707 Lombard St

Philadelphia, Pa. 19147

March 17, 2015

RECEIVED

MAR 17 2015

PA PUBLIC UTILITY COMMISSION
SECRETARY'S BUREAU

Rosemary Chiavetta

Pennsylvania Public Utility Commission

400 North Street

Harrisburg, Pennsylvania 17120

Re: Exception to Initial Decision in case **C-2014-2451351**

I wish to file an exception to the initial decision in case C-2014-2451351. I also wish to withdraw the formal complaint C-2015-2471357 which was inadvertently interpreted as a filing of a new matter rather than an exception to the initial decision. I just received a call from PECO's counsel, Shawane Lee, informing me that I need to file an exception rather than use the PUC's formal complaint form with the appeal box checked order to appeal the initial decision. I was informed that I need to send this letter along with the attached materials previously sent with my "appeal" in order to file an exception. Therefore, kindly accept the attached as my exception to the initial decision.

On March 3, 2015 I received notification of an initial finding by Judge Pell on my complaint to the public utility commission. I then filed an appeal with the public utility commission. Unfortunately the appeal was interpreted as a new formal complaint in a new matter rather than what I had intended, which is to *file an exception to the initial decision. This is why I wish to withdraw the new matter formal complaint* and instead file this exception.

Sincerely,

Louise A Francis

Louise A Francis

Louise Francis

706 Lombard St

Philadelphia, Pa. 19147

March 6, 2015

Revised March 17, 2015

Discussion of Appeal (Exeption) of Initial Decision in case **C-2014-2451351, Louise Francis vs PECO**:

The utility, PECO, sent a 10-day shut-off notice to my residence. My bills are fully paid and up to date. The reason given by PECO for the shut-off is not granting access to the electric meter at my residence. I dispute this claim. Within the 10-day period I filed a formal complaint with the Pennsylvania Public Utility Commission.

On March 3, 2015 I received an email notification from the Pennsylvania public utility *commission that a decision had been by the public utility commission's judge (hereafter* referred to as PUC) made in favor of PECO. I am appealing the decision. The notice assigning the case to a judge was numbered 2014-2451351.

I was very surprised that I had had very little communication from the public utility commission of any kind regarding my complaint, and what schedules and requirements were. I was also not given a hearing to state my case. I believe the case is extremely valid and is supported by scientific research and by my rights as a Pennsylvania citizen. I believe that it is my right to demand to be heard, and my right to be free of physical harm from a large monopolistic corporation.

The PUC incorrectly cited a previous case decided by the PUC that resulted in a decision that consumers cannot "opt out". This citation was incorrect because the complaint did not request an opt-out. While I am currently working with others in Pennsylvania and with state legislators to get a law passed allowing an opt-out, I did not request an opt-out and I believe that my request to not have my meter replaced at this time is not the same as an opt-out. The PUC in its decision is claiming that Act 129 requires consumers to allow smart meters to be installed in their residence by the time frame set by PECO (i.e. the end of 2014). I have reviewed Act 129 as posted on the public utility commission's website. Act 129 does not require smart meters by the end of 2014. Act 129 also does not authorize sanctions against utility customers who disagree with the utility's artificial schedule for the installation of smart meters.

Nowhere in PECO's corporate charter is the utility allowed to damage or maim its customers. It should be noted that a lot has been learned about the harms inflicted by smart meters since the cases cited by the PUC to justify their decision. Recent testimony provided to Representative Mike Reese described some of the adverse effects of Smart Meters experienced by Pennsylvania customers. The adverse effects include severe headaches, waking up in the middle of the night and cardiac symptoms. Similar adverse effects have been reported routinely wherever smart meters have been installed and are considered valid complaints in other jurisdictions. I have attached a small sample of the documentation of the harmful effects of smart meters. PECO claims its meters are safe. This claim is based on tobacco science and cherry picking of information to use only that which supports its position. The PUC then rubberstamps PECO's position, despite abundant evidence that their so-called evidence is misleading.

The public utility commission's mission statement is: "The Pennsylvania Public Utility Commission balances the needs of consumers and utilities; ensures safe and reliable utility service at reasonable rates; protects the public interest; educates consumers to make independent and informed utility choices; furthers economic development; and fosters new technologies and competitive markets in an environmentally sound manner." Balancing the needs of consumers and utilities is not accomplished when virtually all decisions by this commission supports the position of PECO.

It does not appear that in the matter of Smart Meters, the PUC is balancing the needs of consumers and utilities, but is routinely siding with the utility in a matter that is of great importance and urgency to PECO's consumers. It should be noted that PECO has been granted a monopoly in the state of Pennsylvania on the delivery of electric service, even when under so-called "competition" a customer can choose a different energy supplier. We don't seem to have the option to have a different deliverer who will not force their agendas on us. Regulation is supposed to substitute for lack of competition and enable consumers to get a fair deal. However when the utilities regulator is so biased in favor of the utility, regulation becomes a mere fiction.

It should be noted that the PUC's response to my complaint is full of legalese language that is not consumer friendly. Although the PUC claims that it is making the most favorable interpretation of my complaint possible, in fact they have dismissed it out of hand. Instead they have given 100% of the weight in their decision to boilerplate propaganda supplied by PECO. For instance, PECO claims that Act 129 requires me to

accept a meter that they, and not I, want me to have. The PUC sided with PECO. The PUC incorrectly interpreted other cases in order to agree with PECO. In response to the PUC's denial of my claim, I have reviewed the text of Act 129 as stated on the PUC's web site. Act 129 does not require me to accept a meter according to PECO's specific agenda and schedule, which according to their statements made in the past, was by the end of 2014.

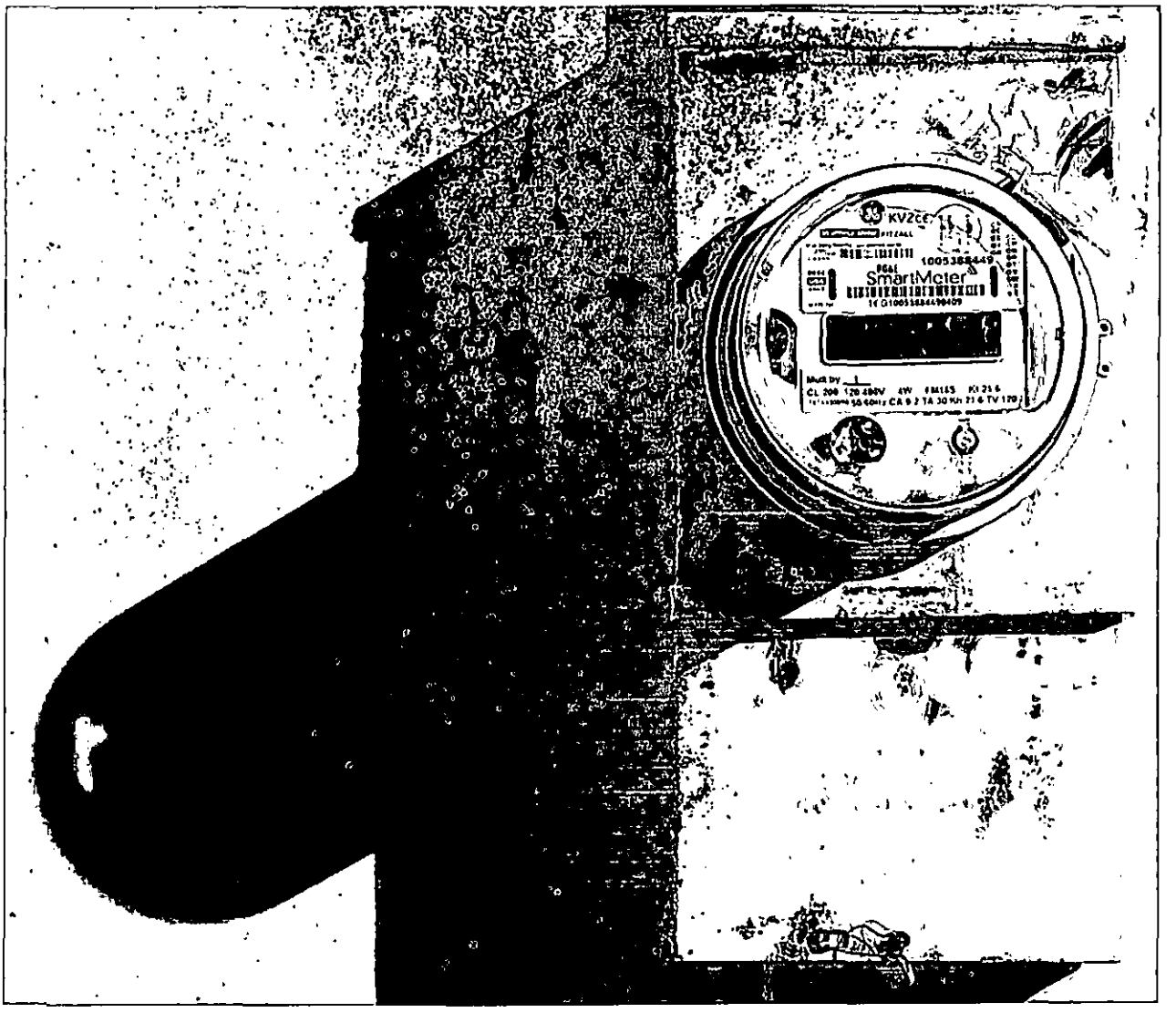
In their decision, the PUC states "Moreover, Commission regulations allow PECO to notify a customer that it will terminate their service if the customer will not permit access to a meter for the purpose of replacement." This is an incorrect citation and interpretation of the regulations. My meter does not need replacement. It is fallacious to claim that it does. Despite that, I would be willing to replace it with an analog meter.

In summary, there are significant flaws in the initial decision of the PUC to deny my claim.

Fairfax, Calif., Approves Three-Year Ban on SmartMeters

The city initially prohibited installation of SmartMeters with an urgency ordinance in 2010, which it renewed in 2011 and 2012.

BY RICHARD HALSTEAD, MCCLATCHY NEWS SERVICE / FEBRUARY 11, 2014



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The Fairfax, Calif., Town Council has agreed to impose a three-year ban on

the installation of Pacific Gas and Electric Co.'s SmartMeters.

SmartMeters are electronic monitoring devices that continuously measure the electricity and natural gas use at households and businesses and relay data to the utility; the goal is to enable power companies to better understand patterns of power consumption throughout the day so they can adjust power generation accordingly.

Fairfax Councilman Larry Bragman says, however, that the meters are a poor investment of ratepayers' money. The council voted unanimously last week to impose the ban.

"There are potential health effects that have not been fully studied," Bragman said. And, he adds, "The impact to privacy has not been dealt with effectively by the California Public Utilities Commission (CPUC). That is becoming more of an issue, now that the awareness of privacy issues has become so much more a matter of public concern."

Fairfax initially prohibited installation of SmartMeters with an urgency ordinance in 2010, which it renewed in 2011 and 2012.

"You can renew an urgency ordinance only twice," Bragman said. "So at that point we had to introduce a formal ordinance."

Fairfax Mayor David Weinsoff said a couple of years ago when the Fairfax Town Council conducted public hearings on SmartMeters the community's opposition was overwhelming.

"When a community speaks so loudly and so wisely, really there was no question that the council should continue to impose this moratorium," Weinsoff said.

Brittany McKannay, a PG&E spokeswoman, said, "The CPUC, which regulates PG&E, is the only entity with the jurisdiction to impose a moratorium on the SmartMeter program. We believe every customer should be able to choose whether they want the benefits of a modern grid or want to opt out of the SmartMeter program for any reason."

In February 2012, the California Public Utilities Commission, which regulates PG&E, ruled that the investor-owned utility could require customers who want to keep their analog meter to pay a one-time fee of $75, plus an ongoing monthly fee of $10.

Bragman said several government entities, including the Fairfax Town Council and the Marin County Board of Supervisors, have filed an administrative challenge to the ruling. Christopher Chow, a commission spokesman, said a ruling on the challenge is still several month away.

The Marin County Board of Supervisors voted last week to extend a moratorium on installation of SmartMeters in Marin's unincorporated areas for another year. The county first imposed its ban on SmartMeters in 2011.

McKannay told Marin County supervisors last week, when they approved the moratorium, that so far 191,931 SmartMeters have been installed in Marin, and 3,495 customers have opted out.

Bragman said there would likely be more people opting out if not for the fee. He said one of the bases for the challenge is that the opt-out violates California Public Utilities law because it imposes a tariff on customers who are concerned about the health effects of the radio frequency waves used by the SmartMeters.

"Most of the customers who are opting out are doing so because they don't want to be exposed to the electromagnetic field output of the meter," Bragman said.

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Public health implications of wireless technologies

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Abstract

Global exposures to emerging wireless technologies from applications including mobile phones, cordless phones, DECT phones, WI-FI, WLAN, WiMAX, wireless internet, baby monitors, and others may present serious public health consequences. Evidence supporting a public health risk is documented in the BioInitiative Report. New, biologically based public exposure standards for chronic exposure to low-intensity exposures are warranted. Existing safety standards are obsolete because they are based solely on thermal effects from acute exposures. The rapidly expanding development of new wireless technologies and the long latency for the development of such serious diseases as brain cancers means that failure to take immediate action to reduce risks may result in an epidemic of potentially fatal diseases in the future. Regardless of whether or not the associations are causal, the strengths of the associations are sufficiently strong that in the opinion of the authors, taking action to reduce exposures is imperative, especially for the fetus and children. Such action is fully compatible with the precautionary principle, as enunciated by the Rio Declaration, the European Constitution Principle on Health (Section 3.1) and the European Union Treaties Article 174.

