**City of Toronto**
**Community and Neighbourhood Services**
**Toronto Public Health**
**Health Promotion and Environmental Protection Office**

# HEALTH CONCERNS OF RADIO FREQUENCY FIELDS NEAR BASE TELEPHONE TRANSMISSION TOWERS

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# TABLE OF CONTENTS


EXECUTIVE SUMMARY ........ 1

INTRODUCTION ........ 5

UNDERSTANDING ELECTROMAGNETIC WAVES ........ 5

FREQUENCIES USED FOR CELLULAR TELEPHONES ........ 5

MODIFYING FACTORS ........ 6

MEASUREMENT OF DOSE ........ 6

REGULATING RADIO FREQUENCIES ........ 7

EXPOSURE POTENTIAL ........ 7

HEALTH EFFECTS ........ 8

THERMAL EFFECTS ........ 8

NON-THERMAL EFFECTS ........ 9

HUMAN STUDIES ........ 13

PRUDENT AVOIDANCE ........ 14

HIGH EXPOSURE SCENARIOS ........ 14

CURRENT CANADIAN STANDARDS ........ 15

LEVELS OF CONCERN ........ 16

NEED FOR PRUDENT AVOIDANCE ........ 18

APPROACH TO PRUDENT AVOIDANCE ........ 18

RECOMMENDATIONS ........ 20

TABLES ........ 22

REFERENCES ........ 28

## EXECUTIVE SUMMARY

The use of wireless communication technology is increasing rapidly. In particular, cellular telephones and their associated transmission towers are becoming more widespread. Cellular telephones allow for improved communication and are becoming an integral part of how we live and work. They can enhance work productivity, improve service capabilities, and provide for increased personal or family security. However, there is an associated concern over the potential health effects of this technology, in particular the emissions of radio waves.

In Canada, the regulation of telecommunication devices is a federal matter, which is administered by Industry Canada. Telecommunication devices must meet the requirements of Safety Code 6: *Limits of Human Exposure to Radiofrequency Electromagnetic Fields in the Frequency Range from 3 kHz to 300 GHz*. This code, developed by Health Canada, includes guidelines for exposure to the public. Allowable power densities for public exposures vary depending on frequency and range between 2 and 10 $W/m^2$.

The use of wireless telecommunication devices (e.g., radio, television, and wireless telephones) has resulted in ubiquitous radio frequency (RF) fields in the environment. On the ground, maximum power fields are usually found 30 to 250 meters from base telephone towers. Results from monitoring studies typically show levels of RF well below current safety standards. For example, in Vancouver at a school with a roof-mounted antenna, the highest levels measured (25 times less than Safety Code 6 standards) were on the roof. At ground level around the school, the maximum RF levels measured were 230 times below current standards. Indoor levels were even lower (4,900 times below the limit).

In discussing health effects of radio waves, it is common to distinguish between thermal, athermal and non-thermal effects, as follows:

- Thermal 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 0.1°C).
- Athermal effects occur when there is sufficient energy to cause an increase in the temperature of the body, but no change in temperature is observed due to natural or external cooling.
- Non-thermal effects are those occurring when the energy of the wave is insufficient to raise temperatures above normal temperature fluctuations of the biological system being studied.

The thermal effects of RF fields in general are well known. They include changes in temperature regulation, endocrine function, cardiovascular function, immune response, nervous system activity, and behaviour. Current standards are set to prevent adverse health outcomes from the thermal effects of RF.

Some of the non-thermal effects of concern that have been studied include the following: the potential to promote the formation of tumours; the increase in the permeability of the blood-brain barrier; the potential influence on the natural pain control mechanism; and, changes in sleep patterns. The Royal Society of

Canada (RSC), at the request of Health Canada, has recently reviewed the health effects of RF. It notes that there is increasing evidence that biological effects occur at low levels of RF which do not result in any thermal effects. It concludes that it is still uncertain whether these biological effects should be considered as adverse effects. However, the scientific evidence is not sufficient to rule out the possibility of adverse health effects at such low levels of exposure.

Other areas of concern are the impacts of RF on reproduction and cancer. The RSC concludes that the weight-of-evidence available today does not suggest that RF can cause cancer or reproductive effects in humans. More research is needed to confirm if RF can cause genetic damage or if biological effects would lead to adverse health impacts.

The precautionary principle argues for caution when there are uncertainties on what level of exposure could have potential adverse effects. Waiting for confirmation of adverse effects from epidemiological studies before taking action does not adhere to a public health approach, which encourages prevention over cure. So far, human studies have not indicated a strong link between RF exposures and adverse human health effects. This is reassuring – if there are any health impacts at current levels of RF found in the environment, they are likely to be small. However, due to various methodological limitations, such studies by themselves are not sufficient as proof of either safety or harm.

The public is exposed to radio frequency fields from a multitude of sources in addition to cellular telephone services. Radio, television, radio taxis, pager services, emergency communications (e.g., police, ambulance, radar) all depend on the use of radio waves. Given the size and density of the city, the presence of many high buildings close to each other and the numerous other sources of RF there is concern that overall exposure levels in Toronto may be greater than in other Canadian communities. Therefore, the siting of telephone transmission antennas in the city merits special consideration.

In deciding whether current exposure levels of RF are a concern, there are several areas of uncertainty that need to be addressed. For example,

- *Non-thermal effects*: Current standards are based on thermal effects of RF. Available data show that biological effects do occur at levels below those where thermal effects are known to occur. While there is uncertainty in the health significance of these effects, it is also uncertain whether current standards would protect from potential adverse effects should these be confirmed.

- *Duration of exposure*: Current standards are based on short-term effects. Longer-term animal studies at lower levels of RF showed behavioural changes because of mild heat stress. Stress is known to lead to various adverse health outcomes. In addition, a doubling of cancer incidence has been reported in cancer-prone mice at average exposure levels of RF close to occupational exposure limits. More studies are needed to confirm if long-term low level exposures can lead to adverse effects.

- *Use of threshold effect*: Present standards are based on a threshold for irreversible effects, rather than a no-effect level. Preference is normally given to the use of a no-adverse effect level (NOAEL) in developing environmental health standards.

Based on current practice of environmental standard setting in various agencies, the uncertainties identified above suggest that a protection factor of 1,000 to 10,000 is justified and prudent. Current levels for the public under Safety Code 6 incorporate a protection factor of 50. The current standard uses a factor of 5 to derive public exposure levels from occupational levels. This is less than is often customary, where a factor of 4.2 is used to convert exposure levels from a 40 hour work week to continuous exposures, and an additional protection factor of 10 to take into account that some people in the general population are often more sensitive than workers. Ensuring that levels of RF were kept 100 times below Safety Code 6 recommendations would be equivalent to using a safety factor of 5,000. This is within the range given above.

In examining the need for a prudent avoidance policy, Toronto Public Health considered two factors:

- Specific situations where high levels of exposure may occur; and
- The weight-of-evidence that harm may occur at these levels of exposures.

