Biological Effects of Radiofrequency Fields

Human Health Studies

Experimental Studies in Humans

Concerns have been expressed about the possible interactions of RF with several human organ systems, such as the nervous, circulatory, reproductive and endocrine systems, particularly those emitted by wireless communication handsets, such as mobile phones (IEGMP, 2000). One way of investigating causal-effect relationships in this area is to perform experiments with voluntary human beings in controlled circumstances (so-called provocation studies). Most of these experiments use short- to medium-term exposures to RF fields, within the same frequency range and at levels equal or below the safety standards, so as to rule out thermal effects. Therefore, they assume that non-thermal effects might be present. In the present chapter, we will review the recent literature on experimental studies in humans, with a focus on certain organ systems. The large majority of papers address radiofrequencies and modulations used in cell phone communication systems, due to its ubiquity.

Experimental results published so far have used several designs, such as self-controls, non-randomized and randomized controls, crossover, blinded and non-blinded designs, etc. (see the Annex I of this chapter for a brief methodological explanation on these designs). The quality and strength of evidence varies a lot among these designs, so that sometimes it is difficult to compare experimental results among different studies and arrive at unequivocal conclusions.

What we have observed also is that, despite the large number of published studies, the proportion of them that have high quality designs are still rare in the RF literature. Most of the studies have focused on mobile telephony, so other kinds of exposures, occupational or not, have not been adequately covered in the literature. In addition, due to ethical limitations, only a few organ systems and functions have been studied, and few long-term exposure experiments have been completed, so little information is currently available on potentially slow-acting effects.

Nervous System and Behavior

Several reviews of the literature on RF acute exposure on the nervous system of human beings have been published. (e.g. Valentini *et al*, 2007, Hossmann & Hermann 2003; D'Andrea *et al*, 2003a and 2003b, IEGCP, 2001). The most frequent experimental studies on central nervous system (CNS) functions can be classified into the following groups:

- Spontaneous and stimulation-induced electrical activity of the brain, such as in the electroencephalogram (EEG) and event-related potentials (ERP)
- Blood flow and tissue metabolism
- Cognition and attention, reaction time

- Sleep and wakefulness

D'Andrea *et al* (2003a and 2003b) reviewed the effects of RF exposure on the nervous system in general, and on behavior and cognition. They found that it is difficult to draw a consistent set of conclusions concerning hazards to human health, due to the variations among studies including exposure parameters such as frequency, orientation, modulation, power density, and duration of exposure. Adverse and non-adverse behavioral and neural consequences of exposure to high power RF, with sufficient energy to induce thermal effects inside the human brain, are real and well documented (Goldstein *et al*, 2003), and have served as a firm base for establishing safety standards and limits since the 1980s. Hyperthermia, of course, has several deleterious effects on nervous tissue in general and on peripheral nerves in particular, so that high-level exposure in occupational accidents can promote reversible and irreversible injury. Hocking & Westerman (2003) in a review of EMF effects on pain, have found from studying several such cases, that after very high exposures, nerves may be grossly injured, resulting in dysesthesia. Fortunately, only a small proportion of similarly exposed people develop symptoms.

However, the first question should be: is there a heating effect of low-level RF irradiation of the head? The majority of users report subjectively a heating sensation in the skin of the face and in the ear after a minute of more using a standard cell phone close to the head. This increase has been objectively determined to be in the order of 2 to 30C after 6 minutes of use, most of it due to heat trapped by holding the phone with a plastic case in contact with the head and not by RF absorption within the head (Anderson & Rowley, 2007). Experimental studies using high precision thermography on both sides of the head of volunteers, however, have shown that the insulation, heating by battery currents and the electrical power dissipation of the handset led to statistically significant rises in the skin temperature, while the RF exposure did not (Straume *et al*, 2005). Curcio et al. (2004) measured the ascending rate of tympanic temperature with exposure to a standard GSM cell phone in a double-blind experiment, and found a correlation with an increase in reaction time. Since heat can be perceived by users with an active cell phone, it is doubtful, therefore, that RF effects might be the real effective variable on cognitive effects. So, the effect of heating on brain tissue inside the RF plume of a cell phone used against the skull should be a better variable. The same group (Curcio et al., 2009) tested this by using near-infrared spectroscopy of the brain, and discovered that the hemodynamics of the frontal cortex was the only parameter to increase slightly with exposure times of up to 40 min to a GSM cell phone.