Keywords: Wireless technology; Brain cancer; Radiofrequency; Cell phones; Wireless antenna facilities; Childrens' health

1. Introduction and background

Exposure to electromagnetic fields (EMF) has been linked to a variety of adverse health outcomes that may have significant public health consequences [1–13]. The most serious health endpoints that have been reported to be associated with extremely low frequency (ELF) and/or RF include childhood and adult leukemia, childhood and adult brain tumors, and increased risk of the neurodegenerative diseases, Alzheimer's and amyotrophic lateral sclerosis (ALS). In addition, there are reports of increased risk of breast cancer in both men and women, genotoxic effects (DNA damage and micronucleation), pathological leakage of the blood–brain barrier, altered immune function including increased allergic and inflammatory responses, miscarriage and some cardiovascular effects [1–13]. Insomnia (sleep disruption) is reported in studies of people living in very low-intensity RF environments with WI-FI and cell tower-level exposures [85–93]. Short-term effects on cognition, memory and learning, behavior, reaction time, attention and concentration, and altered brainwave activity (altered EEG) are also reported in the scientific literature [94–107]. Biophysical mechanisms that may account for such effects can be found in various articles and reviews [136–144].

The public health implications of emerging wireless technologies are enormous because there has been a very rapid global deployment of both old and new forms in the last 15 years. In the United States, the deployment of wireless infrastructure has accelerated greatly in the last few years with 220,500 cell sites in 2008 [14–16]. Eighty-four percent of the population of the US own cell phones [16]. Annualized wireless revenues in 2008 will reach $144 billion and US spending on wireless communications will reach $212 billion by 2008. Based on the current 15% annual growth rate enjoyed by the wireless industry, in the next 5 years wireless will become a larger sector of the US economy than both the agriculture and automobile sectors. The annualized use of cell phones in the US is estimated to be 2.23 trillion minutes in 2008 [16]. There are 2.2 billion users of cell phones worldwide in 2008 [17] and many million more users of cordless phones.

Over 75 billion text messages were sent in the United States, compared with 7.2 billion in June 2005, according to

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CTIA, the Wireless Association, the leading industry trade group [16]. The consumer research company Nielsen Mobile, which tracked 50,000 individual customer accounts in the second quarter of this year, found that Americans each sent or received 357 text messages a month then, compared with 204 phone calls. That was the second consecutive quarter in which mobile texting significantly surpassed the number of voice calls [17].

The Electronics Industries Alliance (EIA) represents 80% of the $550 billion US electronics industry "that provides two million jobs for American workers." Its members include companies from the consumer electronics and telecommunications industries, among others [17].

There is intense industry competition for market share. Telecom taxes form an immense revenue generator for the government sector. Sale of the airwaves (auctions selling off wireless bandwidth) is a multi-million dollar industry for governments, and multi-billion dollar global advertising budgets are common. Lobbying dollars from the telecom-related industries are estimated to be $300 million annually. The media is nearly silent on health issues, perhaps in part because of global advertising revenues that compromise journalistic independence and discourage balanced coverage of health, equity and economic issues.

2. Evidence supporting a public health risk

Even if there is only a small risk to health from chronic use of and exposure to wireless technologies, there is the potential for a profound public health impact. RF radiation now saturates the airwaves, resulting in exposure to both users and non-users. The effects are both short-term (sleep disruption, hormone disruption, impairment of cognitive function, concentration, attention, behavior, and well-being) and they are almost certainly long-term (generational impacts on health secondary to DNA damage, physiological stress, altered immune function, electrosensitivity, miscarriage risks, effects on sperm quality and motility leading to infertility, increased rates of cancer, and neurological diseases including Alzheimer's disease and ALS—at least for ELF exposures). (Chapters 5–12 of the BioInitiative Report [1] and papers in this Supplement.)

There is credible scientific evidence that RF exposures cause changes in cell membrane function, metabolism and cellular signal communication, as well as activation of proto-oncogenes and triggering of the production of stress proteins at exposure levels below current regulatory limits. There is also generation of reactive oxygen species, which cause DNA damage, chromosomal aberrations and nerve cell death. A number of different effects on the central nervous system have also been documented, including activation of the endogenous opioid systems, changes in brain function including memory loss, slowed learning, motor dysfunction and performance impairment in children, and increased frequency of headaches, fatigue and sleep disorders. Melatonin secretion is reduced, resulting in altered circadian rhythms and disruption of several physiological functions. (Chapters 5–12 of the BioInitiative Report [1] and papers in this Supplement.)

These effects can reasonably be presumed to result in adverse health effects and disease with chronic and uncontrolled exposures, and children may be particularly vulnerable [1,19]. The young are also largely unable to remove themselves from such environments. Second-hand non-ionizing radiation, like second-hand smoke may be considered of public health concern based on the evidence at hand.

2.1. Malignant brain tumors

At present, the most persuasive evidence for cancer resulting from RF exposure is that there is a significantly increased risk of malignant glioma in individuals that have used a mobile phone for 10 or more years, with the risk being elevated only on the side of the head on which the phone is used regularly (ipsilateral use) [1,3,4,6–8,18]. While the risk for adults after 10 or more years of use is reported to be more than doubled, there is some evidence beginning to appear that indicates that the risk is greater if the individual begins to use a mobile phone at younger ages. Hardell et al. [18] reported higher odds ratios in the 20–29-year-old group than other age ranges after more than 5 years of use of either analog or cordless phones. Recently in a London symposium Hardell reported that after even just 1 or more years of use there is a 5.2-fold elevated risk in children who begin use of mobile phones before the age of 20 years, whereas for all ages the odds ratio was 1.4. Studies from Israel have found that the risk of parotid gland tumors (a salivary gland in the cheek) is increased with heavy cell phone use [7]. The risk of acoustic neuroma (a benign but space-occupying tumor on the auditory nerve) is also significantly increased on the ipsilateral side of the head after 10 or more years of mobile phone use [1,3]. This relationship has also been documented in some of the published reports of the WHO Interphone Study, a decade-long 13-country international assessment of cell phone risks and cancer [6,8].

Kundi reports that "(E)pidemiological evidence compiled in the last 10 years starts to indicate an increased risk, in particular for brain tumors (glioma, meningioma, acoustic neuroma), from mobile phone use. Considering biases that may have been operating in most studies the risk estimates are rather too low, although recall bias could have increased risk estimates. The net result, when considering the different errors and their impact is still an elevated risk" [19].

The latency for most brain tumors is 20 years or more when related to other environmental agents, for example, to X-ray exposure. Yet, for cell phone use the increased risks are occurring much sooner than twenty years, as early as 10 years for brain tumors in adults and with even shorter latencies in children. This suggests that we may currently be significantly underestimating the impact of current levels of

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use of RF technology, since we do not know how long the average latency period really is. If it is 20 years, then the risk rate will likely be much higher than an overall doubling of risk for cell phone users if the peak comes later than 10 years. It may also signal very troubling risks for those who start using cell phones, and perhaps all wireless devices, in early childhood. We may not have proof of effect for decades until many hundreds of thousands of new cases of malignant gliomas are set in motion by long-term cell phone use.

The preliminary evidence that mobile phone use at younger ages may lead to greater risk than for older persons is of particular concern. There is a large body of evidence that childhood exposure to environmental agents poses greater risk to health than comparable exposure during adulthood [20,21]. There is reason to expect that children would be more susceptible to the effects of EMF exposure since they are growing, their rate of cellular activity and division is more rapid, and they may be more at risk for DNA damage and subsequent cancers. Growth and development of the central nervous system is still occurring well into the teenage years so that neurological changes may be of great importance to normal development, cognition, learning, and behavior.

A greater vulnerability of children to developing brain cancer from mobile phone use may be the consequence of a combination of patterns of use, stage of development and physical characteristics related to exposure. In addition to the fact that the brain continues to develop through the teen years, many young children and teenagers now spend very large periods of time using mobile phones. The brain is the main target organ of cell phones and cordless phones, with highest exposure to the same side as the phone is used. Further, due to anatomical reasons, the brain of a child is more exposed to RF radiation than the brain of an adult [22,23]. This is caused by the smaller brain size, a thinner pinna of the ear, thinner skin and thinner skull bone permitting deeper penetration into the child's brain. A recent French study showed that children absorb twice the RF from cell phone use as do adults [24].

In addition to concerns about cancer, there is evidence for short-term effects of RF exposure on cognition, memory and learning, behavior, reaction time, attention and concentration, altered brainwave activity (altered EEG) [95–108], and all of these effects argue for extreme caution with regard to exposure of children. The development of children into adults is characterized by faster cell division during growth, the long period needed to fully develop and mature all organ systems, and the need for properly synchronized neural development until early adulthood. Chronic, cumulative RF exposures may alter the normal growth and development of children and adversely affect their development and capacity for normal learning, nervous system development, behavior and judgment [1,97,102].

Prenatal exposure to EMF has been identified as a possible risk factor for childhood leukemia (1). Maternal use of cell phones has been reported to adversely affect fetal brain development, resulting in behavioral problems in those children by the time they reach school age [25]. Their exposure is involuntary in all cases. Children are largely unable to remove themselves from exposures to harmful substances in their environments.

2.2. *Plausible biological mechanisms for a relationship between RF exposure and cancer*

2.2.1. *DNA damage and oxidative stress*

Damage to DNA from ELF and from RF cell phone frequencies at very low intensities (far below FCC and ICNIRP safety limits) has been demonstrated in many studies [1,2,26–35]. Both single- and double-strand DNA damage have been reported by various researchers in different laboratories. This is damage to the human genome, and can lead to mutations which can be inherited, or which can cause cancer, or both.

Non-ionizing radiation is assumed to be of too low energy to cause direct DNA damage. However both ELF and RF radiation induce reactive oxygen species, free radicals that react with cellular molecules including DNA. Free-radical production and/or the failure to repair DNA damage (secondary to damage to the enzymes that repair damage) created by such exposures can lead to mutations. Whether it is greater free-radical production, reduction in anti-oxidant protection or reduced repair capacity, the result will be altered DNA, increased risk of cancer, impaired or delayed healing, and premature aging [36–54]. Exposures have also been linked to decreased melatonin production, which is a plausible biological mechanism for decreased cancer surveillance in the body, and increased cancer risk [34,39,44,46,47,49,50,54]. An increased risk of cancers and a decrease in survival has been reported in numerous studies of ELF and RF [55–69].

2.2.2. *Stress proteins (heat shock proteins or HSP)*

Another well-documented effect of exposure to low-intensity ELF and RF is the creation of stress proteins (heat shock proteins) that signal a cell is being placed under physiological stress) [70–80]. The HSP response is generally associated with heat shock, exposure to toxic chemicals and heavy metals, and other environmental insults. HSP is a signal of cells in distress. Plants, animals and bacteria all produce stress proteins to survive environmental stressors like high temperatures, lack of oxygen, heavy metal poisoning, and oxidative stress.

We can now add ELF and RF exposures to this list of environmental stressors that cause a physiological stress response. Very low-level ELF and RF exposures can cause cells to produce stress proteins, meaning that the cell recognizes ELF and RF exposures as harmful. This is another important way in which scientists have documented that ELF and RF exposures can be harmful, and it happens at levels far below the existing public safety standards. An additional concern is that if the stress goes on too long, the protective effect is diminished. The reduced response with prolonged exposure means the cell is less protected against

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damage, and this is why prolonged or chronic exposures may be harmful, even at very low intensities.

2.2.3. RF-induced gene expression changes

Many environment agents cause diseases, including cancer, not by direct damage to DNA but rather by up- or down-regulation of genes that regulate cell growth and function. Usually there are many genes whose expression is changed, and it is difficult to determine the exact changes responsible for the disease. Both ELF and RF exposures have been shown to result in altered gene expression. Olivares-Banuelos et al. [81] found that ELF exposure of chromaffin cells resulted in changed expression of 53 transcripts. Zhao et al. [82] investigated the gene expression profile of rat neurons exposed to 1800 MHz RF fields (2 W/kg) and found 24 up-regulated genes and 10 down-regulated genes after a 24-h exposure. The altered genes were involved in multiple cellular functions including cytoskeleton, signal transduction pathways and metabolism. Kariene et al. [83] exposed human skin to mobile phone radiation, and found by punch biopsy that 8 proteins were significantly altered in expression, consistent with gene induction. Several other studies have found altered gene expression following RF exposure, although none have been found that explain specific disease states [84].

DNA activation at very low ELF and RF levels, as in the stress response, and DNA damage (strand breaks and micronuclei) at higher levels, are molecular precursors to changes that are believed to lead to cancer. These, along with gene induction, provide plausible biological mechanisms linking exposure to cancer.

The biochemical pathways that are activated are the same for ELF and for RF exposures, and are non-thermal (do not require heating or induced electrical currents). This is true for the stress response, DNA damage, generation of reactive oxygen species as well as gene induction. Thus it is not surprising that the major cancers resulting from exposure to ELF and RF are the same, namely leukemia and brain cancer. The safety standards for both ELF and RF, based on protection from heating, are irrelevant and not protective. ELF exposure levels of only 5–10 mG have been shown to activate the stress response genes (http://www.bioinitiative.org, Sections 1 and 7 [1]).

