictions that differ from the approaches at a national level including setting more protective standards. As Borraz and Salomon (2005) discuss, this often reflects a difference in local views and tolerance of the population, which may necessitate stronger precautionary action. For example, in large cities in France (as in some other European nations), where public concern about cell phone towers is pronounced, local charters have come to be viewed, including by national government representatives, as the solution to potential conflicts in cell tower siting decisions (Borraz et al, 2004).

The experience in Paris is particularly instructive. With the signing of the Paris Charter in 2003, the city’s 3 mobile phone operators agreed to adhere to maximum public exposure intensity, averaged over 24 hours, of 2V/m. This measure is equivalent to 0.01W/m² at 900 MHz (or 0.1W/m² at 1800 MHz) and therefore at the higher frequency is similar to the levels recommended by the Board of Health (Hyland, 2003). Cellular carriers in Paris were quoted in the French media as stating that less than 1% of the city’s

base station antennas would need adjusting to meet the new standard (as reported in Microwave News 2003: 4). According to one industry source, before the agreement, mobile operators were effectively unable to install new base stations in Paris (Freeman, 2006). Although an evaluation of the charter's impact is not yet available, it appears that the conflict around siting of base stations in Paris has effectively lessened in recent years (Borraz et al, 2004; Freeman, 2006).

Other local initiatives reflect different approaches. In 2000, the Federal State of Salzburg, Austria, implemented an even stricter exposure standard through a similar voluntary agreement with industry. Similar to the circumstances in France, the Salzburg initiative was fuelled by citizen discontent and opposition to cell phone tower sitings (Oberfeld & Konig, 2000). The Salzburg Department of Public Health's proposed standard was derived by applying an uncertainty factor of 500 to data for effects of RFs on sleep (EEG change, REM sleep suppression) (Oberfeld & Konig, 2000). As shown in Table 4 above, the Salzburg public exposure limit is 100 times lower than that recommended by the Toronto Board of Health. Calculations indicated however, that almost all of the existing and planned installations would comply with the Salzburg standard (Oberfeld & Konig, 2000).

The parliament of Brussels, Belgium, is in the process of implementing proposed RF exposure limits of 3 V/m to 4.5 V/m, which are similar to those in Salzburg. These more protective exposure limits will come into effect in March 2009. In the interim, prior to full implementation of this standard, local officials have called for a moratorium on siting new cell phone towers and antennas (Le Soir, 2007).

In 2002 in Bavaria, Germany, where local protests to cell phone base station installations are stronger than elsewhere in the country, local governments and mobile phone carriers entered into a "Mobile Phone Pact" which allows for community engagement, participation and greater transparency in siting decisions. While the State of Bavaria commits to additional precautionary measures through the pact, alternative exposure standards are not included among these. However the community can make suggestions as to preferred locations for cell phone towers (Vogel, 2007). The pact has since been renewed and reports are that "less than 10% of the mobile phone base stations in Bavaria are built in dissent with the respective community" (Vogel, 2007).

5.4 Action on WiFi

Concern about exposure to WiFi among children and young adults has prompted action to remove or prevent its installation in many schools in the U.K. In 2006, the president of Lakehead University in Thunder Bay, Ontario limited installation of universal wireless access at the campus to areas not already served by the existing comprehensive campus fibre-optic network (Sibley, 2007; Lakehead University, 2004). His decision cited the potential for health effects and the need for precaution but was also based on the wide availability of an acceptable alternative.

In 2006, a prudent avoidance approach was used to assess the exposures from Toronto Hydro's WiFi installation One Zone™. Industry Canada estimates for a wireless fidelity (WiFi) mono-pole antenna showed that within a 10 metre radius around the antenna, maximum RF levels would be 1,000 to 10,000 times below the SC6 limit. Further away from the antenna levels were estimated to be even lower. These estimates indicate therefore, that the Toronto Hydro Telecom WiFi service would meet the guidelines recommended by the Board of Health in 1999.

5.5 Views on Need for Lower Exposure Guidelines

There continues to be debate about whether the current ICNIRP guidelines for RF exposure limits are adequately protective of human health. The debate centres on the interpretation of what is an adverse health effect, reflecting a difference in how the studies on non-thermal effects are viewed and the prominence they are given in determining a safe level of exposure.

The WHO acknowledges that governments might want to adopt precautionary measures to reduce exposure to RF fields because of public concerns, however, they continue to support existing international guidelines as providing adequate protection for health (WHO, 2000; Valberg et al, 2006).¹⁸ Instead, the WHO proposes that precaution could be incorporated into policies that encourage the cellular equipment manufacturers and the public to reduce RF fields voluntarily. The WHO and other countries acknowledge that biological effects are evident below the ICNIRP guidelines. However, they do not view these effects as representing adverse impacts to human health.