There are situations where Toronto residents could be exposed to levels of RF approaching Safety Code 6. Given the degree of uncertainty as to whether or not such levels could result in adverse health effects, Toronto Public Health supports the implementation of a prudent avoidance policy. Such a policy encourages the adoption of individual or societal actions to avoid unnecessary exposures to radio frequencies that entail little or no cost.

Toronto Public Health was requested to consider a policy of prudent avoidance based on restricting the siting of base transmitter antennas a certain distance from schools and day-care centres and away from residential areas. Given the density of Toronto, the mixed land use, and the existing network of antennas, it would be difficult to implement such an approach. Toronto Public Health believes that a prudent avoidance policy that ensures that the public is exposed to levels less than those recommended by Safety Code 6 would provide a greater level of protection, and in a more consistent way, than either a distance- or land-use based policy could.

In Canada, the final authority for the approval of the installation of base transmission towers lies with Industry Canada. The City of Toronto has little direct control over this matter. It is therefore recommended that the City work with the industry to develop a protocol for the siting of antennas in the City. A protocol incorporating a policy of prudent avoidance is in accord with the recommended policy and procedures of Industry Canada. This protocol could be developed by the City's Telecommunications Steering Committee in conjunction with all the relevant parties. It should include the following elements:

(1) A request that applicants who wish to install new, replacement or modified antennas demonstrate that radio frequency exposures in the areas where people other than telecommunications workers would normally use (e.g. roof-top gardens, balconies, or grounds) will be at least 100 times lower than those currently recommended by Safety Code 6;

(2) In situations where residents express concern over an existing base cellular telephone antenna, the owner and /or operator of the facility be requested to monitor levels of RF fields around the antenna and provide this information to the affected community and the Telecommunications Steering Committee; and

(3) A mechanism for notifying residents of a proposed site for new telephone base antennas. This notification should include the advantages of using the proposed site, alternative sites considered, and the maximum expected exposure to RF due to installations in areas that the public or building occupants would normally use.

The application of this prudent avoidance policy and protocol is expected to be feasible and readily achievable. It will also provide a rational basis with which to evaluate and respond to community concerns about both existing and future installations. The predicted exposures from single installations are very low, and thus in most cases, this policy is not expected to have an adverse impact on existing facilities. However, this policy provides an extra measure of protection as the number of installations increases in the city, and in the event that new research provides evidence that adverse effects do occur at levels lower than those currently known to do so.

# INTRODUCTION

The use of wireless communication technology is increasing rapidly. In particular, cellular telephones and their associated transmission towers are becoming more widespread. Cellular telephones allow for improved communication and are becoming an integral part of how we live and work. They can enhance work productivity, improve service capabilities, and provide for increased personal or family security. However, there is an associated concern over the potential health effects of this technology, in particular the emissions of radio waves.

The use of wireless telecommunication devices (e.g., radio, television, and wireless telephones) has resulted in ubiquitous radio frequency (RF) fields in the environment. In Canada, the regulation of telecommunication devices is a federal matter, which is administered by Industry Canada. In addition, telecommunication devices must meet safety requirements as set out by Health Canada.

The public is exposed to radio frequency fields from a multitude of sources in addition to cellular telephone services: radio, television, radio taxis, pager services, emergency communications (e.g., police, ambulance, radar). Given the size and density of the city, the presence of many high buildings close to each other and the numerous other sources of RF, there is concern that overall exposure levels in Toronto may be greater than in other Canadian communities. Therefore, the siting of telephone transmission antennas in the city merits special consideration.

This report summarises current knowledge on the potential health effects and reviews current safety standards. It then discusses the need for a prudent avoidance policy in the City of Toronto.

# UNDERSTANDING ELECTROMAGNETIC WAVES

Radio waves are a form of radiant energy, which includes visible light. Wavelength and frequency are basic characteristics by which electromagnetic waves are described. Waves with shorter wavelength than visible light include ultraviolet light, X-rays, and gamma-rays. Waves with longer wavelength than visible light include infrared light, microwaves, radio waves, and extremely low frequency (ELF) fields such as those produced by electrical power lines. Waves with sufficient energy to break chemical bonds are referred to as ionising radiation. These include X-rays and other higher frequency waves. Other waves are non-ionising.

## *Frequencies Used for Cellular Telephones*

The frequency of a wave is the number of cycles per second. It is measured in hertz (Hz). Radio frequencies are in the million of hertz range or megahertz (MHz). One gigahertz (GHz) is 1,000 MHz. The higher the frequency, the shorter the wavelength. The frequencies currently, and anticipated to be, used for wireless communication in Canada are given in Table 1. 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.

### *Modifying Factors*

Various factors influence the effect of electromagnetic fields (EMFs) including radio frequency (RF) fields:

*The strength of the field*: In general, the stronger the field, the stronger is the anticipated effect. However, there is evidence that, in some cases, a window effect may exist. In these cases, effects have been seen at low and high levels, but not at levels in between.

*The frequency or wavelength*: Frequency and wavelength are directly related - the higher the frequency, the shorter the wavelength. Most people are familiar with the differences in effects between X-rays, ultraviolet radiation, visible light, and infrared radiation, for example. Waves with the highest frequency and shortest wavelengths are thought to present the most hazards. X-rays and ultraviolet light have a higher frequency than visible light, and are known to cause cancer. At frequencies below those of visible light, adverse impacts are usually associated with the heating effects of the waves on biological systems. There is evidence that some effects are specific to a frequency or small range of frequencies.

*Modulations in the field*: Modulations are changes in the fields such as variation in the frequency or strength. Different effects have been noted with pulsed or continuous waves, and these differences can also depend on the frequency of the modulation.

*Resonance*: The amount of energy absorbed depends on the size of the object. Maximum energy is absorbed when the size of the intercepting body approaches that of the wavelength. The larger the body the lower the resonant frequency. For a standing adult, it is about 77 MHz, and for a mouse about 2450 MHz. (Hitchcock & Patterson, 1995). The impact of RF is therefore also related to the size of the body being affected.

*Distance from the source*: The characteristics of waves change as the distance from the source increases. Close to the source, the near-field, the fields are more complex. At distances which are multiples of the wavelength (the far-field), fields are more predictable. Except for special work situations, exposures to fields from base station transmitters would normally occur in what is known as the far-field zone.

### *Measurement of Dose*

When looking at the impact of electromagnetic waves on living organisms, the specific absorption rate (SAR) is the most reliable indicator of the potential for RF-induced biological effects (Hitchcock & Patterson, 1995). It is related to the rate at which RF energies are absorbed by a given mass of material.

Its unit of measure is watts per kilogramme (W/Kg). The amount of energy absorbed by a body depends on its characteristics such as size and density as well as the strength and frequency of the field the body is exposed to. At distances that can be considered in the far-field, the power density is sufficient to indicate RF field strength. Its units are watts per square metre ($W/m^2$) or milliwatts per square centimetre ($mW/cm^2$) -- 10 $W/m^2$ equals 1 $mW/cm^2$. Since it is difficult to measure the SAR outside of a laboratory, exposure limits are given in terms of power densities as well as SAR.