3. Sleep, cognitive function and performance

The relationship of good sleep to cognition, performance and healing is well recognized. Sleep is a profoundly important factor in proper healing, anti-inflammatory benefits, reduction in physical symptoms of such as tendonitis, over-use syndrome, fatigue-induced lethargy, cognition and learning. Incomplete or slowed physiological recovery is common when sleep is impaired. Circadian rhythms that normalize stress hormone production (cortisol, for example) depend on synchronized sleep patterns.

People who are chronically exposed to low-level wireless antenna emissions report symptoms such as problems in sleeping (insomnia), as well as other symptoms that include fatigue, headache, dizziness, grogginess, lack of concentration, memory problems, ringing in the ears (tinnitus), problems with balance and orientation, and difficulty in multi-tasking [85–93,99]. In children, exposures to cell phone radiation have resulted in changes in brain oscillatory activity during some memory tasks [97,102]. Cognitive impairment, loss of mental concentration, distraction, speeded mental function but lowered accuracy, impaired judgment, delayed reaction time, spatial disorientation, dizziness, fatigue, headache, slower motor skills and reduced learning ability in children and adults have all been reported [85–108].

These symptoms are more common among "electrosensitive" individuals, although electrosensitivity has not been documented in double-blind tests of individual identifying themselves as being electrosensitive as compared to controls [109,110]. However people traveling to laboratories for testing are pre-exposed to a multitude of RF and ELF exposures, so they may already be symptomatic prior to actual testing. There is also evidence that RF exposures testing behavioral changes show delayed results; effects are observed after termination of RF exposure. This suggests a persistent change in the nervous system that may be evident only after time has passed, so is not observed during a short testing period.

3.1. Plausible biological mechanisms for neurobehavioral effects

3.1.1. The melatonin hypothesis

While there remains controversy as to the degree that RF and ELF fields alter neurobehavioral function, emerging evidence provides a plausible mechanism for both effects on sleep and cognition. Sleep is controlled by the central circadian oscillator in the suprachiasmatic nucleus, located in the hypothalamus. The activity of this central circadian oscillator is, in turn, controlled by the hormone, melatonin, which is released from the pineal gland [111]. There is considerable evidence that ELF exposure reduces the release of melatonin from the pineal gland—see Section 12 of the Bioinitiative Report [1]. There has been less study of the effects of RF exposure on melatonin release, but investigations have demonstrated a reduced excretion of the urinary metabolite of melatonin among persons using a mobile phone for more than 25 min per day [112]. In a study of women living near to radio and television transmitters, Clark et al. [113] found no effect on urinary melatonin metabolite excretion among pre-menopausal women, but a strong effect in post-menopausal women.

The "melatonin hypothesis" also provides a possible basis for other reported effects of EMFs. Melatonin has important actions on learning and memory, and inhibits electrophysiological components of learning in some but not all areas of the brain [114,115]. Melatonin has properties as a free-radical scavenger and anti-oxidant [116], and consequently,

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a reduction in melatonin levels would be expected to increase susceptibility to cancer and cellular damage. Melatonin could also be the key to understanding the relationship between EMF exposure and Alzheimer's disease. Noonan et al. [117] reported that there was an inverse relationship between excretion of the melatonin metabolite and the 1–42 amino acid form of amyloid beta in electric utility workers. This form of amyloid beta has been found to be elevated in Alzheimer's patients.

3.1.2. Blood–brain barrier alterations

Central nervous system effects of EMFs may also be secondary to damage to the blood–brain barrier (BBB). The blood–brain barrier is a critical structure that prevents toxins and other large molecules that are in peripheral blood from having access to the brain matter itself. Salford et al. [118] have reported that a 2-h exposure of rats to GSM-900 radiation with a SAR of 2–200 mW/kg resulted in nerve cell damage. In a follow-up study, Eberhardt et al. report that 2-h exposures to cell phone GSM microwave RF resulted in leakage of albumin across the blood–brain barrier and neuronal death [119]. Neuronal albumin uptake was significantly correlated to occurrence of damaged neurons when measured at 28 days post-exposure. The lowest exposure level was 0.12 mW/kg (0.00012 W/kg) for 2 h. The highest exposure level was 120 mW/kg (0.12 W/kg). The weakest exposure level showed the greatest effect in opening the BBB [118]. Earlier blood–brain studies by Salford and Schirmacher [120,121] report similar effects.

4. What are sources of wireless radiation?

There are many overlapping sources of radiofrequency and microwave emissions in daily life, both from industrial sources (like cell towers) and from personal items [cell and cordless phones, personal digital assistants (PDAs), wireless routers, etc.]. Published data on typical levels found in some cities and from some sources are available at http://www.bioinitiative.org [1,122–124].

Cell phones are the single most important source of radiofrequency radiation to which we are exposed because of the relatively high exposure that results from the phone being held right against the head. Cell phones produce two types of emissions that should be considered. First, the radiofrequency radiation (typically microwave frequency radiation) is present. However, there is also the contribution of the switching battery pack that produces very high levels of extremely low frequency electromagnetic field [125–127].

Cordless telephones have not been widely recognized as similar in emissions to cell phones, but they can and do produce significant RF exposures. Since people tend to use them as substitutes for in-home and in-office corded or traditional telephones, they are often used for long periods of time. As the range of cordless phones has increased (the distance away that you can carry on a conversation is related to the power output of the phone), the more powerful the RF signal will be. Hence, newer cordless phones may in some cases be similar to the power output of cell phones. The cumulative emissions from cell and cordless phones taken together should be recognized when considering the relative risks of wireless communication exposures.

PDAs such as the BlackBerry, Treo and iPhone units are 'souped-up' versions of the original voice communication devices (cell phones). The often produce far higher ELF emissions than do cell phones because they use energy from the battery very intensively for powering color displays and during data transmission functions (email, sending and receiving large files, photos, etc.) [125–127]. ELF emissions have been reported from PDAs at several tens to several hundreds of milligauss. Evidence of significantly elevated ELF fields during normal use of the PDA has public health relevance and has been reported in at least three scientific papers [125,128,129]. In the context of repetitive, chronic exposure to significantly elevated ELF pulses from PDAs worn on the body, relevant health studies point to a possible relationship between ELF exposure and cancer and pregnancy outcomes [130–133].

We include discussion of the ELF literature for two reasons. As mentioned above ELF activates the same biology as RF, it contributes to the total EMF burden of the body. In addition, PDAs and cell phones emit both radiofrequency/microwave radiation (RF) and extremely low frequency ELF from the battery switching of the device (the power source). Studies show that some devices produce excessively high ELF exposures during voice and data transmission. ELF is already classified as a 2B (Possible) Carcinogen by IARC, which means that ELF is indisputably an issue to consider in the wireless technology debate. ELF has been classified as a Group 2B carcinogen for all humans, not just children. The strongest evidence came from epidemiological studies on childhood leukemia, but the designation applies to all humans, both adults and children [1,25].

Wireless headsets that allow for conversations with cell phones at a distance from the head itself reduce the emissions. Depending on the type of wireless device, they may operate (transmit signal) only during conversations or they may be operational continuously. The cumulative dose of wireless headsets has not been well characterized under either form of use. Substantial cumulative RF exposure would be expected if the user wears a wireless headset that transmits a signal continuously during the day. However a critical factor is where the cell phone is placed. If worn on a belt with a headset, the exposure to the brain is reduced but the exposure to the pelvis may be significant.

Cell towers (called "masts" in Europe and Scandinavian countries) are wireless antenna facilities that transmit the cell phone signals within communities. They are another major source of RF exposures for the public. They differ from RF exposures from wireless devices like cell phones in that they produce much lower RF levels (generally 0.05 to 1–2 $\mu W/cm^2$ in the first several hundred feet around them) in comparison to several hundred microwatts per centimeter

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squared for a cell phone held at the head. However they create a constant zone of elevated RF for up to 24 h per day, many hours per day, and the exposure is whole body rather than localized at the head. These facilities are the distribution system for wireless voice communications, internet connections and data transmission within communities. They are often erected on free-standing towers. They may be constructed on telephone poles or electrical poles. They may be built into the façade or rooftops of buildings behind wood screening. These are called stealth installations for wireless antenna facilities. Some installations are camouflaged to resemble 'false trees or rocks'. They emit RF to provide cell service to specific "cells" or locations that receive the signal.

Other forms of wireless transmission that are common in areas providing cell service are wireless land area networks (WLAN), (WiMAX) and WIFI networks. Some cities are installing city-wide WIFI service to allow any user on the street to log into the internet (without cables or wire connections). WIFI installations may have a signal reach for a few hundred feet where WiMAX installations may transmit signal more than 10 miles, so produce a stronger RF emission for those in close proximity. Each type has its particular signal strength and intended coverage area, but what they have in common is the production of continuous RF exposure for those within the area. We do not know what the cumulative exposure (dose) might be for people living, working or going to school in continuously elevated RF fields, nor are the possible health implications yet known. However, based on studies of populations near cell sites in general, there is a constellation of generally observed health symptoms that are reported to occur [85–107]. In this regard it is important to note that children living near to AM radio transmitters have been found to elevated risks of leukemia [134,135]. While AM radio RF fields are lower in frequency than that common in mobile phones, this is a total body irradiation with RF. The fact that leukemia, not brain cancer, is apparent in these studies suggests that leukemia is the cancer seen at the lowest levels of both ELF and RF fields under the circumstances of whole-body exposure.

Commercial surveillance systems or security gates pose an additional source of strong RF exposures. They are ubiquitous in department stores, markets and shops at the entry and exit points to discourage shoplifting and theft of goods. Security gates can produce excessively high RF exposures (although transitory) and have been associated with interference with pacemakers in heart patients. The exposure levels may approach thermal public safety limits in intensity, although no one expects a person to stand between the security gate bars for more than 6 min (safety limits for uncontrolled public access are variable depending on the frequency, but are all averaged over a 6-min exposure period).

RFID chips (radiofrequency identification chips) are being widely used to track purchases and for security of pets, and in some cases to keep track of patients with Alzheimer's disease and of children. RFID chips are implanted in fabrics, inserted in many types of commercial goods, and can be implanted under the skin. They create a detectable signal to track the location of people and goods.

5. Problems with existing public health standards (safety limits)

If the existing standards were adequate none of the effects documented above should occur at levels to which people are regularly exposed. The fact that these effects are seen with our current ambient levels of exposure means that our existing public safety standards are obsolete. It also means that new, biologically based public exposure standards for wireless technologies are urgently needed. Whether it is feasible to achieve low enough levels that still work and also protect health against effects of chronic RF exposure – for all age groups – is uncertain. Whether we can protect the public and still allow the kinds of wireless technology uses we see today is unknown.

The nature of electromagnetic field interactions with biological systems has been well studied [136–144]. For purposes of standard-setting processes for both ELF and RF, the hypothesis that tissue damage can result only from heating is the fundamental flaw in the misguided efforts to understand the basic biological mechanisms leading to health effects.

The thermal standard is clearly untenable as a measure of dose when EMF stimuli that differ by many orders of magnitude in energy can stimulate the same biological response. In the ELF range, the same biological changes occur as in the RF, and no change in temperature can even be detected. With DNA interactions the same biological responses are stimulated in ELF and RF ranges even though the frequencies of the stimuli differ by many orders of magnitude. The effects of EMF on DNA to initiate the stress response or to cause molecular damage reflect the same biology in different frequency ranges. For this reason it should be possible to develop a scale based on DNA biology, and use it to define EMF dose in different parts of the EM spectrum. We also see a continuous scale in DNA experiments that focus on molecular damage where single and double strand breaks have long been known to occur in the ionizing range, and recent studies have shown similar effects in both ELF and RF ranges [144].

Existing standard-setting bodies that regulate wireless technologies, assume that there are no bioeffects of concern at exposure levels that do not cause measurable heating. However, it has been established beyond any reasonable doubt that bioeffects and some adverse health effects occur at far lower levels of RF and ELF exposure where no heating (or induced current) occurs; some effects are shown to occur a thousand times or more below the existing public safety limits. New, biologically based public exposure limits are urgently needed. New wireless technologies for cell and cordless phones, other wireless communication and data transmission systems affect living organisms in new ways that our antiquated safety limits have not foreseen, nor protected against.

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The exposure of children to electromagnetic fields has not been studied extensively; in fact, the Federal Communications Commission (FCC) standards for exposure to radiofrequency radiation are based on the height, weight and *stature of a 6-foot tall man, not scaled to children or adults* of smaller stature. They do not take into account the unique susceptibility of growing children to exposures, nor are there studies of particular relevance to children.

In addition there is a problem in the consideration of the level of evidence taken into consideration by these bodies. There have not been adequate animal models shown to have cancer as an endpoint, and a perception that no single mechanism is proven to explain these associations. Thus these committees have tended to ignore or minimize the evidence for direct hazard to humans, and believe there is no proof of cause and effect. These bodies assume from the beginning that only conclusive scientific evidence (absolute proof) will be sufficient to warrant change, and refuse to take action on the basis of a growing body of evidence which provides early but consequential warning of risks.