In contrast, there are a number of international researchers who view the science for biological (non-thermal) effects to date as establishing evidence of harm at levels of exposure well below current guidelines. The 2000 Salzburg Resolution on Mobile Telecommunication Base Stations characterized the evidence as indicating “there is no threshold below which there are no effects of radio frequencies on human health” (Salzburg Resolution, 2000:1). Consequently, the signatories recommended that exposure levels from RFs be kept “as low as technologically achievable” and as a preliminary¹⁹ measure to protect public health, that the total of all high frequency radiation should not exceed 1mW/m^2 ($= 0.001\text{ W/m}^2$ or $0.1\ \mu\text{W/cm}^2$). More recently, the International Commission for Electromagnetic Safety (ICEMS)²⁰, supported the call for a lowering of the exposure guidelines as one of several affirmations in the Benevento Resolution (ICEMS, Benevento Resolution, 2006). Finally, many of the same scientists, now identified as the BioInitiative Working Group, have argued similarly that the scientific evidence warrants preventive actions regarding RF exposure (Carpenter & Sage, 2007). In light of their assessment of evidence for reported human health effects at 1,000- to 10,000- fold below the safety standard for cell phone towers, the BioInitiative

¹⁸ Reporting on conclusions from a 2005 WHO expert workshop on base stations and wireless networks.

¹⁹ Describing these as “preliminary” acknowledges that there is still insufficient data to accurately estimate the risk of low level exposure to radio frequencies.

²⁰ An independent group of scientists from around the globe, some of the same signatories to the Salzburg Resolution.

Working Group proposes an interim cautionary target limit of $0.1 \mu\text{W}/\text{cm}^2$ for outdoor, cumulative exposure from RFs (Carpenter & Sage, 2007: 22). This is consistent with the recommendations from the Salzburg Resolution in 2000.

5.6 Toronto Board of Health's Prudent Avoidance Approach

The rationale for taking precautionary measures to reduce exposure through lowered guidelines, is informed by the need to take actions to reduce risks where the science is uncertain, where exposure is widespread and increasing, and where public concern is heightened. While precaution was a key foundation for the TPH Prudent Avoidance policy, of no less importance was analysis of the key gaps or uncertainties in the science which, under typical risk assessment practice, warrant consideration of additional uncertainty or “safety” factors in determining tolerable levels of exposure (TPH, 1999).

The proposal in 1999 to limit emissions from base stations in Toronto to a level not exceeding 100 times below Safety Code 6 was equivalent to adding at least 5 separate uncertainty factors to account for:

- 1) protection from biological effects which prove to be adverse – Safety Code 6 accounts for “thermal” effects (i.e. those due to heating) but does not account for “non-thermal” effects despite experimental evidence of behavioural and biochemical changes in animal and in lab systems, respectively;
- 2) extrapolating from short-term to long-term effects - Safety Code 6 is based on short-term effects (i.e. from acute exposure) and does not account for long-term effects (from cumulative, chronic exposure).
- 3) use of a lowest observed adverse effect level (LOAEL), instead of a no-observed adverse effect level (NOAEL), the latter being the typical standard in risk assessments,
- 4) intraspecific variability (that is within the human species) – Safety Code 6 incorporates one safety factor to account for the variation in human sensitivity to thermal effects because of age or health status, and
- 5) the potentially greater susceptibility of children to RFs.

The 1999 report also noted that Safety Code 6 does not take into account the potential proliferation of cellular antennas in urban centres such as Toronto, which may result in cumulative RF levels that are higher than in other parts of Canada. Standards set by regulatory agencies based on the short-term effects of other substances (such as chemicals), often incorporate a 1,000- to 10,000-fold protection factor which accounts for the uncertainties noted in points 3) through 5) above. An additional factor of 100 in Safety Code 6, as recommended by the Board of Health, would result overall in a 5,000-fold protection factor from acute effects, which is consistent with the standard setting practices for other substances.

In its 1999 decision, the Board of Health supported this line of reasoning for a Prudent Avoidance Policy that focused on an approach to minimizing exposure to RFs by incorporating an additional 100-fold protective factor beyond Safety Code 6. This equates to a limit of $0.1 \text{ W}/\text{m}^2$ for RF power density from cell phone towers and antennas.