One way to document this for the head's interior would be to carry out functional brain imaging studies which label regional cerebral blood flow (rCBF) responses using PET (Positron Emission Tomography). Radioactive labeling of red blood cells provides this measurement, allowing for a medium-resolution mapping, *i.e*. it is able to show the location of the alterations. Haarala *et al* (2002) and Aalto *et al* (2004) were the first to use this approach. They demonstrated a decrease of rCBF in the temporal lobe near the antenna, but an increase in a more distant area, the frontal cortex. Huber *et al* (2005) also investigated in healthy young men the effect of a 'base-station-like' and a 'handset-like' exposure using PET, They observed an increase in rCBF in the dorsolateral prefrontal cortex on the side of exposure. Only 'handset-like' RF exposure affected rCBF. This parameter may reflect two phenomena, however: local heating, with the subsequent increase in compensatory blood flow, or an increase in functional activity of the nervous, tissue, which leads also to rCBF. Since other areas of the cortex were not activated, probably the PET study reflected a functional change in an area related to emotional

processing and not localized heating. If heating provoked by proximity to the RF source was to be observed, a temperature gradient emanating from points nearest the source and decreasing through the scalp, skull bone, meninges and then brain tissue adjacent to the source of emission near the ears, was to be expected. This gradient correlates well with the thermographic studies of the surface of the head and the temporal bone, but not within the brain tissues.

The most important research question is whether RF levels below those producing thermal effects could induce changes in the nervous system and its activities. D'Andrea *et al* (2003a) concluded that at least for the review period, no firm evidence existed for such subthermal effects and that nearly all evidence was related to the generation of heat in the nervous tissues.

Cognition, Memory and Attention

A small number experiments have been carried out before 2000 (Preece *et al*., 1999, Koivisto *et al*, 2000, 2001) and were reviewed in detail by the so-called Stewart Report (IEGCP, 2001). The objective of such studies was to detect deleterious effects of RF fields on cognitive functions such as short- and long-term memory, attention, reaction time, concentration, etc.

There are several reliable methods to record and quantify such behavioral and cognitive variables using standardized, instrumented or computerized techniques. These experiments recorded a large set of such variables (14 to 30) in subjects under a crossover design and low-level radiation power densities, by using cell phones used near the head.

Slight differences were observed during the irradiation versus the sham exposures in one or two variables, such as simple reaction time, a mental digit subtraction task and a vigilance task. Surprisingly, in all of them RF increased cognitive and attention processing times, such as a consistent decrease in reaction time (RT) up to 20-36 milliseconds, which is quite a large figure, without a reduction in accuracy at the expense of speed, and sometimes with an increase in accuracy. Both groups of investigators suggested that exposure to mobile phone signals at power levels within existing exposure guidelines had demonstrated biological effects that were of sufficient magnitude to influence behavior. They proposed that the probable mechanism could be the effect of small temperature increases on synaptic transmission in the region of cerebral cortex directly under the headset antenna. Other papers have provided more data in favor of the existence of this effect on attention. For example, Papageorgiou *et al* (2006) reported that the RF emitted by mobile phones affect pre-attentive information processing as reflected in the P50 evoked potential.

A significant number of contradictory studies exist, however, particularly when using better designed experimental studies, such as differential exposure to both sides of the head, and double-blind randomized cross-over designs. Under these conditions Haarala *et al*, (2004, 2005, 2007), Curcio *et al* (2008), Besset *et al* (2005), Krause *et al*. (2007) and Russo *et al* (2006) could not find any evidence for a differential effect of exposure to mobile phone signals on several cognitive, memory and attention tasks, including the first studied by Preece and the Koivisto and Papageorgiu groups. Haarala *et al* (2005) concluded that a standard mobile phone has no effect on children's cognitive function as measured by response speed and accuracy. Using adolescents too, Preece *et al* (2005)

were unable to replicate their own 2001 experiments, denying evidence for cognitive effects of cell phones.