The Radiofrequency Interagency Working Group of the US governmental agencies involved in RF matters (RFIAWG) issued a Guidelines Statement in June of 1999 that concluded the present RF standard "may not adequately protect the public" [145]. The RFIAWG identified fourteen (14) issues that they believe are needed in the planned revisions of ANSI/IEEE RF exposure guidelines including "to provide a strong and credible rationale to support RF exposure guidelines". In particular, the RFIAWG criticized the existing standards as not taking into account chronic, as opposed to acute exposures, modulated or pulsed radiation (digital or pulsed RF is proposed at this site), time-averaged measurements that may erase the unique characteristics of an intensity-modulated RF radiation that may be responsible for reported biologic effects, and stated the need for a *comprehensive review of long-term, low-level exposure studies*, neurological-behavioral effects and micronucleus assay studies (showing genetic damage from low-level RF) [145]. This important document from relevant US agencies questions existing standards in the following ways: (a) selection of an adverse effect level for chronic exposures not based on tissue heating and considering modulation effects; (b) recognition *of different safety criteria for acute and chronic exposures at* non-thermal or low-intensity levels; (c) recognition of deficiencies in using time-averaged measurements of RF that does not differentiate between intensity-modulated RF and continuous wave (CW) exposure, and therefore may not adequately protect the public; (d) having standards based on adult males rather than considering children to be the most *vulnerable group*.

6. Prudent public health responses

Emerging environmental health problems require preventative public health responses even where scientific and medical uncertainties still exist, but where policy decisions today may greatly reduce human disease and societal costs tomorrow.

Policy decisions in public health must address some amount of uncertainty when balancing likely benefits and estimated costs. Although new insight will allow better appreciation of difficult issues, such as those occurring in environmental *and occupational health*, an expanded perspective may also enlarge the list of problems that need to be managed. Ignoring the problems carries its own costs (as deferring a decision is a decision in itself). With environmental and other public health problems becoming increasingly complex and international in scope, scientific documentation alone rarely justifies simple solutions [146].

Social issues regarding the controversy over public and occupational exposures to ELF and RF center on the resolute adherence to existing ICNIRP and FCC/IEEE standards by many countries, in the face of growing scientific evidence of health risks at far lower levels [10]. The composition of these committees, usually with excessive representation of the physics and engineering communities rather than public health professionals, results in a refusal to adopt biologically based exposure standards. Furthermore, there is widespread belief that governments are ignoring this evidence and there is widespread distrust of and lack of confidence in governments and their health agencies. The basis on which most review bodies and standard-setting agencies have avoided the conclusion that the science is strong enough to warrant new safety limits for ELF and RF is to require a demonstration of absolute proof before taking action. A causal level of evidence, or scientific certainty standard is implicit in nearly all reviews of the ELF and RF science, although this runs counter to good public health protection policies.

There is no question that global implementation of the *safety standards proposed in the Bioinitiative Report, if* implemented abruptly and without careful planning, have the potential to not only be very expensive but also disruptive of life and the economy as we know it. Action must be a balance of risk to cost to benefit. The major risk from maintaining the status quo is an increasing number of cancer cases, especially in young people, as well as neurobehavioral problems *at increasing frequencies. The benefits of the status quo* are expansion and continued development of communication technologies. But we suspect that the true costs of even existing technologies will only become much more apparent with time. Whether the costs of remedial action are worth the societal benefits is a formula that should reward precautionary behavior. Prudent corporate policies should be expected to *address and avoid future risks and liabilities, otherwise, there* is no market incentive to produce safe (and safer) products.

The deployment of new technologies is running ahead of any reasonable estimation of possible health impacts and estimates of probabilities, let alone a solid assessment of risk. However, what has been missing with regard to EMF has been an acknowledgement of the risk that is demonstrated by

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the scientific studies. There is clear evidence of risk, although the magnitude of the risk is uncertain, and the magnitude of doing nothing on the health effects cost to society is similarly uncertain. This situation is very similar to our history of dealing with the hazards of smoking decades ago, where the power of the industry to influence governments and even conflicts of interest within the public health community delayed action for more than a generation, with consequent loss of life and enormous extra health care costs to society. New standards are warranted now, based on the totality of scientific evidence; the risks of taking no-action, the large population at risk, costs associated with ignoring the problem in new and upgraded site selection and construction, and the loss of public trust by ignoring the problem.

Direct medical and rehabilitative health costs associated with treatment for diseases that are reasonably related to wireless technologies may be very large. Although there is uncertainty involved in how much disease is related to wireless exposures, the mere scale of the problem with several billion users of cell phones and even larger impacts on bystander populations (from cell site exposures, from other WI-FI and wireless exposures in-home and commercial use, etc.) the associated public health costs will likely be monumental. Furthermore the costs to families with cancers, neurological diseases or learning disabilities in children related in part or in whole to wireless technologies extend beyond medical costs. They may reasonably extend to family disruption and family psychological problems, losses in job productivity and income loss.

The history of governments and their official health agencies to deal with emerging and newly identified risks to health is not good [147–149]. This is particularly true where industry investments in new products and technologies occur without full recognition, disclosure or even knowledge of possible health consequences. Large economic investments in polluting industries often make for perilously slow regulatory action, and the public health consequences may be very great as a result [150,151].

Free markets do not internalize the costs to society of "guessing wrong". Unexpected or hidden health costs of new technologies may not be seen for many years, when the ability to recall or to identify the precise exposures related to disease outcomes is difficult or impossible. The penalty nearly always falls to the individual, the family or the taxpayer and not to the industry that benefits economically—at least in free-market economies. Thus, the profits go to industry but the costs may go to the individual who can suffer both diminished quality of life and health and economic disadvantage. If all disease endpoints that may be reasonably related to chronic exposure to electromagnetic fields are considered even a small attributable fraction for one or more industries, it will have enormous global impact on public health. The public health implications are immense. But they can be reduced by strong government and public health interventions providing information on alternatives to wireless technologies, public education campaigns, health advisories, requirements for redesign of wireless devices, proscription of use of wireless devices by children and teenagers, strong and independent research programs on causes and prevention of EMF-related diseases, and consultation with all stakeholders on issues relating to involuntary exposures (bystander or second-hand radiation exposures from wireless technologies) (Table 1).

Table 1
Public health implications of wireless technologies argue for change in governmental and health agency actions.

Secure US and EU legislative mandates for safer technologies for communication and data transmission, for security and surveillance needs.
Promote wired alternatives for voice and data communication (cable, fiber-optic)
Discourage or ban use of cell phones by children and young teen-agers
Provide permanent (unremovable) labels on cell phones "Not for use by children under the age of 16"
Implement national public education campaigns on health issues (cell phones, cordless phones, PDAs, wireless internet, city-wide WI-FI, WLAN and WiMAX exposures
Promote industry redesign for safer products: support innovation for alternatives and solutions
Slow or stop deployment of wireless technologies to discourage reliance on wireless technologies for communication and security needs
Put the burden of proof on industry to show "new wireless tech" is safe before deployment
Adopt and enforce restricted use areas for sensitive or more vulnerable segments of society including low-EMF environments in public areas and "No Cell" zones in airports, hospitals, schools
Acknowledge FCC and ICNIRP thermal safety standards are obsolete for wireless technologies
Appoint new standard-setting bodies familiar with biological effects to develop new guidelines for public safety limits.
Develop new biologically based standards that address low-intensity, chronic exposures
Require standard of evidence and level of proof = public health
Reject "causal" standard of evidence for taking action on science
Make industry financially liable for "guessing wrong" and ignoring health risks

The scientific information contained in this Supplement argues for thresholds or guidelines that are substantially below current FCC and ICNIRP standards for localized exposures to wireless devices and for whole-body exposure. Uncertainty about how low such standards might have to go to be prudent from a public health standpoint should not prevent reasonable efforts to respond to the information at hand. No lower limit for bioeffects and adverse health effects from RF has been established, so the possible health risks of wireless WLAN and WI-FI systems, for example, will require further research. No assertion of safety at any level of wireless exposure (chronic exposure) can be made at this time. The lower limit for reported human health effects has dropped 100-fold below the safety standard (for mobile phones and PDAs); 1000–10,000-fold for other wireless (cell towers at distance; WI-FI and WLAN devices). The entire basis for safety standards is called into question, and it is not unreasonable to question the safety of RF at any level.

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It is likely that for both ELF and RF, as for other carcinogens, there is no threshold of exposure that is without risk, but the magnitude of the risk increases linearly with the level of exposure. Our society will not go back to the pre-electric and pre-wireless age, but the clear evidence of health hazards to the human population from exposure mandates that we develop ways in which to reduce exposure through education, new technologies and the establishment of biomedically based standards.

7. Conclusions and recommended actions

New ELF limits are warranted based on a public health analysis of the overall existing scientific evidence. These limits should reflect environmental levels of ELF that have been demonstrated to increase risk for childhood leukemia, and possibly other cancers and neurological diseases. ELF limits should be set below those exposure levels that have been linked in childhood leukemia studies to increased risk of disease, plus an additional safety factor. It is no longer acceptable to build new power lines and electrical facilities that place people in ELF environments that have been determined to be risky. These levels are in the 2–4 milligauss (mG) range (0.2–0.4 □T), not in the 10 s of mG or 100 s of mG. The existing ICNIRP limit is 1000 mG (100 □T) and 904 mG (90.4 □T) in the US for ELF is outdated and based on faulty assumptions. These limits are can no longer be said to be protective of public health and they should be replaced. A safety buffer or safety factor should also be applied to a new, biologically based ELF limit, and the conventional approach is to add a safety factor lower than the risk level.

While new ELF limits are being developed and implemented, a reasonable approach would be a 1 mG (0.1 □T) planning limit for habitable space adjacent to all new or upgraded power lines and a 2 mG (0.2 □T) limit for all other new construction. It is also recommended that a 1 mG (0.1 □T) limit be established for existing habitable space for children and/or women who are pregnant (because of the possible link between childhood leukemia and in utero exposure to ELF). This recommendation is based on the assumption that a higher burden of protection is required for children who cannot protect themselves, and who are at risk for childhood leukemia at rates that are traditionally high enough to trigger regulatory action. This situation in particular warrants extending the 1 mG (0.1 □T) limit to existing occupied space. "Establish" in this case probably means formal public advisories from relevant health agencies. While it is not realistic to reconstruct all existing electrical distribution systems, in the short-term; steps to reduce exposure from these existing systems need to be initiated, especially in places where children spend time, and should be encouraged. These limits should reflect the exposures that are commonly associated with increased risk of childhood leukemia (in the 2–5 mG (0.2–0.5 □T) range for all children, and over 1.4 mG (0.14 □T) for children age 6 and younger). Nearly all of the occupational studies for adult cancers and neurological diseases report their highest exposure category is 4 mG (0.4 □T) and above, so that new ELF limits should target the exposure ranges of interest, and not necessarily higher ranges.

Avoiding chronic ELF exposure in schools, homes and the workplace above levels associated with increased risk of disease will also avoid most of the possible bioactive parameters of ELF discussed in the relevant literature.

It is not prudent public health policy to wait any longer to adopt new public safety limits for ELF. These limits should reflect the exposures that are commonly associated with increased risk of childhood leukemia (in the 2–5 mG (0.2–0.5 □T) range for all children, and over 1.4 mG (0.14 □T) for children age 6 and younger). Avoiding chronic ELF exposure in schools, homes and the workplace above levels associated with increased risk of disease will also avoid most of the possible bioactive parameters of ELF discussed in the relevant literature.

The rapid deployment of new wireless technologies that chronically expose people to pulsed RF at levels reported to cause bioeffects, which in turn, could reasonably be presumed to lead to serious health impacts, is a public health concern. There is suggestive to strongly suggestive evidence that RF exposures may cause changes in cell membrane function, cell communication, metabolism, activation of proto-oncogenes and can trigger the production of stress proteins at exposure levels below current regulatory limits. Resulting effects can include DNA breaks and chromosome aberrations, cell death including death of brain neurons, increased free-radical production, activation of the endogenous opioid system, cell stress and premature aging, changes in brain function including memory loss, retarded learning, performance impairment in children, headaches and fatigue, sleep disorders, neurodegenerative conditions, reduction in melatonin secretion and cancers (BioInitiative Report Chapters 5–10, 12) [1].

This information now argues for thresholds or guidelines that are substantially below current FCC and ICNIPR standards for whole-body exposure. Uncertainty about how low such standards might have to go to be prudent from a public health standpoint should not prevent reasonable efforts to respond to the information at hand. No lower limit for bioeffects and adverse health effects from RF has been established, so the possible health risks of wireless WLAN and WI-FI systems, for example, will require further research and no assertion of safety at any level of wireless exposure (chronic exposure) can be made at this time. The lower limit for reported human health effects has dropped 100-fold below the safety standard (for mobile phones and PDAs): 1000–10,000-fold for other wireless (cell towers at distance; WI-FI and WLAN devices). The entire basis for safety standards is called into question, and it is not unreasonable to question the safety of RF at any level.

A cautionary target level for pulsed RF exposures for ambient wireless that could be applied to RF sources from cell tower antennas, WI-FI, WI-MAX and other similar sources

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is proposed. The recommended cautionary target level is 0.1 microwatts per centimeter squared ($\mu W/cm^2$) (or 0.614 V per meter or V/m) for pulsed RF where these exposures affect the general public; this advisory is proportionate to the evidence and in accord with prudent public health policy. A precautionary limit of 0.1 $\mu W/cm^2$ should be adopted for outdoor, cumulative RF exposure. This reflects the current RF science and prudent public health response that would reasonably be set for pulsed RF (ambient) exposures where people live, work and go to school. This level of RF is experienced as whole-body exposure, and can be a chronic exposure where there is wireless coverage present for voice and data transmission for cell phones, pagers and PDAs and other sources of radiofrequency radiation. An outdoor precautionary limit of 0.1 $\mu W/cm^2$ would mean an even lower exposure level inside buildings, perhaps as low as 0.01 $\mu W/cm^2$. Some studies and many anecdotal reports on ill health have been reported at lower levels than this; however, for the present time, it could prevent some of the most disproportionate burdens placed on the public nearest to such installations. Although this RF target level does not preclude further rollout of WI-FI technologies, we also recommend that wired alternatives to WI-FI be implemented, particularly in schools and libraries so that children are not subjected to elevated RF levels until more is understood about possible health impacts. This recommendation should be seen as an interim precautionary limit that is intended to guide preventative actions; and more conservative limits may be needed in the future.