***Regulating Radio Frequencies***

In Canada, the regulation of telecommunication devices is a federal matter, which is administered by Industry Canada. It has set out a procedure for the approval of the siting of telecommunication antennas: *Environmental Process, Radiofrequency Fields and Land-Use Consultation.* It is the policy of Industry Canada to consider environmental effects, safety requirements, and consultation with land-use authorities before issuing an authorization. Industry Canada encourages applicants to address the concerns of the community.

Telecommunication devices that are installed in Canada must meet the requirements of Safety Code 6: *Limits of Exposure to Radio Frequency Fields at Frequencies from 10 kHz to 300 GHz*. Developed by Health Canada, it outlines the safety requirements for telecommunication installations and devices. This includes guidelines for exposure to the public. Allowable power densities vary depending on frequency and range between 2 and 10 $W/m^2$ (see Table 2). In cases when multiple frequencies are emitted at the same time, or when multiple transmitters are located in the same vicinity, the total of such emissions cannot exceed these values. In October 1999, Health Canada revised Safety Code 6. There were some slight changes in exposure limits, but whole body SAR levels, which are relevant for public exposure to RF from telephone base transmitters, are the same as in earlier versions of the Code. The exposure limits set out are similar to those of other jurisdictions and international bodies. Concern has been raised regarding the adequacy of the permissible exposure levels and various jurisdictions has recommended that levels of RF are kept below these limits (BUWAL, 1999; NZine, 1997; Vermont, 1996).

## EXPOSURE POTENTIAL

The use of wireless telecommunication devices (e.g., radio, television, and wireless telephones) has resulted in ubiquitous RF fields in the environment. Radio and television broadcast antennas typically transmit at much higher power than telephone systems. Two groups of people are at higher risk of exposure to RF from cellular telephones: workers near or around transmitting devices and users of the phones.

At ground level, maximum power fields are usually found 30 to 250 meters from base telephone towers. Power densities inside buildings are much lower than outside since the walls and ceilings act as a barrier.

This is even the case on the top floors of buildings with roof-top installations. When antennas are mounted on the side of buildings, the radio waves are sent outwards away from the building, resulting in minimal exposures to those inside the building.

Results from other monitoring typically show levels of RF several thousand times below current safety standards, 10 mW/m$^2$ or even less (Health Canada, 1998; Thansandote, et al., 1996 & 1999). In monitoring done at five Vancouver schools, the highest levels of RF were found at a school with a roof-mounted analogue antenna. Levels measured were on the roof were 25 times less than Safety Code 6 standards (RSC, 1999). At ground level around the school, the maximum RF levels measured were 230 times below current standards. Indoor levels were even lower (4,900 times below the limit). In schools with no telephone antennas in the vicinity, the highest levels of RF were from AM radio broadcast. Monitoring done around the Leslie Street water tower in Toronto found levels of RF to be below the detection limit of 26.5 mW/m$^2$ (Imagineering, 1999). In Corbyville, Ontario, measurements in the neighbourhood of an analogue base station found power densities of 0.010 mW/m$^2$ (about 10,000 less than the limit). And, at a southern Ontario farm RF levels were measured to be 0.0002 mW/m$^2$, which is more than a million times below Safety Code 6 permissible levels (Gadja, et al., 1998 - as cited in RSC, 1999).

## HEALTH EFFECTS

The summary of health effects given here is mostly extracted from the recent review by the Royal Society of Canada (RSC, 1999). It was performed at Health Canada's request as part of the on-going evaluation of the adequacy of Canadian standards for RF exposure. This review was thus considered the most appropriate source for a discussion on the potential of adverse health effects from RF at exposures below current standards.

In discussing health effects of radio waves, it is common to distinguish between thermal, athermal and non-thermal effects:

- *Thermal 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).
- *Athermal effects* occur when there is sufficient energy to cause an increase in the temperature of the body, but no change in temperature is observed due to natural or external cooling.
- *Non-thermal* effects are those occurring when the energy of the wave is insufficient to raise temperatures above normal temperature fluctuations of the biological system being studied.

### *Thermal Effects*

The thermal effects of RF fields in general are well documented. They include: changes in temperature regulation, endocrine function, cardiovascular function, immune response, nervous system activity and behaviour (Elder, 1987; Roberts, et al., 1986; Cleary, 1990 - as cited in RSC, 1999). Genetic changes have been observed only in the presence of substantial temperature rise (Elder, 1987; Michaelson and Lin, 1987; Blackman, 1984 - as cited in RSC, 1999). Irreversible effects, including cataracts and developmental effects in offspring, have been noted at exposures greater than 10 W/Kg (RSC, 1999). At lower intensities, between 1- 4 W/Kg, these irreversible effects are not expected to occur. Physiological and behavioural effects of moderate thermal exposure to RF are considered reversible upon cessation of exposure.

The most sensitive effects noted are behavioural responses. A threshold exposure level of 4 W/Kg has been identified in short-term behavioural studies, and these have been used to derive levels of 0.4 W/Kg for occupational exposures and 0.08 W/Kg for public exposures (RSC, 1999). Based on results from longer-term studies, D'Andrea (1991) suggests that a threshold for behavioural effects in rats may be lower – between a SAR of 1.5 and 3.6 W/Kg at 1300 MHz, and 0.4 and 0.7 W/Kg at 2450 MHz. These effects are still thought to be due to thermal effects, even if whole body temperature changes have not been recorded. It is generally assumed that adverse effects of RF occur only at levels where heating also occurs. Field strengths to which the general public is exposed are well below those at which thermal changes occur.

Several medical devices use electromagnetic energy and can result in exposure greater than 4 W/Kg. Magnetic Resonance Imaging (MRI) is the main source of RF exposure from medical use in Canada. Exposure limits are 2 W/Kg over 25% of the body for 15-minute exposures, or less, and 1 W/Kg for exposures greater than 15 minutes have been established (RSC, 1999). The US Food and Drug Administration has recently approved a RF therapy for chronic psycho-physiological insomnia. This therapy is effective at levels below 4 W/Kg. In its review, the Royal Society considered this the strongest evidence of biological effects below current human exposure standards (RSC, 1999).

### *Non-thermal Effects*

Many effects have been noted at field strengths that do not induce temperature changes. The health significance of these changes is debated since results from human and experimental studies vary greatly and are inconsistent. Even the best studies have severe limitations. Various biological effects have been reported at SAR below 0.08 W/Kg or power densities (depending on frequencies) of 2-10 W/m$^2$. These include effects on cell proliferation, calcium ion efflux, blood-brain barrier permeability, behaviour, and the enzyme ornithine decarboxylase.

#### *Cell Proliferation*

Increase in cell proliferation is linked to the development of cancer. The influence of RF exposure on cell proliferation *in vitro* has been studied with mixed findings. Table 3 summarises the papers reviewed by the Royal Society of Canada (RSC, 1999).