It was suggested by the reviewers that although in some studies shorter response times were obtained, this should not be interpreted as a beneficial effect of cell phones, since in more complex situations, they might be detrimental. In addition, since no long term experiments were carried out, there is limited relevance of such studies for the question of whether mobile phone use is detrimental to health. Studies in children are also lacking (Sienkiewicz *et al*, 2005)

Electrophysiology and Sleep

Several electrophysiological studies on the effect of acute RF fields on the human EEG and ERP have been performed, with somewhat mixed results. Some studies have been unable to demonstrate any effect, while others reported mild effects on these parameters, mostly by subtle alterations of some parts of the EEG spectrum. For example, d'Costa *et al* (2003), Huber *et al* (2002) and Curcio *et al* (2005) did blinded acute exposure experiments to ascertain if resting wakefulness EEG spectral power was influenced, and all found a small increase in the alpha band. This effect was recently confirmed by a double-blind counterbalanced crossover design with 120 volunteers (Croft *et al*. 2008). Pulse modulation of RF was necessary to induce waking and sleep EEG changes. Loghran *et al* (2005) showed a decrease in rapid eye movement sleep latency and increased electroencephalogram spectral power in the 11.5-12.25 Hz frequency range during the initial part of sleep following exposure. Together with the studies that showed that RF from cell phones induced mild relaxation, and a quicker induction to REM sleep (which is associated to dreaming in humans) in the first period of sleep, no detrimental effects on sleep health could be demonstrated.

More recent experimental studies using better methodology, such as sham-controlled, double-blind, crossover designs, have determined that, although these effects on EEG exist, they are rather modest and that "the effects on the EEG were varying, unsystematic and inconsistent with previous reports. The effects of RF on brain oscillatory responses may be subtle, variable and difficult to replicate for unknown reasons" (Krause *et al*., 2007, Hinrikus *et al*, 2004).

In relation to the previous studies that apparently had shown effects on the nervous system (cognition, EEG and sleep), the 2001 review by the Stewart Report suggested that "exposure to mobile phone signals at exposure levels that fall within existing exposure guidelines have biological effects that are of sufficient magnitude to influence behavior. The causal mechanism is unclear, but could include a small, localised heating effect. The question of the effect on the safety of mobile phones is uncertain." In another review of the literature of the previous decade, Valentini *et al* (2007) concluded also that RF may influence normal physiology through small changes in cortical excitability. The significance of these results for the health of users is unknown, and there is considerable controversy on their existence and meaning, because better controlled studies carried out in 2007 and 2008 were unable to provide any confirmation. Uncontrolled variables and random fluctuations due to small samples might be responsible for observed positive responses. So, the proposal of a specific mechanism now seems unwarranted.

Even these conclusions have been challenged by better controlled, double blind, more recent studies. For example, Inomata-Terada *et al* (2008) investigated whether pulsed RF

emitted by a mobile phone had short term effects on the human motor cortex, by measuring motor evoked potentials (MEPs) elicited by single pulse transcranial magnetic stimulation (TMS), before and after mobile phone exposure (both active and sham). No short-term effects were detected.

In relation to sleep, Mann & Röschke (2004) reviewed the scientific literature on the effects of RF fields. They found several past studies that revealed a number of slight sleep-promoting effects and an increase in the alpha power of the sleep EEG induced by RF, which were consistent with resting EEG experiments. They concluded, however, that "at the present level of knowledge, no final conclusions can be drawn from the available data concerning potential health hazards. Although there seem to be some biological effects, these do not provide evidence for any adverse health consequences." A demonstration of such effects for heavy use of cell phones during the day would have potential consequences in terms of health, since sleep is very important for overall well-being and its disruption might lead to impairment of cognitive functions, memory and stress.

Recent, better designed studies have been unable to prove any effect of low-level exposure to RF from mobile phones on sleep function. Fritzer *et al* (2008) investigated the effect of exposure during six nights not only on sleep parameters evaluated by polysomnography, but also on an array of neuropsychological tests. Data analysis was done by comparing the baseline night with the first and last exposure night and the first two sleep cycles of the respective nights. They did not find "significant effects, either on conventional sleep parameters or on EEG power spectra and correlation dimension, as well as on cognitive functions." Their opinion was that "previously realized sleep studies yielded inconsistent results regarding short-term exposure. Moreover, data are lacking on the effect that short- and long-term exposure might have on sleep as well as on cognitive functions."

Other negative results were reported by Kleinlogel *et al* (2008) for EEG and visual, auditory and attention-task related ERP in a randomized, crossover, double blind study.