Broadcast facilities that chronically expose nearby residents to elevated RF levels from AM, FM and television antenna transmission are also of public health concern given the potential for very high RF exposures near these facilities (antenna farms). RF levels can be in the 10 s to several 100 s of $\mu W/cm^2$ in residential areas within half a mile of some broadcast sites (for example, Lookout Mountain, Colorado and Awbrey Butte, Bend, Oregon). Like wireless communication facilities, RF emissions from broadcast facilities that are

elevated levels of RF will very likely need to be re-evaluated for safety.

For emissions from wireless devices (cell phones, personal digital assistant or PDA devices, etc.) there is enough evidence for increased risk of brain tumors and acoustic neuromas now to warrant intervention with respect to their use. Redesign of cell phones and PDAs could prevent direct head and eye exposure, for example, by designing new units so

mode.

These effects can reasonably be presumed to result in adverse health effects and disease with chronic and uncontrolled exposures, and children may be particularly vulnerable. The young are also largely unable to remove themselves from such environments. Second-hand radiation, like second-hand smoke is an issue of public health concern based on the evidence at hand.

In summary, the following recommendations are made:

- ELF limits should be set below those exposure levels that have been linked in childhood leukemia studies to increased risk of disease, plus an additional safety factor. It is no longer acceptable to build new power lines and electrical facilities that place people in ELF environments that have been determined to be risky (at levels generally at 2 mG (0.2 μT) and above).
- While new ELF limits are being developed and implemented, a reasonable approach would be a 1 mG (0.1 μT) planning limit for habitable space adjacent to all new or upgraded power lines and a 2 mG (0.2 μT) limit for all other new construction. It is also recommended for that a 1 mG (0.1 μT) limit be established for existing habitable space for children and/or women who are pregnant. This recommendation is based on the assumption that a higher burden of protection is required for children who cannot protect themselves, and who are at risk for childhood leukemia at rates that are traditionally high enough to trigger regulatory action. This situation in particular warrants extending the 1 mG (0.1 μT) limit to existing occupied space. "Establish" in this case probably means formal public advisories from relevant health agencies.
- While it is not realistic to reconstruct all existing electrical distributions systems, in the short-term; steps to reduce exposure from these existing systems need to be initiated and should be encouraged, especially in places where children spend time.
- A precautionary limit of 0.1 $\mu W/cm^2$ (which is also 0.614 V per meter) should be adopted for outdoor, cumulative RF exposure. This reflects the current RF science and prudent public health response that would reasonably be set for pulsed RF (ambient) exposures where people live, work and go to school. This level of RF is experienced as whole-body exposure, and can be a chronic exposure where there is wireless coverage present for voice and data transmission for cell phones, pagers and PDAs and other sources of radiofrequency radiation. Some studies

at lower levels than this; however, for the present time, it could prevent some of the most disproportionate burdens placed on the public nearest to such installations. Although this RF target level does not preclude further rollout of WI-FI technologies, we also recommend that wired alternatives to WI-FI be implemented, particularly in schools and libraries so that children are not subjected to elevated RF levels until more is understood about pos-

as an interim precautionary limit that is intended to guide preventative actions; and more conservative limits may be needed in the future.

References

[1] C. Sage, D.O. Carpenter (Eds.), BioInitiative Working Group BioInitiative Report: A Rationale for a Biologically-based Public

Please cite this article in press as: C. Sage, D.O. Carpenter, Public health implications of wireless technologies, Pathophysiology (2009), doi:10.1016/j.pathophys.2009.01.011

Exposure Standard for Electromagnetic Fields (ELF and RF), 2007. http://www.bioinitiative.org.

[2] REFLEX Program. Risk evaluation of potential environmental hazards from low frequency electromagnetic field exposure using sensitive in vitro methods. A project funded by the European Union under the programme Quality of Life and Management of Living Resources, Key Action 4 (2004).

[3] L. Hardell, C. Sage, Biological effect from electromagnetic field exposure and public exposure standards, Biomed. Pharmacother. 62 (2008) 104–109, doi:10.1016/j.biopha.(2007)12.004.

[4] L. Hardell, M. Carlberg, F. Söderqvist, K. Hansson Mild, Meta-analysis of long-term mobile phone use and the association with brain tumours, Int. J. Oncol. 32 (2008) 1097–1103.

[5] P. Kan, S.E. Simonsen, J.L. Lyon, J.R.W. Kestle, Cellular phone use and brain tumor: a meta-analysis, J. Neurooncol. (2007), doi:10.1007/s11060-007-9432-1.

[6] E. Cardis, Interphone Study Memo, International Agency for Cancer Research, October 2008.

[7] S. Saderzki, A. Chetrit, A. Jarus-Hakak, E. Cardis, Y. Deutch, S. Dvendevani, A. Zultan, I. Novikov, L. Freedman, M. Wolf, Cellular phone use and risk of benign and malignant parotid gland tumors—a nationwide case–control study, Am. J. Epidemiol. (2008), doi:10.1093/aje/kwm325.

[8] A. Lahkola, T. Salminen, J. Raitanen, S. Heinavaara, M.J. Schoemaker, H.C. Christensen, M. Feychting, C. Johansen, L. Klaeboe, S. Lonn, A.J. Swerdlow, T. Tynes, A. Auvinen, Meningioma and mobile phone use—a collaborative case–control study in five North European countries, Int. J. Epidemiol. Adv. Access (August) (2008), doi:*10.1093/ije/dyn155*.

[9] T. Takebayashi, S. Akiba, Y. Kikuchi, et al., Mobile phone use and acoustic neuroma risk in Japan, Occup. Environ. Med. 63 (2007) 802–807.

[10] D.O. Carpenter, C.L. Sage, Setting prudent public health policy for electromagnetic field exposures, Rev. Environ. Health 23 (2) (2008) 91–117.

[11] *D.O. Carpenter, C.L. Sage, BioInitiative Working Group, Key scientific* evidence and public health policy options, BioInitiative Report at http://www.bioinitiative.org, 17 (2007).

[12] European Commission, Health and Consumer Protection, Scientific Committee on SCENIHR Report on Emerging and Newly Identified Health Risks—Possible Effects of Electromagnetic Fields (EMF) on Human Health, 2007.

[13] World Health Organization, Extremely Low Frequency Fields Environmental Health Criteria Monograph 238, 2007. http://www.who.int/peh-emf/project/en and http://www.who.int/peh-emf/meetings/elf_emf_workshop_2007/en/index.html.

[14] http://news.cnet.com/Emerging-markets-fuel-cell-phone-growth/2100-1039_3-6159491.html.

[15] http://news.softpedia.com/news/2-14-billion-cell-phone-subscribers-in-2005-2120.shtml.

[16] http://www.ctia.org/media/industry_info/index.cfm/AID/10323.

[17] http://www.nytimes.com/2008/09/20/us/20messaging.html and Members Info. Electronics Industries Alliance Website, November, 2000.;
Members Info. Electronics Industries Alliance Website, November 2000.

[18] L. Hardell, M. Carlberg, K. Hansson Mild, Pooled analysis of two case–control studies on use of cellular and cordless telephones and the risk for malignant brain tumours diagnosed in 1997–2003, Int. Arch. Environ. Health 79 (2006) 630–639, doi:10.1007/s00420-006-0088-5.

[19] M. Kundi, The controversy about a possible relationship between mobile phone use and cancer, Environ. Health Persp. (September) (2008), doi: 101289/ehp.11902.

[20] J. Pronczuk-Garbino (Ed.), Children's Health and the Environment: A Global Perspective, World Health Organization, Geneva, Switzerland, 2005, p. 367.

[21] World Health Organization, Children's Health and Environment: A Review of Evidence: A Joint Report from the European Environmental Agency and The World Health Organization, 2002. http://www.who.int/peh-emf.

[22] O.P. Gandhi, G. Lazzi, C.M. Furse, Electromagnetic absorption in the human head and neck for mobile telephones at 835 and 1900 MHz, IEE Trans. Microw. Theory Tech. 44 (1996) 1884–1896.

[23] O.P. Gandhi, G. Kang, Some present problems and a proposed experimental phantom for SAR compliance testing of cellular telephones at 835 and 1900 MHz, Phys. Med. Biol. 47 (2002) 1501–1518.

[24] J. Wiart, A. Hadjem, M.F. Wong, I. Bloch, Analysis of RF exposure in the head tissues of children and adults, Phys. Med. Biol. 53 (2008) 3681–3695;
J. Wiatt, A. Hadjem, M.F. Wong, I. Bloch, Analysis of RF exposure in the head tissues of children and adults, Wiatt Phys. Med. Biol. 53 (June) (2008) 2771–2783.

[25] H.A. Divan, L. Kheifets, C. Obel, J. Olsen, Prenatal and postnatal exposure to cell phone use and behavioral problems in children, Epidemiology 19 (4) (2008).

[26] International Commission on Non-ionizing Radiation Protection, Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 GHz), *Health Phys. 74(4) (1998)* 494–522. http://www.icnirp.de.

[27] Institute of Electrical and Electronics Engineers, Inc (IEEE), Section 4.2 of "IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz," ANSI/IEEE C95.1-1992, New York, NY, 1992.

[28] H. Lai, N.P. Singh, Single and double strand DNA breaks in rat *brain cells after acute exposure to radiofrequency electromagnetic* radiation, Int. J. Radiat. Biol. 69 (1996) 513–521.

[29] S. Ivancsits, A. Pilger, E. Diem, O. Jahn, H.W. Rudinger, Cell type-specific genotoxic effects of intermittent extremely-low frequency electromagnetic fields, Mutat. Res. 583 (2005) 184–188.

[30] J. Phillips, et al., DNA damage in molt-4 lymphoblastoid cells exposed to cellular telephone radiofrequency fields in vitro, Bioelectrochem. Bioenerg. 45 (1998) 103–110.

[31] R.J. Aitken, L.E. Bennetts, D. Sawyer, A.M. Wiklendt, B.V. King, Impact of radio frequency electromagnetic radiation on DNA integrity in the male germline, Int. J. Androl. 28 (2005) 171.

[32] J.Y. Kim, S.Y. Hong, Y.M. Lee, S.A. Yu, W.S. Koh, J.R. Hong, T. Son, S.K. Chang, M. Lee, In vitro assessment of clastogenicity of mobile-phone radiation (835 MHz) using the alkaline comet assay and chromosomal aberration test, Environ. Toxicol. 23 (2008) 319.

[33] S. Lixia, K. Yao, W. Kaijun, I. Deglang, H. Huajun, G. Xiangwei, W. Baohong, Z. Wei, L. Jianling, W. Wei, Effects of 1.8 GHz radiofrequency field on DNA damage and expression of heat shock protein 70 in human lens epithelial cells, Mutat. Res. 602 (2006) 135.

[34] R. Paulraj, J. Behari, Single strand DNA breaks in rat brain cells exposed to microwave radiation, Mutat. Res. 596 (2006) 76.

[35] M. Mashevich, D. Folkman, A. Kesar, A. Barbul, R. Korenstein, E. Jerby, L. Avivi, Exposure of human peripheral blood lymphocytes to electromagnetic fields associated with cellular phones leads to chromosomal instability, Bioelectromagnetics 24 (2003) 82.

[36] I.G. Akoev, M.S. Pashovkina, L.P. Dolgacheva, T.P. Semenova, V.L. Kalmykov, Enzymatic activity of some tissues and blood serum from animals and humans exposed to microwaves and hypothesis on the possible role of free radical processes in the nonlinear effects and modification of emotional behavior of animals, Radiat. Biol. Radioecol. 42 (3) (2002) 32–330.

[37] C. Blackman, et al., The influence of 1.2 μT, 60 Hz magnetic fields on melatonin and tamoxifen-induced inhibition of MCF-7 cell growth, Bioelectromagnetics 22 (2) (2001) 122–128.

[38] D.E. Blask, S.M. Hill, Effects of melatonin on cancer: studies on MCF-7 human breast cancer cells in culture, J. Neural Transm. Suppl. 21 (1986) 433–449.

Please cite this article in press as: C. Sage, D.O. Carpenter, Public health implications of wireless technologies, Pathophysiology (2009), doi:10.1016/j.pathophys.2009.01.011

[39] J.B. Burch, J.S. Reif, C.W. Noonan, T. Ichinose, A.M. Bachand, T.L. Koteles, M.G. Yost, Melatonin metabolite excretion among cellular telephone users, Int. J. Rad. Biol. 78 (2002) 1029–1036.

[40] Girgert, et al., Induction of tamoxifen resistance in breast cancer cells by ELF electromagnetic fields, Biochem. Biophys. Res. Commun. 336 (2005) 1144–1149.

[41] Harland, et al., Environmental magnetic fields inhibit the antiproliferative action of tamoxifen and melatonin in a human breast cancer cell line, Bioelectromagnetics 18 (1997) 555–562.

[42] Harland, et al., Evidence for a slow time-scale of interaction for magnetic fields inhibiting tamoxifen's antiproliferative action in human breast cancer cells, Cell Biochem. Biophys. 31 (3) (1999) 295–306.