*Calcium ions efflux*

The ability of electromagnetic waves to increase the flow of calcium ions out of cells was first demonstrated in 1975 by Bawin et al. (as cited in RSC, 1999). This effect has been used as a marker for nervous system effects in *in vitro* experiments. It is not dose dependent. Rather it shows a "window effect". Certain frequencies, power densities, modulations, and temperatures are effective and others are not. There is no gradient apparent, for example greater effect at higher frequencies or greater effect at higher power densities (Hitchcock and Patterson, 1995). Responses have been observed at power densities as low as 0.05 W/Kg using RF of 915 MHz (Dutta et al., 1984 as cited in RSC, 1999). The Royal Society of Canada notes that there is insufficient data to assess such effects of low level exposures to RF over 1000 MHz as these have not been tested (RSC, 1999). It concludes that power density windows have been observed for extremely low frequency (ELF) modulation or RF and microwave carriers and that ELF-modulated RF radiation could effect calcium efflux from brain tissue.

*Ornithine Decarboxylase (ODC) and Polyamines*

Ornithine decarboxylase (ODC) is an enzyme, which is related to cell growth and development. There is a correlation between increased levels of ODC and an increase in cell growth and multiplication in normal or cancer cells. A small increase of ODC activity has been shown to occur in both cell cultures and in animals exposed to various electromagnetic waves. One to four hour exposures to modulated radio frequencies of 450 MHz at a SAR of 0.08 W/Kg resulted in a 1.5 - 2.6 increase in level of ODC (RSC, 1999). The Royal Society of Canada notes that mammalian cells and tissues are capable of sensing exposures to low-frequency components of magnetic, microwave and RF fields at SARs of between 0.1 to 2.5 W/Kg, and that effects can occur within less than one hour of exposure.

Although ODC expression has been related to various effects, the one of most concern has been the link with cancer. ODC production has been associated with cancer promotion rather than to its initiation or progression. Current data suggests that ODC-over-expression, even if it is not associated with cell proliferation, might be sufficient to cause tumour promotion. However, the observed increase in ODC from ELF is much less than generally seen by chemical agents, where as much as a 500-fold increase has been recorded. The Royal Society of Canada concludes that the potential additive or synergistic effects of ELF should be considered when addressing the potential health impacts of RF, and further research is needed in this area before the risks, if any, can be quantified.

*Melatonin*

Melatonin is a hormone of the pineal gland whose production is highest during the night (dark period). It plays a critical effect in various bodily functions including reproduction. Given the significance of visible light on the pineal function, and data which suggests that ELF may affect melatonin production and utilisation, it is also possible that RF could have an effect on this hormone. Although, some studies have shown no impacts of RF on melatonin production, the Royal Society of Canada concludes that these are not sufficient to reject the hypothesis that RF can affect pineal function, regulation of melatonin levels, or cellular utilisation of this hormone (see Table 4).

*Cell Membrane Effects*

The flow of calcium, potassium and sodium ions through cell membranes is important for various cell functions and for the transmission of messages between cells. Various studies have shown that ELF and RF can have an impact on the movement of these ions through the cell membrane. These have been noted at various exposure levels (0.2-200 W/Kg) and frequencies ranging from 27 MHz to 10 GHz (RSC, 1999). The significance of these effects is not known.

Some studies have shown that RF can affect the blood-brain barrier at levels below current Canadian exposure guidelines (see Table 5). RF of 915 MHz caused a significant increase in permeability at 0.016 - 0 0.1 W/Kg (Prato et al., 1994 - as cited in RSC, 1999). The Royal Society of Canada suggests that the variability in the results obtained in various studies on permeability may be due to the sensitivity of certain cells to specific frequencies and/or modulations in the waves.

*Central Nervous System Effects*

Work done in the Soviet Union during the 1950s and 1960s suggests that microwave (MW) radiation could have an effect on the brain (RSC, 1999). However, these findings have not been replicated elsewhere. Given that the brain is the most electrically active part of the body, it is possible to hypothesise that microwaves could induce effects within the central nervous system.

There are a number of instances where there is a correlation between a biological effect and a clinical condition. For instance, in Alzheimer's disease a loss of acetylcholine leads to memory and cognitive impairments. There is evidence to suggest that MW radiation can influence cholinesterase enzymes. The Royal Society of Canada concludes that, at this time, the data are insufficient to show a link between MW exposure and Alzheimer's or related diseases (RSC, 1999). It also concludes that there are no data to support a link between RF and seizures or epilepsy.

There is some evidence of impact of RF on sleep patterns: the shortening of sleep onset and reduction of rapid eye movement (REM) sleep. The data is insufficient to draw any firm conclusions on the implications of these findings for health (RSC, 1999).

*Behavioural Effects*

Present safety standards are based on the threshold for behavioural effects of RF. There is evidence that some electromagnetic fields, including RF, have an impact on the nervous system at levels where no heating effects are expected. In some studies, rats exposed to RF have performed less well in spatial memory tasks. It has been suggested that these may be related to bio-chemical changes in the opioid (pain control) system which have been observed at RF of 2450 Hz at 0.6 W/Kg or 10 W/m$^2$ (Lai, 1996; Lai et al., 1992, 1994 - as cited in RSC, 1999). Low-level microwave fields ( 2450 MHz at 10 W/m$^2$) have caused synergistic effects with psychoactive drugs (Thomas et al. 1979, as cited in RSC, 1999).

*Mechanisms of Action*

Some of the effects of electromagnetic waves, including RF, do not depend on an increase in temperature (RSC, 1999). There are similarities in extremely low frequency (ELF) effects on cellular calcium ion flux, ODC activity, and behavioural activity related to the opioid system and those observed with RF fields. Different waveforms can have different effects. Continuous and ELF-modulated RF can at times produce different non-thermal effects. The Royal Society of Canada notes that a better understanding of the mechanism by which non-thermal effects occur is necessary, otherwise, each time the communication industry modifies its waveform, it will need to be tested to determine if it might elicit a detrimental biological effect.

*Genetic damage*

A large number of studies have looked at the potential of RF fields to cause damage to genes. These have not resulted in consistent positive findings (RSC, 1999). A recent study (Lai and Singh, 1995) showed DNA damage in the brain of rats exposed to waves at 2450 MHz, however these results have not been corroborated. Some cell transformation assays suggest that RF fields may be synergistic in combination with other known or promoting agents (Balcer-Kubczek and Harrison, 1991, as cited in RSC, 1999).