One possible explanation for slight alterations in the levels of consciousness, reaction time and cognitive processing by some studies has been overlooked and merits further research, viz., the possibility that some people have higher sensitivity to otherwise subtle sensory clues emanating from the real RF emitting devices, as compared to the sham ones. These could be, for example, ultrasound buzzing, a higher temperature sensitivity of the skin, or other. It has already been proved that younger people have a hearing threshold for sound frequencies with a much higher pitch (up to 24 kHz) than older people, which might introduce an age-related bias into the results (Corso, 1963). It has been proved, also, that a phenomenon called "microwave hearing" can be observed in some animals and human subjects. Apparently, it is related to the expansion of fluids in the inner ear caused by heating (reference) and this could explain a lot of positive behavioral and neural effects related to alertness, both in animals and humans.

Vision, hearing and vestibular systems

There are few experimental studies published in these areas. Two Brazilian physicians, Balbani & Montovani (2008) reviewed the literature on cell phones, hearing and vestibular system. They argue that, since cell phones are very close to the user's ear, the skin, inner ear, cochlear nerve and the temporal lobe surface might absorb a part of its radiofrequency energy, so that effects could be expected. In addition, an increase in the

temperature of the inner fluids of the vestibular apparatus theoretically could induce neural responses in the receptor cells, such as vertigo and nystagmus. Vertigo is one of the complaints frequently made by people who are allegedly hypersensitive to RF radiation emitted by cell phones. The proximity of a mobile phone to the human eye also raises the question as to whether RF could affect the visual functions.

In the auditory system, Uloziene *et al* (2005) investigated the acute effects of RF on auditory perception, using standard audiometry to evaluate hearing. They concluded that a 10-min exposure of RFs emitted from a mobile phone had no immediate after-effect on measurements and no measurable hearing deterioration was detected. The exposure was too short, however, and hearing deterioration can be observed only after long term stimulation with high sound intensities, so any possible effect would not be detected by these experiments. In other studies using auditory evoked responses and brain-evoked response audiometry (BERA), a more objective measure of the integrity of the auditory system, Hamblin *et al* (2006), Stefanics *et al* (2007), Cinel *et al* (2007), Oysu *et al* (2005) and Sievert *et al* (2005), assessed short term effects of cell phone emissions under normal use conditions on the auditory evoked potential, auditory threshold and BERA, respectively. None of the studies found any significant effect.

In the vestibular system, Sievert *et al* (2007) employed video-nystagmographic recordings, BERA and otoacoustic emission recordings, with and without a mobile phone in use. Thermographic investigations suggested that the mobile phone does not induce any increases of temperature which would lead to a relevant stimulus for the auditory and vestibular system, and that RFs generated by using the mobile phone do not have an effect on the inner ear and auditory system to the inferior colliculus in the brainstem and on the vestibular receptors in the inner ear and the vestibular system. In another paper (Pau *et al*, 2005) the same group recorded intra-temporal bone temperature elevation during cell phone use and could find none above 0.10C, suggesting that mobile phone RF transmitting power is not sufficient to cause significant heating. More recently, Bamiou *et al* (2008) also reported not finding any effects of 30 min GSM radiation exposure on vestibular function, using transient evoked otoacustic emissions (TEOAE) and video-oculography (VOG).

The literature review by Balbani & Montovani (2008) concluded that acute exposure to mobile phone RF signals do not influence the cochlear outer hair cells function in vivo or in vitro, the cochlear nerve electrical properties nor the vestibular system physiology in humans. There seems to be no evidence of cochleo-vestibular lesion caused by cellular phones.

In the visual system, Schmid *et al* (2005) tested 58 human volunteers for four different visual function parameters, using a double blinded, crossover study, and found no statistical differences between acutely exposed and non-exposed. Interestingly, they measured power density distribution in the visual cortex, and determined that in the high exposure condition the resulting average exposure of the test subjects in the cortex of the left temporal lobe of the brain was 0.63 W/kg (1 g averaged SAR) and 0.37 W/kg (10 g averaged SAR). The low exposure condition was 1/10 of high exposure and sham was at least 50 dB (corresponding to a factor of 100,000) below the low exposure. Irlenbusch *et al* (2008) investigated a sensitive parameter of retinal function, the visual discrimination threshold (VDThr). No statistically significant differences in the VDThr were found in comparing the data obtained for RF exposure with those for sham exposure.