[43] A. Ilhan, A. Gurel, F. Armutcu, S. Kamisli, M. Iraz, O. Akyol, S. Ozen, Ginkgo biloba prevents mobile phone-induced oxidative stress in rat brain, Clin. Chim. Acta 340 (1–2) (2004) 153–162.

[44] Ishido, et al., Magnetic fields (MF) of 50 Hz at 1.2 μT as well as 100 μT cause uncoupling of inhibitory pathways of adenylyl cyclase *mediated by melatonin 1a receptor in MF-sensitive MCF-7 cells*, Carcinogenesis 22 (7) (2001) 1043–1048.

[45] H. Koylu, H. Mollaoglu, F.N. Ozguner, Melatonin modulates 900 Mhz microwave-induced lipid peroxidation changes in rat brain, Toxicol. Ind. Health 22 (5) (2006) 211–216.

[46] R.P. Liburdy, T.R. Sloma, et al., ELF magnetic fields, breast cancer, and melatonin: 60 Hz fields block melatonin's oncostatic action on ER+ breast cancer cell proliferation, J. Pineal Res. 14 (1993) 89–97.

[47] R.P. Liburdy, et al., Magnetic Fields, melatonin, tamoxifen and human breast cancer cell growth, in: R.G. Stevens, B.W. Wilson, L.E. Anderson (Eds.), The Melatonin Hypothesis—Breast Cancer and Use of Electric Power, Battelle Press, Columbus, Richland, 1997, pp. 669–700.

[48] L.I. Loberg, Gene expression in human breast epithelial cells exposed to 60 Hz magnetic fields, Carcinogenesis 20 (1999) 1633–1636.

[49] Luben, et al., Replication of 12 mG EMF effects on melatonin responses of MCF-7 breast cancer cells in vitro, in: Abstract A-1 of the 1996 Annual Review of Research on Biological Effects of Electric and Magnetic Fields from the Generation, Delivery and Use of Electricity, San Antonio, TX, November 17–21, 1996, p. 1.

[50] Luben, et al., Independent replication of 60-Hz 1.2 μT EMF effects on melatonin and tamoxifen responses of MCF-7 cells in vitro, in: Abstract A-3.4, Bioelectromagnetics Society Annual Meeting, St. Pete Beach, FL, June 7–11, 1998, pp. 17–18.

[51] Morris, In vitro exposure of MCF-7 human breast cancer cells to 60-Hz magnetic fields, in: Abstract p-125A, Bioelectromagnetics Society Annual Meeting, St. Pete Beach, FL, June 7–11, 1998, pp. 204–205.

[52] F. Oktem, F. Ozguner, H. Mollaoglu, A. Koyu, E. Uz, Oxidative damage in the kidney induced by 900-MHz-emitted mobile phone: protection by melatonin, Arch. Med. Res. 36 (4) (2005) 350–355.

[53] F. Ozguner, G. Aydin, H. Mollaoglu, O. Gokalp, A. Koyu, G. Cesur, Prevention of mobile phone induced skin tissue changes by melatonin in rat: an experimental study, Toxicol. Ind. Health 20 (6–10) (2004) 133–139.

[54] F. Ozguner, A. Altinbas, M. Ozaydin, A. Dogan, H. Vural, A.N. Kisioglu, G. Cesur, N.G. Yildirim, Mobile phone-induced myocardial oxidative stress: protection by a novel antioxidant agent caffeic acid phenethyl ester, Toxicol. Ind. Health 21 (9) (2005) 223–230.

[55] A.W. Guy, C.K. Chou, L.L. Kunz, J. Crowley, J. Krupp, Effects of long-term low-level radiofrequency radiation exposure on rats, US Air Force School of Aerospace Medicine Brooks Air Force Base, Texas TR-85-64 Final Report August 1985, Approved for public release: distribution is unlimited.

[56] C.K. Chou, Long-term low level microwave irradiation of rats, Bioelectromagnetics 13 (1992) 469–496.

[57] H. Dolk, et al., Cancer incidence near radio and television transmitters in Great Britain, Am. J. Epidemiol. 145 (1) (1997) 1–9.

[58] V. Garaj-Vrhovac, D. Horvat, Z. Koren, The relationship between colony-forming ability, chromosome aberrations and incidence of micronuclei in V79 Chinese hamster cells exposed to microwave radiation, Mutat. Res. 263 (3) (1991) 143–149.

[59] V. Garaj-Vrhovac, A. Fucic, D. Horvat, The correlation between the frequency of micronuclei and specific chromosome aberrations in human lymphocytes exposed to microwave radiation in vitro, Mutat. Res. 281 (3) (1992) 181–186.

[60] V. Garaj-Vrhovac, Micronucleus assay and lymphocyte mitotic activity in risk assessment of occupational exposure to microwave radiation, Chemosphere 39 (13) (1999) 2301–2312.

[61] M. Ha, H. Im, M. Lee, H.J. Kim, B.C. Kim, Y.M. Gimm, et al., Radio-frequency radiation exposure from AM radio transmitters and childhood leukemia and brain cancer, Am. J. Epidemiol. 166 (2007) 270–279.

[62] B. Hocking, et al., Cancer incidence and mortality and proximity to TV towers, Med. J. Aust. 165 (11–12) (1996) 601–605.

[63] B. Hocking, Decreased survival for childhood leukemia in proximity to TV towers, in: Poster Presented at the Annual Scientific Meeting of *the Royal Australian College of Physicians in Adelaide, SA, Australia*, May, 2000.

[64] D.E. Foliart, B.H. Pollock, G. Mezei, R. Iriye, J.M. Silva, K.L. Epi, L. Kheifets, M.P. Lind, R. Kavet, Magnetic field exposure and long-term survival among children with leukemia, Brit. J. Cancer 94 (2006) 161–164.

[65] A. Huss, A. Spoerri, M. Egger, Röösli for the Swiss national cohort study, residence near power lines and mortality from neurodegenerative diseases: longitudinal study of the Swiss population, Am. J. Epidemiol. (November) (2008) (Epub ahead of print).

[66] F. Marinelli, D. La Sala, G. Cicciotti, L. Cattini, C. Trimarchi, S. Putti, A. Zamparelli, L. Giuliani, G. Tomassetti, C. Cinti, Exposure to 900 MHz electromagnetic field induces an unbalance between pro-apoptotic and pro-survival signals in T-lymphoblastoid leukemia CCRF-CEM cells, J. Cell Physiol. 198 (2) (2004) 324–332.

[67] P. Michelozzi, C. Ancona, D. Fusco, F. Forastiere, C.A. Perucci, Risk of leukemia and residence near a radio transmitter in Italy, Epidemiology 9 (Suppl.) (1998) 354.

[68] M. Repacholi, et al., Lymphomas in Eμ-Pim1 transgenic mice exposed to pulsed 900 MHz electromagnetic fields, Radiat. Res. 147 (1997) 31–40.

[69] A. Stang, et al., The possible role of radiofrequency radiation in the development of uveal melanoma, Epidemiology 12 (1) (2001) 7–12.

[70] M. Blank (2007). Section 7, pp. 1–40. Evidence for Stress Response (Stress Proteins). In BioInitiative Report: A Scientific Perspective on Health Risk of Electromagnetic Fields. Published Online 31 August 2007, http://www.bioinitiative.org/report/index.htm.

[71] C. Daniells, I. Duce, D. Thomas, P. Sewell, J. Tattersall, D. de Pomerai, Transgenic nematodes as biomonitors of microwave-induced stress, Mutat. Res. 399 (1998) 55–64.

[72] D. de Pomerai, et al., Non-thermal heat-shock response to microwaves, Nature 405 (2000) 417–418.

[73] S. Kwee, et al., The biological effects of microwave radiation, in: Proceedings of the Second World Congress for Electricity and Magnetism in Biology and Medicine, Bologna, Italy, June, 1997.

[74] S. Kwee, et al., Changes in cellular proteins due to environmental non-ionizing radiation, I. Heat-shock proteins, Electro Magnetobiol. 20 (2001) 141–152.

[75] D. Leszczynski, S. Oenväärä, J. Reivinen, R. Kuokka, Non-thermal activation of the hsp27/p38MAPK stress pathway by mobile phone radiation in human endothelial cells: molecular mechanism for cancer- and blood–brain barrier-related effects, Differentiation 70 (2002) 120–129.

[76] D. Leszczynski, R. Nylund, S. Joenvaara, J. Reivinen, Applicability of discovery science approach to determine biological effects of mobile phone radiation, Proteomics 4 (2) (2004) 426–431.

[77] S. Lixia, Y. Ke, W. Kaijun, L. Dequiang, H. Huajun, G. Xiangwei, W. Baohong, Z. Wei, L. Jianling, W. Wei, Effects of 1.8 GHz

Please cite this article in press as: C. Sage, D.O. Carpenter, Public health implications of wireless technologies, Pathophysiology (2009), doi:10.1016/j.pathophys.2009.01.011

radiofrequency field on DNA damage and expression of heat shock protein 70 in human lens epithelial cells, Mutat. Res. (2006), doi:10.1016/j.mrfmmm.2006.08.010.

[78] M. Simko, C. Hartwig, M. Lantow, M. Lupke, M.O. Mattsson, Q. Rahman, J. Rollwitz, Hsp 70 expression and free radical release after exposure to non-thermal radiofrequency electromagnetic fields and ultrafine particles in human Mono Mac 6 cells, Toxicol. Lett. 161 (2006) 73–82 (Elsevier Science Direct).

[79] S. Velizarov, The effects of radiofrequency fields on cell proliferation are non-thermal, Bioelectrochem. Bioenerg. 48 (1999) 177–180.

[80] D. Weisbrot, H. Lin, L. Ye, M. Blank, R. Goodman, Effects of mobile phone radiation on reproduction and development in *Drosophila melanogaster*, J. Cell Biochem. 89 (1) (2003) 48–55.

[81] T. Olivares-Banuelos, L. Navarro, A. Gonzalez, R. Drucker-Colin, Differentiation of chromaffin cells elicited by ELF MF modifies gene expression pattern, Cell Biol. Int. 28 (2004) 273–279.

[82] R. Zhao, S. Zhang, Z. Xu, L. Ju, D. Lu, G. Yao, Studying gene expression profile of rat neuron exposed to 1800 MHz radiofrequency electromagnetic fields with cDNA microassay, Toxicology 235 (2007) 167–175.

[83] A. Karinen, S. Heinavaara, R. Nylund, D. Leszczynski, Mobile phone radiation might alter protein expression in human skin, BMC Genomics 9 (2008) 77, doi:10.1186/1471-2164-9-77.

[84] J. Vanderstraeten, L. Verschaeve, Gene and protein expression following exposure to radiofrequency fields from mobile phones, Environ. Health Persp. 116 (2008) 1131–1135.

[85] G. Abdel-Rassoul, O.A. El-Fateh, M.A. Salem, A. Michael, F. Farahat, M. El-Batanouny, E. Salem, Neurobehavioral effects among inhabitants around mobile phone base stations, Neurotoxicology 28 (2007) 434–440.

[86] P. Achermann, Exposure to pulsed high-frequency electromagnetic field during waking affects human sleep EEG, Neuroreport 11 (15) (2000) 3321–3325.

[87] E.S. Altpeter, T.H. Krebs, Study on health effects of the shortwave transmitter station of Schwarzenburg, Bern, Switzerland, University of Bern BEW Publications Study No. 56, The Federal Office of Energy, 1995.

[88] A.A. Borbely, et al., Pulsed high-frequency electromagnetic field affects human sleep and sleep electroencephalogram, Neurosci. Lett. 275 (3) (1999) 207–210.

[89] R. Huber, T. Graf, K.A. Cote, L. Wittmann, E. Gallmann, D. Matter, J. Schuderer, N. Kuster, A.A. Borbely, P. Achermann, Exposure to pulsed high-frequency electromagnetic field during waking affects human sleep EEG, Neuroreport 11 (15) (2000) 3321–3325.

[90] K. Mann, Effects of pulsed high-frequency electromagnetic fields on human sleep, Neuropsychobiology 33 (1996) 41–47.

[91] G. Oberfeld, The microwave syndrome—further aspects of a Spanish study, in: Proceedings of the Third International Workshop on Bioelectromagnetic Effects of Electromagnetic Fields, Kos, Greece, 2004.

[92] R. Santini, M. Seigne, L. Bonhomme-Faivre, S. Bouffet, E. Defrasne, M. Sage, Symptoms experienced by users of digital cellular phones: a pilot study in a French engineering school, Pathol. Biol. (Paris) 49 (3) (2001) 222–226.

[93] R. Santini, P. Santini, P. Le Ruz, J.M. Danze, M. Seigne, Survey study of people living in the vicinity of cellular phone base stations, Electromag. Biol. Med. 22 (2003) 41–49.

[94] TNO Physics and Electronics Laboratory, The Netherlands, Effects of Global Communication System Radio-frequency Fields on Well-being and Cognitive Functions of Human Beings With and Without Subjective Complaints, Netherlands Organization for Applied Scientific Research (2003), pp. 1–63.

[95] E.S. Altpeter, T.H. Krebs, Study on health effects of the shortwave transmitter station of Schwarzenburg, Bern, Switzerland, University of Bern BEW Publications Study No. 56, The Federal Office of Energy, Switzerland, 1995.

[96] S.E. Chia, Prevalence of headache among handheld cellular telephone users in Singapore: a community study, Environ. Health Persp. 108 (11) (2000) 1059–1062.

[97] H. Chiang, et al., Health effects of environmental electromagnetic fields, J. Bioelectr. 8 (1989) 127–131.