*Cancer*

The link between RF exposure and cancer, specifically leukaemia, was first suggested by Prausnitx and Susskind in 1962 (RSC, 1999). Other studies have shown increased rates of cancer or tumour formation (mammary tumours, skin tumours) by RF alone or in conjunction with other agents. Given the doses used in the experiments, it is not possible to eliminate thermal effects as a contributing factor. A recent study (Repacholi, et al., 1997) in cancer-prone mice showed a 2.4 fold increase in lymphomas. Other studies have not been able to replicate this finding (RSC, 1999). Preskorn et al. (1978, as cited in RSC, 1999), found a reduction of tumours after exposures to RF. Two recent long-term studies in tumour prone mice (Frei, et al., 1998; Toler, et al., 1997 - as cited in RSC, 1999) did not show increased incidence of breast cancer or of lymphoma, leukaemia, or brain tumours. Several animal studies have looked at the ability of

RF fields to accelerate tumour development. Most of these have given negative results (Table 6).

### *Human Studies*

#### *Cancer*

Various studies have looked at the humans exposed to RF fields to determine if such exposures could be associated with adverse health effects. Elwood (1999) recently reviewed the published studies on RF exposure to humans and potential cancer effects. Some initial cluster studies have pointed to a possible association with RF and cancer, but when follow-up analyses were undertaken, these did not support the initial findings (Elwood, 1999). Table 7 summarises the relative risk of leukaemia from various studies (Elwood, 1999). The study showing the strongest link between RF and cancer is a study of Polish military personnel (Szmigielski, 1996 - as cited in Elwood, 1999). However, since this study showed an increase in all types of cancers, including many never associated with electromagnetic waves, it is not possible to know if RF or other factors might have caused these increases. In a study of Canadian and French electric utility workers, which Elwood (1999) judges the best conducted study so far, no increase in cancer was found, except for lung cancer. The applicability of this study to RF may be limited however, since the major exposures were to extremely low frequency (ELF) fields. The biggest limitation of all existing epidemiological studies on RF is the poor measure of exposure, which weakens any association of risk to RF exposure.

Studies have also suggested that RF may cause other cancers, such as those of the brain, breast, lymph nodes, skin or testicles (RSC, 1999). Elwood (1999) concludes that all studies have methodological limitations. Furthermore, except for the Polish study, studies show relative risks of less than two, not a strong association (RSC, 1999). Human studies presently available are not sufficient to confirm a cancer risk due to RF exposure.

#### *Other Effects*

A few studies have looked at possible reproductive effects in humans, including malformations, from exposure to RF fields (See Table 8). These have shown inconsistent results (RSC, 1999). There are also some reports that RF can affect the heart beat (RSC, 1999).

An excess risk of suicides has been noted in one study but subsequent studies have not confirmed this association (RSC, 1999). Radio frequency radiation sickness syndrome has been defined as a systemic human response to chronic low-intensity RF exposure. The syndrome includes various symptoms that have been associated with RF exposure, such as, depression, headaches, irritability, fatigue, sleepiness, and loss of appetite, memory, or concentration. The non-specificity of such symptoms, and the difficulty of measuring them, limit the ability to equate these to human health impacts. The Royal Society of Canada identified this as one area that needs more research, in particular, double-blind experiments.

Due to the limited ability to dissipate heat, the eye is an organ that can easily be over-exposed to radio or microwaves. High exposures have been linked to adverse effects to the retina, lens, iris, and cornea, including the development of cataracts. Experiments in animals have shown effects for RF of 2450 Hz (continuous and pulsed) at SAR of 5.3 to 7 W/Kg (Kues, et al, 1985, as cited in RSC, 1999). It is possible that some of these effects are non-thermal.

## PRUDENT AVOIDANCE

The precautionary principle argues for caution in decision-making when there are uncertainties regarding the potential adverse effects due to limitations in the amount and quality of scientific evidence. Waiting for confirmation of adverse effects from epidemiological studies before taking action does not adhere to a public health approach, which encourages prevention over cure. Prudent avoidance encourages the adoption of individual or societal actions that will reduce exposures to potential hazards at little or no cost.

In examining the need for prudent avoidance policy, Toronto Public Health considered two factors:

- Specific situations where high levels of exposure may occur; and
- The weight-of-evidence that harm may occur at these levels of exposures

So far, human studies have not provided conclusive evidence on the link between RF exposures and adverse human health effects. This is reassuring – if there are any health impacts at current levels of RF found in the environment, they are likely to be small. However, due to various methodological limitations, such studies by themselves are not sufficient as proof of either safety or harm.

### *High Exposure Scenarios*

In the City of Toronto, the public is exposed to radio frequency fields from a multitude of sources in addition to cellular telephone services. Radio, television, radio taxis, pager services, emergency communications (e.g. police, ambulance, radar) all depend on the use of radio waves. Levels of RF measured in cities are generally higher than background levels in rural areas. Given the density of the city, the presence of many high buildings close to each other, and the numerous RF sources, Toronto residents experience a much higher probability of exposure to multiple sources than other Canadians.

Available exposure data indicate that the public is exposed at very low levels, much lower than levels permitted under Safety Code 6. There are, however, some situations where levels could approach those of Safety Code 6. High exposures are not necessarily related to the visibility of the structure on which the antenna is mounted, such as on a self-standing tower. Areas where it would be anticipated that the public might be exposed to the highest levels of RF from base telephone transmitters are:

- On roof-tops of apartment and office buildings where gardens, terraces, or other recreation activities are found. The limited data available suggests that, if base transmission towers were situated on such roof-tops, exposures to the people who use such roof-top facilities could approach the levels set in Safety Code 6 (Cleveland and Ulcek, 1999, Moulder, 1999).

- On roof-tops or balconies of neighbouring buildings which are very close to each other. Levels inside high-rise buildings are attenuated by the outside wall and windows. However, there is little data on exposure levels on roof-tops and on the balconies on the top floors of apartment buildings. It would be expected that RF fields would be stronger at such levels compared to the ground. Additional caution might be required when antennas are placed on a building that is very close to another building of similar height, which has balconies or roof-top amenities (Vermont, 1996).

### *Current Canadian Standards*

In its review, the Royal Society of Canada concluded that current public exposure guidelines were stringent enough to protect from the thermal effects of RF (RSC, 1999). They further noted that although there was evidence of biological effects, clarification of the significance of these effects was necessary before they are included in Safety Code 6. In October 1999, Health Canada published a revised Safety Code 6, which maintained public exposure guidelines for whole body exposure. Health Canada indicates that these exposure levels provide an adequate margin of safety for the protection of the public (Personal communication: Bradley, 1999).

Current standards for RF in Canada and in most other jurisdictions have been developed based on a threshold SAR of 4 W/kg. Below this level, irreversible effects are not thought to occur (ICNIRP, 1998). This is supported with data in humans that show exposures to RF at a whole-body SAR of 1-4 W/Kg for 30 minutes will result in an increase of body temperature of less than $1^{o}$C. To take into account various working conditions, such as high ambient temperatures, humidity, or level of physical activity, which would affect the body's capacity to dissipate heat, the value of 4 W/Kg was divided by 10 to give a recommended occupational level of 0.4 W/Kg. (ICNIRP, 1998). To provide additional protection to the public, agencies have divided the occupational level by 5 (for a total of 50). This accounts for the following concerns:

- The possibility of groups or individuals that are more susceptible because of age or health status;
- The fact that the public may not be aware of exposure and may not easily take precautions to reduce exposure; and,
- The potential for the public to be exposed for longer periods (ICNIRP, 1998; RSC, 1999).