No published experimental research in major journals covered by MEDLINE were found in respect to the chemical senses systems (taste and olfaction) and RF exposure

Endocrine System

The endocrine system is particularly sensitive to many environmental physical agents, Radiofrequency at high powers provoke heating and can affect adversely the endocrine glands (Black & Heinick, 2003). The action of high frequency electromagnetic waves could theoretically be mediated in two ways: first, by direct action on the glandular tissue; and second, by action on the basal brain and hypophysis (or pituitary gland), thus modifying the secretion of hypothalamic releasing factors and/or hormones secreted by the neuro- or adeno-hypophysis. In any case, target glands, such as the thyroid, adrenal cortex, ovary and testicles could be affected. Growth hormone, prolactin, oxytocin, ADH and others might be affected too. There are many studies with experimental animals, but studies with human volunteers using low-level power densities below the ICNIRP safety levels are rare.

Djeridane *et al* (2008) investigated the effect of exposure to 900 MHz GSM RF on steroid (cortisol and testosterone) and pituitary (thyroid-stimulating hormone, growth hormone, prolactin and adrenocorticotropin) hormone levels in healthy males. Exposure was daily, for one month and hormones were measured by blood samples every hour before the beginning, at the middle, and at the end of the exposure period. The study reported that all hormone concentrations remained within normal physiological ranges, and that the circadian profiles were not disrupted. For growth hormone and cortisol, there were significant decreases of about 28% and 12%, respectively, 2 and 4 weeks after exposure, but no difference persisted in the post-exposure period, but factors other than RF could be responsible for this (no control group was set up). No disruptive effect was found in melatonin secretion by GSM cell phone exposure (Bortkiewicz *et al* 2002, de Seze *et al*, 1999). It appears that there is no evidence for effects of RF on endocrine functions in man.

Cardiovascular System

Although some experiments have been carried out in connection with possible effects of non-occupational, low level RF emitted mainly by cell phone handsets (Braune *et al*, 1998), the general conclusion is that there is no evidence for documented effects on heart rate and arterial blood pressure. In a double-blind, crossover study, Barker *et al*, (2007) studied mean arterial pressure (MAP), heart rate variability (HRV) and plasma catecholamine levels in health volunteers. Despite the high statistical power of the study, which could discriminate changes of 1 mmHg in MAP, no difference was found between the exposed and unexposed groups to GSM and TETRA cell phones. Nam *et al* (2007) didn't find any differences in several cardiovascular parameters between CDMA exposed and non-exposed adolescents (systolic and diastolic blood pressures, heart rate, respiration rate, and skin impedance), except for a brief decrease in skin impedance.

Heart rate variability (HRV), a measure of autonomic nervous system activity, did not change significantly in exposed adults (Ahamed *et al*, 2008; Parazzini *et al*.2007). However, in newborn incubators this was observed, but was found to result from fields produced by motors and electric pumps (Bellieni *et al*, 2008). These devices emit many kinds of RF fields, ranging from extremely low (50 to 60 Hz) to high frequency, with different contributions and powers.

Electromagnetic Hypersensitivity Syndrome

Electromagnetic energy outside of the visible spectrum and the infrared is not, under normal circumstances, detectable by human beings, since we don't have specialized receptors to transceive directly its specific frequencies. Furthermore, devices used by the public, such as pagers, cordless telephones, bidirectional radio sets and mobile telephones transmit at very low levels (a typical GMS or UTMS enabled handset has an radiating power of 250 to 300 mW). Radiofrequency signals transmitted by broadcast terrestrial and satellite-based radio and TV have very low power densities at the level of human habitation, as well as digital base stations and wireless access points (typically a few □W/cm2).