[98] B. D'Costa, et al., Human brain wave activity during exposure to radiofrequency field emissions from mobile phones, Aust. Phys. Eng. Sci. Med. 26 (4) (2003).

[99] H.P. Hutter, H. Moshammer, P. Wallner, M. Kundi, Subjective symptoms, sleeping problems and cognitive performance in subjects living near mobile phone base stations, Occup. Env. Med. 63 (2006) 307–313.

[100] M. Koivisto, et al., Effects of 902 MHz electromagnetic field emitted by cellular telephones on response times in humans, Neuroreport 11 (2000) 413–415.

[101] M. Koivisto, et al., The effects of electromagnetic field emitted by GSM phones on working memory, Neuroreport 11 (2002) 1641–1643.

[102] A.A. Kolodynski, V.V. Kolodynska, Motor and psychological functions of school children living in the area of the Skrunda radio location station in Latvia, Sci. Total Environ. 180 (1996) 87–93.

[103] C.M. Krause, L. Sillanmaki, M. Koivisto, A. Haggqvist, C. Saarela, A. Revonsuo, M. Laine, H. Hamalainen, Effects of electromagnetic field emitted by cellular phones on the EEG during a memory task, Neuroreport 11 (4) (2000) 761–764.

[104] C.M. Krause, L. Sillanmaki, M. Koivisto, A. Haggqvist, C. Saarela, A. Revonsuo, M. Laine, H. Hamalainen, Effects of electromagnetic fields emitted by cellular phones on the electroencephalogram during a visual working memory task, Int. J. Radiat. Biol. 76 (12) (2000) 1659–1667.

[105] J. Lass, et al., Effects of 7 Hz-modulated 450 MHz electromagnetic radiation on human performance in visual memory tasks, Int. J. Radiat. Biol. 73 (10) (2002) 937–944.

[106] A.A. Marino, E. Nilsen, C. Frilot, Nonlinear changes in brain electrical activity due to cell phone radiation, Bioelectromagnetics 24 (5) (2003) 339–346.

[107] G. Oberfeld, et al., The microwave syndrome—further aspects of a Spanish study, in: Proceedings of the Third International Workshop on Bioelectromagnetic Effects of Electromagnetic Fields, Kos, Greece, 2004.

[108] A. Preece, et al., Effect of a 915-MHz simulated mobile phone signal on e function in man, Int. J. Radiat. Biol. 75 (1999) 447–456.

[109] S.J. Regel, S. Negovetic, M. Roosli, V. Berdinas, J. Schuderer, A. Huss, U. Lott, N. Kuster, P. Achermann, UMTS base station-like exposure, well-being and cognitive performance, Environ. Health Persp. 114 (2006) 1270–1275.

[110] S. Eltiti, D. Wallace, A. Ridgewell, K. Zougkou, R. Russo, F. Sepulveda, D. Mirshekar-Syahkal, P. Rasor, R. Deeble, E. Fox, Does short-term exposure to mobile phone base station signals increase symptoms in individuals who report sensitivity to electromagnetic fields? A double-blind randomized provocation study, Environ. Health Persp. 115 (2007) 1603–1608.

[111] E.F. Pace-Schott, J.A. Hobson, The neurobiology of sleep: genetics, cellular physiology and subcortical networks, Nat. Rev. Neurosci. 3 (2002) 591–605.

[112] J.B. Burch, J.S. Reif, C.W. Noonan, T. Ichinose, A.M. Bachand, T.L. Koleber, M.G. Yost, Melatonin metabolite excretion among cellular telephone users, Int. J. Radiat. Biol. 78 (2002) 1029–1036.

[113] M.L. Clark, J.B. Burch, M.G. Yost, Y. Zhai, A.M. Bachand, C.T. Fitzpatrick, J. Ramaprasad, L.A. Cragin, J.S. Reif, Biomonitoring of estrogen and melatonin metabolites among women residing near radio and television broadcasting transmitters, J. Occup. Environ. Med. 49 (2007) 1149–1156.

[114] L.M. Wang, N.A. Suthana, D. Chaudhury, D.R. Weaver, C.S. Colwell, Melatonin inhibits hippocampal long-term potentiation, Eur. J. Neurosci. 22 (2005) 2231–2237.

Please cite this article in press as: C. Sage, D.O. Carpenter, Public health implications of wireless technologies, Pathophysiology (2009), doi:10.1016/j.pathophys.2009.01.011

[115] M. Ozcan, B. Yilmaz, D.O. Carpenter, Effects of melatonin on synaptic transmission and long term potentiation in two areas of mouse hippocampus, Brain Res. 1111 (2006) 90–94.
[116] R.J. Reiter, L. Tang, J.J. Garcia, A. Munoz-Hoyos, Pharmacological actions of melatonin in oxygen radical pathophysiology, Life Sci. 60 (1997) 2255–2271.
[117] C.W. Noonan, J.S. Reif, J.B. Burch, T.Y. Ichinose, M.G. Yost, K. Magnusson, Relationship between amyloid beta protein and melatonin metabolite in a study of electric utility workers, J. Occup. Environ. Med. 44 (2002) 769–775.
[118] L.G. Salford, A.E. Brun, et al., Nerve cell damage in mammalian brain after exposure to microwaves from GSM mobile phones, Environ. Health Persp. 111 (2003) 881–883.
[119] J.L. Eberhardt, B.R.R. Persson, A.E. Brun, L.G. Salford, L.O.G. Malmgren, Blood–brain barrier permeability and nerve cell damage in rat brain 14 and 28 days after exposure to microwaves from GSM mobile phones, Electromagn. Biol. Med. 27 (2008) 215–229. doi:10.1080_15363700802344037.
[120] L.G. Salford, et al., Permeability of the blood brain barrier induced by 915 MHz electromagnetic radiation continuous wave and modulated at 8, 16, 50 and 200 Hz, Microsc. Res. Tech. 27 (1994) 535–542.
[121] A. Schirmacher, Electromagnetic fields (1.8 GHz) increase the permeability of sucrose of the blood–brain barrier in vitro, Bioelectromagnetics 21 (2000) 338–345.
[122] Y. Hamnerius, Microwave exposure from mobile phones and base stations in Sweden, in: Proceedings of the International Conference on Cell Tower Siting, sponsored by the University of Vienna & Land-Salzburg, Salzburg, Austria, June 7–8, 2000.
[123] E.D. Mantiply, Summary of measured radiofrequency electric and magnetic fields (10 kHz–30 GHz) in the general and work environment, Bioelectromagnetics 18 (1997) 563–577.
[124] Sage Associates, 2004. An Overview of Low-intensity radiofrequency/microwave radiation studies relevant to wireless communications and data, Bioelectromagnetics Society Annual Meeting, Washington DC, June, 2004.
[125] C. Sage, O. Johansson, S.A. Sage, Personal digital assistant (PDA) cell phone units produce elevated extremely-low frequency electromagnetic field emissions, Bioelectromagnetics 28 (7) (2007) 581–582.
[126] C. Sage, O. Johansson, Response to comment on personal digital assistant (PDA) cell phone units produce elevated extremely-low frequency electromagnetic field emissions, Bioelectromagnetics (July) (2007), 17654541.
[127] C. Sage, O. Johansson, Response to comment on measuring ELF fields produced by mobile phones and personal digital assistants (PDAs), Bioelectromagnetics (July) (2007), 17654536.
[128] M. Tuor, S. Ebert, J. Schuderer, N. Kuster, Assessment of ELF magnetic fields from five mobile handsets, in: ITIS Foundation, Conference Presentation, Monte Verita, 2005.
[129] T. Linde, K.H. Mild, Measurement of low frequency magnetic fields from digital cellular telephones, Bioelectromagnetics 18 (1997) 184–186 (Brief communication).
[130] B. Armstrong, G. Theriault, P. Guenel, J. Deadman, M. Goldberg, P. Heroux, Association between exposure to pulsed electromagnetic fields and cancer in electrical utility workers in Ontario and Quebec, Canada, and France 1970–1989, Am. J. Epidemiol. 140 (1994) 805–820.
[131] G.M. Lee, R.R. Neutra, L. Hristova, M. Yost, R.A. Hiatt, A nested case-control study of residential and personal magnetic field measures and miscarriages, Epidemiology 13 (1) (2002) 21–31.
[132] K.D. Li, R. Oudouli, S. Wi, T. Janevic, I. Golditch, T.D. Bracken, R. Senior, R. Rankin, R. Iriye, A population-based prospective cohort study of personal exposure to magnetic fields during pregnancy and the risk of spontaneous abortion, Epidemiology 13 (2002) 9–20.
[133] G. Theriault, M. Goldberg, A.B. Miller, B. Armstrong, P. Guenel, J. Deadman, E. Imbernon, T. To, A. Chevalier, D. Cyr, C. Wall, Cancer risks associated with occupational exposure to magnetic fields among utility workers in Ontario and Quebec, Canada and France: 1970–1989, Am. J. Epidemiol. 139 (1994) 550–572.
[134] P. Michelozzi, A. Capon, U. Kirchmayer, F. Forastiere, A. Biggeri, A. Barca, C.A. Perucci, Adult and childhood leukemia near a high-power radio station in Rome, Italy, Am. J. Epidemiol. 155 (2002) 1096–1103.
[135] M. Ha, H. Im, M. Lee, H.J. Kim, B.C. Kim, Y.M. Gimm, J.K. Pack, Radio-frequency radiation exposure from AM radio transmitters and childhood leukemia and brain cancer, Am. J. Epidemiol. 166 (2007) 270–279.
[136] C. Sage, D.O. Carpenter (Eds.), BioInitiative Working Group BioInitiative Report: A Rationale for a Biologically-based Public Exposure Standard for Electromagnetic Fields (ELF and RF), 2007. www.bioinitiative.org.:
C. Blackman, H. Lai, Chapters 6 and 14 of the BioInitiative Report, 2007.
[137] A. Chiabrera, B. Bianco, E. Moggia, J.J. Kaufman, Bioelectromagnetics 21 (4) (2000) 312–324.
[138] D.J. Panagopoulos, L.H. Margaritis, in: A.C. Harper, R.V. Buress (Eds.), Mobile Telephony Radiation Effects on Living Organisms, 2008, pp. 107–149, ISBN 978:1-60456-436-5.
[139] W.R. Adey, in: P.J. Rosch, M.S. Markov (Eds.), Potential Therapeutic Applications of Nonthermal Electromagnetic Fields: Ensemble Organization of Cells in Tissue as a Factor in Biological Field Sensing, Bioelectromagnetic Medicine, 2004, pp. 1–16.
[140] S. Engstrom, in: P.J. Rosch, M.S. Markov (Eds.), Magnetic Field Generation and Dosimetry, Bioelectromagnetic Medicine, 2004, pp. 39–50.
[141] A. Pilla, in: F.S. Barnes, B. Greenebaum, (Eds.), Mechanisms and Therapeutic Applications of Time-varying and Static Magnetic Fields in Biological and Medical Aspects of Electromagnetic Fields, third edition, 2007, pp. 351–412.
[142] M. Blank, R. Goodman, Initial interactions in electromagnetic field-induced biosynthesis, J. Cell. Physiol. 199 (2004) 359–363.
[143] M. Blank, R. Goodman, A biological guide for electromagnetic safety: the stress response electromagnetic initiation of transcription at specific DNA sites, Bioelectromagnetics 25 (2004) 642–646.
[144] M. Blank, BEMS Soc. Newslett. (January–February) (2008) 6–7.
[145] G. Lotz, Letter from Greg Lotz, PhD, Chief Physical Agents Effects Branch, Division of Biomedical and Behavioral Science, National Institute of Occupational Safety and Health to Richard Tell, Chair, IEEE SCC28 (SC4) Risk Assessment Work Group, June 17, 1999.
[146] P. Grandjean, Implications of the precautionary principle for primary prevention and research, Ann. Rev. Public Health 25 (2004) 199–223.
[147] D. Davis, The Secret History of the War on Cancer, Basic Books, 2008.
[148] R. Proctor, Cancer Wars, Harper Collins Publishers, 1995.
[149] European Environmental Agency, Late Lessons from Early Warnings, The Precautionary Principle 1896–2000, Copenhagen, Denmark, 2001.
[150] P. Landrigan, How much do chemicals affect our health? Discover Mag. (2008).
[151] California Air Resources Board, Appendix III Proposed Identification of Environmental Tobacco Smoke as a Toxic Air Contaminant, Part B—Health Effects, 2005.

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RADIOFREQUENCY/MICROWAVE RADIATION BIOLOGICAL EFFECTS AND SAFETY STANDARDS: A REVIEW

Scott M. Bolen

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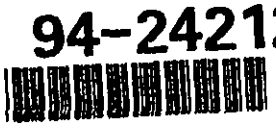

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13. ABSTRACT (Maximum 200 words)
The study of human exposure to radiofrequency/microwave (RF/MW) radiation has been the subject of widespread investigation and analysis. It is known that electromagnetic radiation has a biological effect on human tissue. An attempt has been made by researchers to quantify the effects of radiation exposure on the human body and to set guidelines for safe exposure levels. A review of the pertinent findings is presented along with the American National Standards Institute (ANSI) recommended safety standard (C95.1-1982) and the United States Air Force permissible exposure limit for RF/MW radiation (AFOSH Standard 161-9, 12 Feb 87). An overview of research conducted in the Soviet Union and Eastern Europe is also included in this report.