Current standards for RF assume the following:

- Adverse effects of RF are due to thermal effects;
- Duration of exposure is not important since effects are related to the rate of energy absorption;
- Irreversible effects are the effects of concern; and
- There are no differences in sensitivity to thermal effects between humans and experimental animals.

***Levels of Concern***

The main concern when setting environmental health guidelines is the potential for adverse effects due to long-term low-level exposures to the agent in question. Although current RF standards are based on the best available data now available, there has also been a trend for greater understanding over time to result in periodic reductions of exposure limits to radiation, including RF (Vermont, 1996). Some health activists have suggested that exposure standards to RF should be set 1000 times lower than current limits (NZine, 1997).

In deriving exposure limits for the protection of human health, preference is given to effects observed in humans over long periods of exposure. When these are limited or not available, animal data is used. In nearly all cases, there will be some gaps or limitations in the quality of the data. In addition to modification factors to convert experimental doses to human equivalent doses, factors are used to account for this lack of data or its limitation (Refer to, for example, CalEPA, 1997; MDEP, 1990; US EPA, 1993). These factors are varyingly referred to as safety factors, uncertainty factors or protection factors.[1] A protection factor is usually considered for each of the following areas of uncertainty:

- Using data from animal studies rather than from observations in humans
- Variability in sensitivity among humans
- Use of data from short-term rather than long-term studies
- Severity of the effects observed, such as an adverse effect level rather than a no-adverse effect
- Quality of the overall data available

Protection factors used vary from 1 to 10 depending on the amount and quality of the data available. In many cases, due to their size and developing immune systems, children are more at risk than adults are. It is therefore becoming more common to also include an additional protection factor to take into account this potential for greater sensitivity or risk in children. For example, under the Food Quality Protection Act, unless there is specific data on the potential sensitivity of children, the US Environmental Protection Agency is obliged to consider an additional protection factor of 10 to ensure that exposure standards better protect young children (US EPA, 1999). In the derivation of its air quality guidelines, the Commonwealth of

[1] The term protection factor is preferred in this document since it indicates that a factor is used to increase the level of protection from exposures to RF.

Massachusetts incorporates a protection factor of 1.75 to account for differences between adults and children (MDEP, 1990).

Due to historical reasons, different management approaches have been used when dealing with environmental health risks due to radiation when compared to chemicals (ELI, 1998). This has resulted in some inconsistencies in what is considered a level of "acceptable risk". For example, in chemical management, non-enforceable environmental health goals or objectives are often derived. These are "technology forcing" and in some cases may be more restrictive than legally enforceable standards, which incorporate the technical feasibility and cost of compliance. Given the many factors and values that influence acceptable risk, it is now also recognised that greater public involvement is required in the standards setting process (ELI, 1998).

In deciding whether current exposure levels of RF are a concern, there are several areas of uncertainty that need to be addressed. For example,

- *Non-thermal effects*: Current standards are based on thermal effects of RF. Available data show that biological effects do occur at levels below those where thermal effects are known to occur (RSC, 1999). While there is uncertainty in the health significance of these effects, it is also uncertain whether current standards would protect from potential adverse effects should these be confirmed.
- *Duration of exposure*: Current standards are based on short-term effects. Based on longer-term animal studies, D'Andrea (1991) suggests that SAR of 0.4 – 3.6 W/Kg can lead to behavioural changes because of mild heat stress. Stress is known to lead to various adverse health outcomes. A doubling of cancer incidence has been reported in cancer-prone mice at average exposure levels of 0.13-1.4 W/Kg (Rechapoli, et al., 1997). More studies are needed to confirm if long-term low level exposures can lead to adverse effects.
- *Use of threshold effect*: Present standards are based on a threshold for irreversible effects, rather than a no-effect level. Preference is normally given to the use of a no-adverse effect level (NOAEL) in developing environmental health standards.

Based on current practice of environmental standard setting in various agencies, the uncertainties identified above suggest that a protection factor of 1000 to 10,000 could be justified. Current levels for the public under Safety Code 6 incorporate a protection factor of 50. The current standard uses a factor of 5 to derive public exposure levels from occupational levels. This is less than is often customary, where a factor of 4.2 is used to convert exposure levels from a 40 hour work week to continuous exposures, and an additional protection factor of 10 to take into account that some people in the general population are often more sensitive than workers. Ensuring that levels of RF were kept 100 times below Safety Code 6 recommendations would be equivalent to using a protection factor of 5000. This is within the range given above.

Several jurisdictions have already adopted lower exposure limits. The 1999 Swiss Ordinance on EMF (including RF) adopts a policy of prudent avoidance. New antennas or antennas that are moved or replaced must meet 10 percent of international standards (essentially the same as Safety Code 6 standards) for RF of sensitive use, such as where people live. This is a legally enforceable standard (BUWAL, 1999). Italy has adopted a chronic public exposure level of 15 percent of international standards. The Land of Salzburg (a province in Austria) has entered into a voluntary agreement with the industry requiring that exposures where people reside are kept below 1.5 percent of international standards (BUWAL, 1999). As illustration, for frequencies where the limit of power density in Safety Code 6 is 10 W/m$^2$, the above limits would be equivalent to a value of 1.5 (Italy), 1 (Switzerland), and 0.15 (Salzburg). By comparison, 100 times below Safety Code 6 would give 0.10.

There have been recommendations that exposure levels be set at 1 nanoW/cm$^2$, or 10 μW/m$^2$ (Cherry, 1999). Six municipalities in Australia have adopted an initial siting guidance exposure limit of 0.1 μW/cm$^2$ (or 1 mW/m$^2$) in a co-operative approach with carriers to find sites which the councils and the community would accept (Cherry, 1999). This is about 10,000 times lower than current Safety Code 6 limits.

***Need for Prudent Avoidance***

To avoid unnecessary exposures to radio frequencies, a policy of prudent avoidance encourages the adoption of individual or societal actions that entail little or no cost. The findings on the adverse health impact in human populations are inconsistent. Available data show adverse effects in laboratory and animal experiments at exposure levels below those at which current standards are based. There is uncertainty about the significance of these effects to humans and it is not possible to estimate the risk to humans from these observed effects. Given that levels recommended in Safety Code 6 do not directly address these uncertainties and in the context of a mature urban area, due diligence suggests that public exposure levels should be kept well below these standards.

As the above discussion indicates, there are situations where Toronto residents could be exposed to levels of RF approaching Safety Code 6. In its 1996 review of RF, the Vermont Department of Public Services stated: "We are … persuaded by the scientist and members of the public interest sector who urge a more cautious approach while the necessary research is completed" (Vermont, 1996: 39). The report indicated that one way in which municipalities could achieve this was to develop agreements with the industry to maintain exposure levels below legal limits. Toronto Public Health believes that this approach may be the most appropriate way to proceed in Toronto.