Despite this, a subgroup of the population reports being sensitive to these RF fields, alleging being able to detect when they are near them, or to discriminate when a cell phone is on or off. This has been called electromagnetic hypersensitivity and is not necessarily detrimental to such persons. The pathological phenomenon in this respect consists of individuals who, being sensitive or not, report a number of distressing subjective symptoms during and after using a cell phone and other radiofrequency-emitting devices, or when they are near an RF antenna site. These symptoms are quite nonspecific and are present in many diseases, such as cold and flu-like symptoms (headache, nausea, fatigue, muscle aches, malaise, etc.). In the absence, so far, of a mechanism for explaining them and of an indisputable causal nexus in relation to RF radiation, this constellation was initially named electromagnetic hypersensitivity syndrome, or EHS, but recently the World Health Organization, at a workshop devoted to studying this topic, decided to rename it Idiopathic Environmental Intolerance with Attribution to Electromagnetic Fields (IEI-EMF). The new name positions it within a wide host of other recognized/provisional environmental intolerances to ambient chemical and physical agents, with or without a proven etiology. In fact, the phenomenon was considered serious and prevalent enough to have WHO call for an international conference in Prague, Czech Republic, in 2004, to examine and discuss it (Mild *et al*, 2004). More recently one country (Sweden) has recognized the existence of the EHS phenomenon and has provided state-funded disability pay to some workers with EHS (Grandlund-Lind & Lind, 2004).

The prevalence of EMF sensitivity is not small: Eltiti *et al* (2006), in a survey carried out in the USA reported that 4 in 100 people report being electrosensitive, and that these people suffer more frequently from ill health than the general population. In Switzerland, Schreier *et al* (2006) found a prevalence of 5%. The most common health complaints were sleep disorders (43%) and headaches (34%), which were mostly attributed to power lines and mobile phone handsets. In addition, 53.5% were worried about adverse health effects from EMF, without attributing their own health symptoms to them. The phenomenon is real, and the quality of life of these individuals suffers greatly with debilitating symptoms, to the point that work and recreation becomes difficult (Bergqvist & Vogel, 1995, Irvine, 2007).

It is noteworthy that such unspecific symptoms are very common in many diseases and are extremely prevalent in the population. The problem is that most well-conducted studies have shown that there is no association at all between RF exposure and the EHS symptoms. In a systematic review of 13 IEI-EHF investigations carried out between 2000 and 2004 (Seitz *et al*, 2004) arrived at the conclusion that “based on the limited studies available, there is no valid evidence for an association between impaired well-being and exposure to mobile phone radiation presently. However, the limited quantity and quality of research in this area do not allow to exclude long-term health effects definitely.”

In the most recent meta-analysis, performed by Röösli (2008), the results of seven

experimental studies were pooled, and the conclusion was that “there was no evidence that self-declared IEI-EMF individuals could detect presence or absence of RF-EMF better than other persons. There was little evidence that short-term exposure to a mobile phone or base station causes symptoms based on the results of eight randomized trials investigating 194 EHS and 346 non-EHS individuals in a laboratory.”

The most recent systematic review of all studies has also concluded that EMF exposure is not associated with EHS symptoms (Rubin, 2009). So, it seems from the available evidence that most of the uncertainty surrounding IEI-EMF has been reduced and the phenomenon is largely regarded today as due to other factors, a conclusion of the WHO 2004 report on IEI-EMF (Mild *et al*, 2004):

> *“The majority of studies indicate that IEI individuals cannot detect EMF exposure any more accurately than non-IEI individuals. By and large well controlled and conducted double-blind studies have shown that symptoms do not seem to be correlated with EMF exposure. There are also some indications that these symptoms may be due to pre-existing psychiatric conditions as well as stress reactions as a result of worrying about believed EMF health effects, rather than the EMF exposure itself. It was added that IEI should not be used as a medical diagnosis since there is presently no scientific basis to link IEI symptoms to EMF exposure.”*

The WHO experts also recommended at the same meeting that the victims of the IEI-EMF should receive medical treatment for their conditions, even though the causal link with RF has not been established. This should include a medical evaluation to identify and treat any specific conditions that may be responsible for the symptoms, an assessment of the workplace and home for factors that might contribute to the symptoms (air pollution, excessive noise, poor lighting) a psychological evaluation to identify alternative psychiatric/ psychological conditions that may be responsible for the

Comments on Human Experimentation Results

It is remarkable the change that has occurred in expert opinion about putative health effects of RF below the safety levels, in the last five years. By the end of 2001, a most respectable group of experts in the UK, the Independent Experts Group on Mobile Phones (IEGMP), issued an extensive literature review, which was promptly dubbed “The Stewart Report” (due to the main investigator's name), and which achieved great impact in the specialized as well as in the mass media. The Report made a call for adopting more stringent precautionary approaches by government and public, by expressing the opinion that