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Radiofrequency/Micowave Radiation Biological Effects and Safety Standards: A Review

Scott M. Bolen
June 1988

Abstract

The study of human exposure to radiofrequency/microwave radiation has been the subject of widespread investigation and analysis. It is known that electromagnetic radiation has a biological effect on human tissue. An attempt has been made by researchers to quantify the effects of radiation on the human body and to set guidelines for safe exposure levels. A review of the pertinent findings is presented along with the American National Standards Institute (ANSI) recommended safety standard (C95.1-1982) and the United States Air Force permissible exposure limit for RF/MW radiation (AFOSH Standard 161-9, 12 February 1987). An overview of research that was conducted in the Soviet Union and Eastern Europe is also included in this report.

I. INTRODUCTION

In 1956, the Department of Defense (DOD) directed the Armed Forces to investigate the biological effects of exposure to radiofrequency/microwave (RF/MW) radiation. The Army, Navy, and Air Force Departments commissioned a Tri-Service Program under the supervision of the Air Force to meet the DOD directive [14], [15]. The Rome Air Development Center and the Air Research and Development Headquarters were ultimately given responsibility to manage the program. On July 15-16, 1957 the first of four Tri-Service Conferences was held to discuss the effects of RF/MW radiation. These conferences were the first major effort put forth by the scientific community to explore the biological effects of exposure to RF/MW radiation [14]. Since then, researchers have discovered a number of biological dysfunctions that can occur in living organisms. Exposure of the human body to RF/MW radiation has many biological implications. The effects range from innocuous sensations of warmth to serious physiological damage to the eye [1], [2], [5], [6], [8], [15]. There is also evidence that RF/MW radiation can cause cancer [8].

The absorption of RF/MW radiated energy causes biological reactions to occur in the tissue of the human body. In order to determine safe exposure levels and to understand the effect of RF/MW radiation it is necessary to know the absorption characteristics of the human tissue. The National Institute for Occupational Safety and Health (NIOSH) [8] has reported several physical properties that account for energy absorption in biological materials. Factors which govern energy absorption include: (1) strength of the external electromagnetic (EM) field, 2) frequency of the RF/MW source, 3) the degree of hydration of the tissue, and 4) the physical dimensions, geometry, and orientation of the absorbing body with respect to the radiation EM field [8]. There is some disagreement among researchers in determining a specific measure for the dose of RF/MW radiation contracted by

biological materials. The most commonly accepted measure is the Specific Absorption Rate (SAR). The SAR is defined as the rate at which RF/MW radiated energy is imparted to the body - typically in units of watts per kilogram (W/Kg) [4]. The deposition of energy specified in terms of milliwatts per square centimeter (mW/cm^2) over the irradiated surface is also widely accepted [9].

Based on the known absorption rates and the inherent biological effects of RF/MW radiated energy, researchers have put forth a number of standards regarding safe exposure levels. In some instances standards recommended by different examining authorities are in conflict. For example, the USAF Standard 161-9 (enacted 12 February 1987) allows for a permissible exposure level of 10 mW/cm^2 for persons working in restricted areas and 5 mW/cm^2 for persons working in unrestricted areas [10]. The ANSI guideline specifies a maximum safe exposure level of 5 mW/cm^2 over the whole-body area for anyone in contact with RF/MW radiation [9]. These differences reflect the way in which each examining authority has interpreted the available RF/MW radiation exposure data.

II. BIOLOGICAL EFFECTS

Exposure to RF/MW radiation is known to have a biological effect on animals and humans. Damage to major organs, disruption of important biological processes, and the potential risk of cancer represent the dangers of RF/MW radiation to living organisms. Pulsed radiation appears to have the greatest impact on biological materials [8].

The response of biological materials to the absorption of thermal energy is the most perceptible effect of exposure to RF/MW radiation [7]. The energy emitted from an RF/MW source is absorbed by the human tissue primarily as heat. In this case, the radiated energy is disposed in the molecules of the tissue. Dipole molecules of water and protein are stimulated and will vibrate as energy is absorbed throughout the irradiated tissue area. Ionic conduction will also occur in the same area where the radiation is incident. It is from these two natural processes that radiant energy is converted into heat [11]. The thermal effect of continuous wave (CW) and pulsed radiation is considered to be the same [13].

Nonthermal responses can be less noticeable and are often more difficult to explain than thermal effects. These responses are related to the disturbances in the tissue not caused by heating. Electromagnetic fields can interact with the bioelectrical functions of the irradiated human tissue [8]. Research conducted in the Soviet Union and Eastern Europe suggests that the human body may be more sensitive to the nonthermal effects of RF/MW radiation [3].

There are many reported biological effects to humans and animals that are exposed to RF/MW radiation. A review of the important findings is given in the following:

A. Heating Effect on the Skin

Most RF/MW radiation penetrates only to the outer surface of the body. This is especially true for RF/MW frequencies greater than 3 GHz where the likely depth of penetration is about 1-10 mm [3]. At frequencies above 10 GHz the absorption of energy will occur mostly at the outer skin surface. Since the thermal receptors of the body are contained primarily in this region, the perception of RF/MW radiation at these frequencies

may be similar to that of infrared (IR) radiation [3], [6].

In 1937, J. Hardy and T. Oppel published an investigative paper on the thermal effects of IR radiation. Their findings were used by Om Gandhi and Abbas Riazi [6] to explain the thermal effect of RF/MW radiation on the human body (the reference for Hardy and Oppel can be found in [6]). Figure 1 shows the results obtained from the 1937 report. As described by Gandhi and Riazi, the findings presented by Hardy and Oppel show that sensations of warmth begin to occur when the whole-body is irradiated at a CW power density of about 0.67 mW/cm^2. Hardy and Oppel based their work on exposure to IR radiation. From other published reports, Gandhi and Riazi noted that there is a correlation between the radiating frequency of the incident RF/MW energy and the threshold for perception. For example, on an exposed area of the forehead of 37 cm^2 a perception of warmth was reported for incident power densities of 29.9 and 12.5 mW/cm^2 from sources radiating at 3 and 10 GHz respectively [6].

Other observations made by Hardy and Oppel showed that when smaller body areas were irradiated, larger power densities were required to stimulate the thermal receptors in the skin. Gandhi and Riazi were able to confirm this result with reports from recent papers. They found that irradiation of an exposed body area of 40.6 cm^2 to a power density of about 21.7 mW/cm^2 yielded the same thermal perception as did the irradiation of a smaller body area of 9.6 cm^2 to a power density of about 55.9 mW/cm^2. Hardy and Oppel reported that thermal sensations occurred within about 3 seconds after irradiation of the body tissue. More recent findings indicate a reaction time of closer to 1 second [6].

Gandhi and Riazi [6] have also reported that the depth of penetration of RF/MW radiation has an impact on the power density threshold needed to stimulate the perception of warmth. As a comparison, IR radiation will not penetrate the outer body surface as deeply as RF/MW radiation emitted at a frequency of 2.45 GHz. Clinical observations have shown that irradiation of the ventral surface of the arm by an RF/MW source radiation at 2.45 GHz will cause a sensation of warmth when the incident power density is about 26.7 mW/cm^2. For incident IR radiation a perception of warmth occurs at a power density of 1.7 mW/cm^2. They estimated that at millimeter wavelengths the perception of warmth may occur at a power density level of about 8.7 mW/cm^2.

Exposure to higher levels of radiation can cause serious biological effects. Because of the physical dimensions and geometry of the human body, RF/MW radiated energy is nonuniformily deposited over the whole-body surface. Some areas on the skin and outer body surface will absorb higher amounts of the radiated energy. These areas will be marked by "hot spots" of high temperatures [7], [11], [16]. Experiments conducted on laboratory animals have shown, that skin burns typically occur in the areas of hot spots. The penetration of RF/MW radiation also causes skin burns to be relatively deep [11]. In experiments sponsored by the Tri-Service Commission, it was reported that RF/MW radiation burns over the rib cages of dogs caused severe subcutaneous damage that did not visibly appear for weeks after the injury was sustained [20]. Burns can cause increased vascular permeability. This can lead to significant losses of body fluids and electrolytes. Serious burns can suffer fluid losses for a few days. Blood circulation can be altered in the effected area and other biological functions could be indirectly affected [12].

B. Whole-Body Hyperthermia

Thermal energy absorbed by the whole-body can cause a rise in body temperature. When the human body is irradiated by an RF/MW source at an incident power density of 10 mW/cm^2 there will be a rise in body temperature of about 1° C. The total thermal energy absorbed at this power density is about 58 watts. Typically, at rest the human basal metabolic rate is about 80 watts and it is about 290 watts during periods of moderate activity. Exposure of the human body to low power RF/MW radiation does not appear to impose any appreciable thermal hazard. These figures were reported by The U.S. Department of Health, Education and Welfare [3].

Adverse biological effects can occur when the body is subjected to high doses of RF/MW radiation [16]. In this instance large amounts of thermal energy can be absorbed by the body. A dramatic influx of energy can overburden thermoregulatory mechanisms. If excess heat cannot be exhausted the core temperature of the body will rise to a dangerous level resulting in hyperthermia [12], [16]. The biological response to excess heat buildup is the dilation of blood vessels at the surface of the skin and the evaporation of water through sweating. These are the primary mechanisms for heat dissipation. Hyperthermia can cause severe dehydration and the loss of electrolytes such as sodium chloride. Other harmful effects include fever, heat exhaustion, and heat fatigue. Heat stress is the most serious consequence of hyperthermia. Cardiac failure and heat stroke can result from heat stress [12].

It has also been noted that hyperthermia may cause injury to blood-brain barrier (BBB) [19]. This barrier refers to the several biological materials that separate the essential elements of the central nervous system from the blood [18]. High cerebral temperatures exceeding 43°C may damage the BBB. The result can be a disruption of blood vessel continuity or integrity and degradation of the flow of blood and other body fluids in the brain [19].

C. Local Hyperthermia

The nonuniform deposition of RF/MW radiated energy over the whole-body surface causes the body to be heated unevenly. Local areas where temperatures rise above 41.6°C can experience damage to the tissue [16]. In these areas it is possible that harmful toxins could be released as result of the high temperatures. Heating can cause cell membranes and blood capillaries to become more permeable. An increase in capillary permeability can lead to a loss of plasma proteins. The denaturation of proteins can also occur within cells [11], [16]. This can lead to changes in the physical properties and biological functions of proteins [18]. Denaturation of proteins can also cause polypeptide and histamine-like substances to become active [11], [16]. Histamines can stimulate gastric secretion, accelerate the heart rate, and cause the dilation of blood vessels resulting in lower blood pressure [18]. Areas of the body where blood circulation is poor or where thermal regulation is insufficient, are more susceptible to injury [11].

D. Carcinogenic Effects

The carcinogenic effects of exposure to RF/MW radiation are not well known. It is difficult to clinically establish a link to cancer. The problem that researchers have in linking

RF/MW radiation to cancer is that the disease itself is prevalent and can be caused by a variety of environmental factors. In fact cancer is the second leading cause of death in the United States. There are, however, published reports that reveal some insights into the carcinogenic nature of RF/MW radiation. Nonthermal effects may provide important clues to the understanding of carcinogenic reactions in the human body [8],[32].

i. Pathological Reports

In 1962, S. Prausnitz and C. Susskind reported experimental results that showed an increase in cancer among test animals exposed to RF/MW radiation. In the experiment, 100 male Swiss albino mice were irradiated by a 10 GHz RF/MW source at an incident power density of about 100 mW/cm^2. The mice were exposed for 4.5 minutes/day, 5 days/week for a total of 59 weeks. It was noted that irradiation caused the whole-body temperature of the mice to rise about 3.3°C. Upon examination, it was found that 35% of the mice had developed cancer of the white blood cells. The disease was observed as monocytic or lymphatic leucosis or lymphatic or myeloid leukemia. Only 10% of a similar control group had developed cancer [21].

There have been a few allegations that RF/MW radiation has induced cancer in humans [8], [15]. The NIOSH Technical Report [8] cites charges made in the early 1970's against Philco-Ford and The Boeing Corporation that occupational exposure to RF/MW radiation caused cancer among employees. One incident was reported at each company. At Philco-Ford it was claimed that exposure caused a rare form of brain cancer to manifest in one worker that eventually resulted in death. In each case, there was no scientific proof that RF/MW radiation had induced cancer in the company employees. There was also a report that EM fields induced cancer in an individual that worked at the U.S. Embassy in Moscow. Again, there was no scientific evidence that supported the claim [8].

Recently, the Observer Dispatch, a local newspaper published in Utica, New York, reported that a major study has just been completed in Sweden. The study concluded that children who live near high power lines have a greater risk of developing leukemia than children who live farther away from the power lines. The study involved 500,000 people and provided some evidence to link the electromagnetic fields produced by low frequency power lines to cancer. The researchers, however, cautioned against drawing firm conclusions as a result of the research [33]

ii. Effect on Chromosomes

It has been observed that disturbances in chromosomic activity can cause cancerous aberrations to occur in the human body. In 1974, a paper published by K. Chen, A. Samuel, and R. Hoopingarner (reference found in [8]) reported that chromosomal abnormalities can be linked to chronic myeloid leukemia. Serious genetic mutations can also result from such abnormalities that can lead to malignancies in the tissue [8].

In 1976, A. A. Kapustin, M. I. Rudnev, G. I. Leonskaia, and G.I. Knobecva (reference found in [17]) reported alterations in the chromosomes of bone marrow cells in laboratory animals that were exposed to RW/MW radiation. They exposed inbred albino rats to a 2500 MHz RF/MW source at incident power density levels of 50 and 500 uW/cm^2. Irradiation lasted for 7 hours/day for 10 days. Upon examination of the animals, they

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