***Approach to Prudent Avoidance***

Toronto Public Health was requested to consider a policy of prudent avoidance based on restricting the siting of base transmitter antennas a certain distance from schools and day-care centres and away from residential areas.

For cellular telephone service to be available to residents anywhere within Toronto, carriers aim at providing sufficient signal strength at all locations. This can be achieved by using fewer high-powered transmitters or more low-powered ones. Restricting the siting of antennas based on maintaining a certain distance from specific buildings or land-uses has limitations because there are factors other than distance that need to be considered:

- *The power of transmission*: The strength of a RF field will depend on the power of transmission. A single base station may have 20 to 100 channels depending on the number of users of its network at a location. In addition, a channel will have different power output, which is related to the desired reach of the signal. To achieve the same level of protection in all cases, distance requirements would need to be related to the power of the transmission of the antenna.
- *Number of transmitters*: To reduce the number of new towers, Industry Canada, and most other jurisdictions, encourage co-location of transmitters. In addition to the power used in the transmission, the number of transmitters active at any one time in one location will influence the levels of RF at any given distance from the antenna. To achieve the same degree of protection in all areas, the number of transmitters in one location would also need to be limited and could result in more towers dotting the landscape.
- *Direction of transmission*: Cellular telephone transmitters send their signals in a specific direction. RF levels will be greatest in the direct line of transmission. At the same distance from an antenna, but not in the direct line of transmission, levels of RF will be much lower. Reflectors can also be used to change the direction of the waves away from certain areas resulting in different RF levels even if the distance from the antenna is the same.
- *The height of the antenna*: The further a person is from an antenna, the lower the level of RF. However, distance is a combination of both horizontal distance and height above the person. The closer to the transmitter a person is, the more important height above the person becomes. The height at which a transmitter is located depends on various factors, including the desired reach of the signal and the existence of structures that may interfere with the transmission of the signal. To achieve the same level of protection in all cases, height of the transmitter would also need to be considered.

- *Attenuation*: A structure, such as a roof, wall, or building between the source of RF and a person will reduce signal strengths. Under such circumstances a person may be close to a source but not exposed to high levels of RF.

Given the density of Toronto, the mixed land use, and the existing network of antennas, it would be difficult to adopt an approach limiting the installation of antennas a certain distance from schools or residential areas. Toronto Public Health believes a prudent avoidance policy that ensures that the public is exposed to levels less than those recommended by Safety Code 6 would provide a greater level of protection in a more consistent way than either a distance- or land-use based policy could.

In Canada, the final authority for the approval of the installation of base transmission towers lies with Industry Canada. The City of Toronto has little direct control over this matter. It is therefore recommended that the City work with the industry to develop a protocol for the siting of antennas in the City. A protocol incorporating a policy of prudent avoidance is in accord with the recommended policy and procedures of Industry Canada. This protocol could be developed by the City's Telecommunications Steering Committee in conjunction with all the relevant parties. It should include the following elements:

(1) A request that applicants who wish to install new, replacement or modified antennas demonstrate that radio frequency exposures in the areas where people other than telecommunications workers would normally use (e.g. roof-top gardens, balconies, or grounds) will be at least 100 times lower that those currently recommended by Safety Code 6;

(2) In situations where residents express concern over an existing base cellular telephone antenna, the owner and /or operator of the facility be requested to monitor levels of RF fields around the antenna and provide this information to the affected community and the Telecommunications Steering Committee; and

(3) A mechanism for notifying residents of a proposed site for new telephone base antennas. This notification should include the advantages of using the proposed site, alternative sites considered, and the maximum expected exposure to RF due to the installation in areas that the public or building occupants would normally use.

The application of this prudent avoidance policy and protocol is expected to be feasible and readily achievable. It will also provide a rational basis with which to evaluate and respond to community concerns about both existing and future installations. The predicted exposures from single installations are very low, and thus in most cases, this policy is not expected to have an adverse impact on existing facilities. However, this policy provides an extra measure of protection as the number of installations increases in the city, and in the event that new research provides evidence that adverse effects do occur at levels lower than those currently known to do so.

## RECOMMENDATIONS

It is recommended that:

(1) The Board of Health endorse the adoption of a Prudent Avoidance Policy in the siting of base cellular telephone antennas in the City of Toronto;

(2) The Board of Health forward this report to the Telecommunications Steering Committee for their information and request the Committee to incorporate a Prudent Avoidance Policy in a protocol for the siting of base cellular telephone antennas in the City of Toronto;

(3) A Prudent Avoidance Policy include the following:

(a) A request that applicants who wish to install new antennas or modified antennas demonstrate that radio frequency exposures in the areas where people other than telecommunications workers would normally use (e.g. roof-top gardens, balconies, or grounds) will be at least 100 times lower than those currently recommended by Safety Code 6;

(b) In situations where residents express concern over an existing base cellular telephone antenna, the owner and /or operator of the facility be requested to monitor levels of RF fields around the antenna and provide this information to the affected community and the Telecommunications Steering Committee; and

(c) A mechanism for notifying residents of a proposed site for new telephone base antennas. This notification is to include the advantages of using the proposed site, alternative sites considered, and the maximum expected exposure to RF due to the installation in areas that the public or building occupants would normally use;

(4) The Board of Health and Telecommunications Steering Committee request the federal Minister of Industry to ensure adherence to the City of Toronto's Prudent Avoidance Policy when granting approval for the siting of base cellular telephone antennas in Toronto; and

(5) The Medical Officer of Health forward this report for information purposes to the federal Minister of Health, all other Boards of Health in Ontario, and to the Boards of Education operating schools in the City of Toronto.

## TABLES

### Table 1: Frequencies Used for Cellular Telephones in Canada

| Type of Device | Frequency Used |
|---|---|
| Cellular phones (analogue) | 824-849 MHz |
| Time Division Multiple Access Cellular phones (digital) | 824-849 MHz |
| Cellular base stations (analogue and digital) | 869-894 MHz |
| Personal Communications Services (PCS - digital) | 1850-1990 MHz |
| Mobile Satellite Service (emerging technology) | over 1990 MHz |
| Fixed Wireless Access Systems (soon to be implemented) | 3400-3700 MHz |
| Low Modular Cellular Service (soon to be implemented) | 24 and 38 GHz |
| *Source: RSC, 1999* | |

### Table 2: Radio Frequency Exposure Limits for the Canadian Public

| Frequency | Power Density (W/m$^2$) |
|---|---|
| 30-300 MHz | 2 |
| 300-1,500 MHz | *Frequency* * / 150 |
| 1,500 to 300,000 MHz | 10 |

* *The limit is equal to the frequency of the wave divided by 150. It ranges between 2 and 10 W/m$^2$.*