Since the policy was adopted in 1999, TPH has asked to review data from proponents showing estimates for RF emissions in the vicinity of an installation. Using these estimates, it has been possible for staff to verify if levels in areas where people normally spend time (that is, workplaces, residences or areas where the public has unrestricted access) would be within the levels recommended by the Board (that is, 100 times below SC6). This verification process has indicated that these levels are readily achievable and that the proponents have been able to voluntarily comply without compromise to technology or performance. Most importantly, the process has served as a check to demonstrate that RF exposure to the public is likely to be minimal.

A Prudent Avoidance approach has also been used to assess the exposures from other sources such as radio towers and Toronto Hydro's WiFi installation One Zone™. As described earlier, Industry Canada modelling of RF levels from a wireless fidelity (WiFi) mono-pole antennas indicated maximum RF levels at 10 metres away would be 1,000 to 10,000 times below the SC6 limit and that further away from the antenna, RF levels would be even lower (Industry Canada, 2006, modeling done for Toronto Public Health).

6.0 IMPLICATIONS & CONCLUSIONS

The research published since the 1999 report and summarized above, does not resolve the question of whether there are adverse human health effects from low level, chronic exposure to RF radiation from cellular telecommunication devices and structures. As expert review panels have noted, however, the current evidence is equally not adequate to rule out the possibility that there are biological effects (RSC, 2004; Ahlbom et al, 2004; Feychting et al, 2005). It should be acknowledged as well that some scientists propose that the evidence is already indicative of potential harm below current international exposure standards and call for more protective exposure standards.

Despite disagreement on what the implications for policy are from the state of the science, experts continue to support strengthening of the research to explore these links and to re-assess exposure guidelines. This review notes that there has been an attempt for example, to better investigate the range of symptoms reported by those living near base stations, an area of research that was largely undeveloped at the time of the 1999 report by TPH. The findings of a number of these studies indicate that a proportion of the population living within 200 or 300 metres of a base station experiences symptoms that appear to coincide with what is known as “radiofrequency syndrome” or “microwave sickness” (Navarro et al, 2003; Hutter et al, 2006; Santini et al, 2002, 2003). Such studies are in their infancy and have not yet been conducted in Canada, but offer interesting insights into the potential for health effects (actual or perceived) from RF exposure at levels well below the current exposure guidelines. Some scientists conclude that these findings provide support for policy and siting decisions that ensure that the exposure of people living nearest cell phone tower installations is minimized (Hutter et al, 2007).

Since the 1999 report by TPH, there has been some work done to better characterize public exposure to RFs in Toronto and elsewhere as well. Generally the evidence from outdoor monitoring confirms that exposure is far below the Safety Code 6 guidelines and usually within the levels recommended by the Board of Health. It also confirms that cellular base stations and WiFi currently contribute to less than half of the public's ambient exposure to RFs. However, there are large gaps in our understanding related to the cumulative exposure to RFs in the community, inside buildings and for any individual, in light of the ever-expanding use of wireless technology and devices in society.

Undoubtedly, local governments and public health units are having to face increasing rather than lessening public concern about exposure to RF radiation. This has played out typically around the proposed siting decisions or the locations of existing cellular base stations. Currently, the local council in Norfolk, Ontario is considering requests that an existing cellular antenna (wireless equipment) be removed from town of Simcoe's water tower. The issue is highly controversial because the costs to compensate the owner to re-locate the antenna are substantial. Public confidence in decision-making may be improved if health concerns are addressed early on in the proposal of a cell phone tower siting. For example, in Ontario's Peel Region the school board asked for a public health opinion on whether there would be risks to children from a proposed cell phone tower siting near a school (Louise Aubin, Peel Region Health, 2007, personal communication). The school board was satisfied with the opinion that the exposure would be minimal given the location. Policies and strategies for responding to these concerns and for proactively addressing the potential risks of RF exposure from base stations and other environmental sources have therefore become increasingly important.

TPH has reviewed the recent literature and concludes that uncertainties in the science remain. The line of reasoning outlined in the 1999 TPH report for a) specifying a lower exposure threshold than prescribed in Safety Code 6 and for b) implementing a prudent avoidance policy to guide decisions on where to place cellular transmission towers and WiFi installations continues to be reasonable and feasible and is not contradicted by the current state of the science. Health Canada has not revised its guidelines to address the concerns raised in 1999. It continues to be prudent to limit exposure to RFs and to encourage that telecommunication towers and antennas be sited so that levels of RFs in areas where people normally spend time remain 100 times below Safety Code 6. Therefore, the Medical Officer of Health recommends that the City continue with a prudent avoidance approach and collect data from cell phone carriers on predicted RF levels of proposed towers and antennas. This will allow the City to monitor the potential impact of proposed telecommunications facilities in Toronto and to encourage voluntary adoption of the Prudent Avoidance Policy.

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