> “*The balance of evidence to date suggests that exposures to RF radiation below NRPB and ICNIRP guidelines do not cause adverse health effects to the general population. There is now scientific evidence, however, which suggests that there may be biological effects occurring at exposures below these guidelines. This does not necessarily mean that these effects lead to disease or injury, but it is potentially important information and we consider the implications below. it is not possible at present to say that exposure to RF radiation, even at levels below national guidelines, is totally without potential adverse health effects, and that the gaps in knowledge are sufficient to justify a precautionary approach. We conclude that the balance of evidence indicates that there is no general risk to the health of people*

living near to base stations on the basis that exposures are expected to be small fractions of guidelines. However, there can be indirect adverse effects on their well-being in some cases."

Since the levels of RF radiation at which these investigations were made were below the international levels that are considered safe, *i.e.,* no heating of tissues could be possible, the Stewart Report was effectively suggesting that a non-thermal action of RF of sufficient magnitude to cause observable effects might be possible. In the ensuing years, however, better designed, better controlled experimental studies in humans were carried out and have refuted most of the IEGMP conclusions, not supporting the hypothesis of a non-thermal effect causing adverse health effects. Current science-based evidence points to there being no adverse effects in humans below thermal thresholds, no hazardous influences on the well being of users and non-users of cell phones and people living near base stations, and that no convincing evidence for significant alteration for the users' health exists, for cognitive, behavioral, and neurophysiological changes.

A number of organizations have reviewed the effects of EMF-RF on human health recently. The most authoritative source, the World Health Organization, has issued in 2010 the following statement in regard to this:

World Health Organization (2010) – Fact Sheet 193
http://www.who.int/mediacentre/factsheets/fs193/en/index.html

- "*A number of studies have investigated the effects of radiofrequency fields on brain electrical activity, cognitive function, sleep, heart rate and blood pressure in volunteers. To date, research does not suggest any consistent evidence of adverse health effects from exposure to radiofrequency fields at levels below those that cause tissue heating. Further, research has not been able to provide support for a causal relationship between exposure to electromagnetic fields and self-reported symptoms, or "electromagnetic hypersensitivity*".

Human Experimental Studies in Latin America

We have not found any significant human experimental study on the effects of RF fields on human health in Latin America.

Main conclusions and statement of the Latin American Committee on Human Experimental Studies

Experimental studies with humans have been performed with the intent of investigating possible acute effects of RF fields, particularly those emitted by mobile phones in close contact with the body, on several organ systems of healthy human volunteers. The majority of good quality studies have shown negative results or insignificant alterations in physiological and behavioral parameters of interest.

In the nervous system, many cognitive and behavioral functions have been investigated both in children as well as in adults and it is now generally accepted that there are no significant effects of cell phone usage on cognitive and behavioral parameters. In regard to alterations in the resting EEG, although initial studies showed a mild increase in alpha and REM frequencies, more recent and better designed studies using polysomnography could not demonstrate any effect on the EEG and sleep patterns. Other investigated effects of low-level RF emitted by mobile telephones on sensory systems, such as pain, vision,

hearing and the vestibular systems, as well as on the endocrine and cardiovascular systems were all negative. We may conclude therefore that except for small, inconclusive variation in cognitive task performance and on EEG, the exposure of cell phone users within normal range of intensity and frequency does not affect the central nervous system.

Since the brain is the body's internal organ lying closest to the antenna of a cellular phone in use at the ear, it would theoretically be most affected by non-ionizing radiation emitted by it, both by thermal as well as non-thermal effects. However, despite its known sensitivity to external physical and chemical agents, such fact, although it has been extensively studied by science, has not been proven yet, which allows us to infer that other organs, more distant from the radiation source than the brain, also would not be affected.

Even in those studies that were able to demonstrate a mild effect, they were not detrimental to health, and their significance in long term exposure could not be verified. Studies using functional imaging of the brain and deep thermography have shown that there is no significant heating which is caused directly by RF irradiation either in the bone or in the brain.

In relation to the so called electromagnetic hypersensitivity syndrome, the conclusion is that self-declared sensitive individuals cannot detect RF exposure any better than non-sensitive individuals, and that their symptoms are not due to RF exposure, but to other factors.