*Source: Health Canada, 1999*

**Table 3: Radio Frequencies and Cell Proliferation**

| Frequency | Field Strength | Duration | Effects | Reference |
|---|---|---|---|---|
| 2450 MHz | 5-50 W/Kg, continuous wave | 2 hr | Increased cell proliferation at all doses | Clearly et al., 1990 |
| 27 MHz | 5-50 W/Kg, continuous wave | 2 hr | Increased cell proliferation at all doses | Clearly et al., 1990 |
| 836.55 MHz | 0.59-59 mW/Kg | 12 hr | No cell proliferation | Stagg, et al., 1997 |
| 960 MHz | 0.21- 2.1 mW/Kg with carrier modulation of 217 Hz | 20-40 min. | Decreased cell growth at exposures of 30 minutes or more | Kwee and Raskmark, 1998 |

**Table 4: Effects of Radio Frequencies on Melatonin**

| Frequency | Field Strength | Duration | Effects | Reference |
|---|---|---|---|---|
| 900 MHz | 0.2 $W/m^2$ | Night-time | No changes in serum melatonin levels in human volunteers | Mann, et al., 1998 |
| 3-30 MHz | Pasture near short-wave radio antenna | Not given | No changes in serum melatonin levels in cattle, though a short rise was seen when the antenna was turned on | Stark et al., 1997 |
| 900 MHz | 0.06-6 W/Kg | Up to 6 hr | No effects on nocturnal melatonin | Vollrath, et al. 1997 |

**Table 5: Effects of Radio Frequencies on the Blood Brain Barrier**

| Frequency | Field Strength | Duration | Effects | Reference |
|---|---|---|---|---|
| 915 MHz | 0.016-5 W/Kg continuous and modulated | Not given | Increased permeability in the blood-brain barrier | Salford et al., 1992, 1994 |
| 2850 MHz | 1 $W/m^2$ | Not given | Increased permeability in the blood-brain barrier | Oscar and Hawkins, 1977 |
| 2450 MHz | 100 $W/m^2$ | Not given | Increased permeability to horse radish peroxidase in hamsters | Albert, 1977 |
| 1300 MHz | 30 $W/m^2$ | Not given | Increased permeability to mannitol and insulin in rats (but not dextran) | Oscar and Hawkins, 1977 |

**Table 6: Studies on Tumour Promotion of Radio Frequencies**

| Frequency | Exposure Characteristics | Positive findings | Negative Findings | Reference |
|---|---|---|---|---|
| 2450 MHz | 5, 15 $mW/cm^2$ cancer prone mice | Acceleration of breast cancer and reduction in survival | | Szmigielski, et al., 1982 |
| 2450 MHz | 5, 15 $mW/cm^2$ with 3,4-benzopyrene | Acceleration of skin tumours and reduction in survival | | Szmigielski, et al., 1982 |
| 2450 MHz | 5, 15 $mW/cm^2$ injected with sarcoma cells | Lowered anti-neoplasmic resistance | | Szmigielski, et al., 1982 |
| 2450 MHz | 10 $mW/cm^2$ with dimethylhydrazine (DMH) and TPA | | | Wu, et al. 1994 |
| 900 MHz | Pulsed with benzo(a)pyrene (BaP) | | No increase in tumour latency and survival due to RF exposure | Chagnaud, et al., 1995 |
| 902 MHz | Continuous and pulsed | | No differences in survival and growth | Juutilainen, et al., 1998 |
| 836.55 MHz | 2.5 W modulated with ethylnitrosourea (ENU) | Reduced lifetime | No increase in cancer | Adey, et al. 1997 |
| 850 MHz | SAR 0.9W/Kg, pulsed and continuous waves | | No CNS tumours | Zook, et al. 1998 |
| 2450 MHz | 1.0 $mW/cm^2$, 2.5 hrs/day, 6 d/week, until death with planted melanoma cells | | No effect on survival or tumour growth rate | Santini, et al. (1988) |
| 915 MHz | Continuous (1W)and pulsed (2W) | Slight increase in albumin leakage in brains | No significance in tumour size | Salford et al. (1993) |

### Table 7: Radio Frequencies Fields and Leukaemia

| Study | Relative Risk of Adult Leukaemia (Confidence Interval) | | Reference |
|---|---|---|---|
| | **Positive** | **Negative** | |
| **Adults** | | | |
| 21 radio and TV transmitters in the UK | | 0.97 (0.78-1.21) | Dolk, et al. 1997 |
| Initial study in Northern Sydney, Australia | 1.18 (0.98-1.42)* | | Hocking, et al., 1996 |
| Poland | 3.68-13.90 (1.22-22.12) + | | Szmigielski, 1996 |
| US Navy | 1.24 (0.87-1.72)* | | Robinette, et al. 1980 |
| Norway | 1.1 (0.1-4.1)* | | Tynes, et al., 1996 |
| Canada, France | | 0.8 (0.19-3.36) | Armstrong, et al. 1994 |
| **Children** | | | |
| UK | 1.12 (0.61-2.06)* | | Dolk, et al. 1997 |
| Initial study in Northern Sydney, Australia | 1.58 (1.07-2.34) | | Hocking, et al., 1996 |
| Follow-up study in Sydney, Australia | 1.28 (0.99-1.91) | | McKenzie, et al., 1998 |
| Follow-up study in Sydney, Australia (excluding Lane Cove with abnormally high incidence) | | 0.90 (0.56-1.44) | McKenzie, et al., 1998 |
| San Francisco | | 0.73 | Selvin, et al., 1992 |

* Weak positive evidence

\+ Range of various leukaemia, as total not given.

*Adapted from Elwood, 1999*

## Table 8: Studies on Reproductive Effects of Radio Frequencies

| Study | Positive | Negative | Reference |
|---|---|---|---|
| Swedish physiotherapists | Use of short wave equipment associated with higher risk of malformations and perinatal deaths | | Kallen, et al, 1982 |
| Finnish physiotherapists using deep heat or short-wave therapy | Small increased rate of spontaneous abortions due to use of equipment.<br>Higher level of congenital anomalies for those using equipment 1-4 hours | No increase in anomalies for those using equipment more than 4 hours | Taskinen, 1990 |
| Danish physiotherapists | Higher number of female children | No significant association between short wave exposure and spontaneous abortions | Larsen, et al., 1991 |
| Swiss physiotherapists | | No significant association between short wave exposure and gender ration | Guberan, 1994 |
| Physical therapists in the USA | Slightly higher rate of miscarriage among mothers exposed to microwave | No association of miscarriage with diathermy equipment | Ouellet-Hellstrom and Stewart, 1993 |
| Latvia, 20 Km radius of a radar station | Slight deficit in male children | | Kolodynski and Kolodynska, 1996 |
| Fathers exposed to radar, Baltimore, USA | | No increase in Down's Syndrome | Cohen, et al., 1997 |
| Heart patients, Oklahoma | | No abnormality after use of electric shock or RF for catheter ablation | Goli, et al., 1991 |
| AM broadcast station workers | Rhythm disturbances more frequent among those with EMF exposure | | Bortkiewicz, et al., 1997 |

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