BIOLOGICAL AND HEALTH EFFECTS OF MICROWAVE RADIO FREQUENCY TRANSMISSIONS

A REVIEW OF THE RESEARCH LITERATURE

A REPORT TO THE STAFF AND DIRECTORS OF THE EUGENE WATER AND ELECTRIC BOARD

June 4, 2013

Paul Dart, M.D.
(lead author)

Kathleen Cordes, M.D.

Andrew Elliott, N.D.

James Knackstedt, M.D.

Joseph Morgan, M.D.

Pamela Wible, M.D.

Steven Baker
(technical advisor)

EXECUTIVE SUMMARY

The FCC regulations for permissable exposures to microwave radio frequency (RF) transmissions are only designed to protect against the thermal effects of high exposure levels. Representatives of the telecommunications industry usually assert that there is "no clear or conclusive" scientific evidence regarding the biological effects of low level or "nonthermal" RF exposures. But in actuality, a large body of scientific research documents that RF exposures at low levels can produce adverse biological or health effects.

The installation of RF-transmitting "smart meters" by our electric utility could significantly increase the level of RF exposure in Eugene's residential neighborhoods. Such an increase carries potential health risks. The nature of these risks needs to be carefully considered before making a decision to deploy this technology.

Any decision-making process that ignores this possibility of harm could cause significantly damage both to community health and to EWEB's goodwill in the community.

ELECTROHYPERSENSITIVITY (EHS)

Microwave RF exposures can produce acute symptoms in some individuals. These symptoms can include headache, sleep disturbance, difficulty in concentration, memory disturbance, fatigue, depression, irritability, dizziness, malaise, tinnitus, burning and flushed skin, digestive disturbance, tremor, and cardiac irregularities. This syndrome was described by Russian researchers in the 1950's, who called it "microwave sickness". Between 1953 and 1978 the Russian government purposefully targeted the U.S. embassy in Moscow with beams of microwave RF, producing symptoms of microwave sickness in many embassy employees.

In recent years, the buildout of the wireless telecommunications infrastructure has greatly increased the exposure of the general public to microwave RF, and this has led to an increased number of individuals experiencing symptoms that are now referred to as "Electrohypersensitivity Syndrome" (EHS). Multiple research studies have shown a correlation between these symptoms and residential exposure to radio, radar, and cell tower transmissions.

The prevalence of EHS appears to be increasing, as the exposure of the public to RF continues to expand. Based on recent epidemiologic research, it would be reasonable to assume RF exposures provoke some sort of symptoms in between 3 and 5% of the population of Eugene at the current time. Any significant increase in residential RF exposure is likely to make these individuals more symptomatic, and to produce some new cases of EHS by pushing some other individuals beyond their tolerance limit.

ALTERED PHYSIOLOGY

Laboratory research in animal and human subjects has shown that "nonthermal" levels of RF exposure can alter EEG, immune function, and hormone levels including adrenal and thyroid hormones, testosterone, prolactin, progesterone.

Research shows that low levels of microwave RF exposure can reduce melatonin levels in humans, and that some individuals are more sensitive than others to this effect. The adverse effects of nighttime RF exposure on melatonin secretion are particulary disturbing. The nocturnal rise in melatonin levels supports the natural function of sleep, and disrupting this cycle can produce insomnia. Melatonin is an extremely potent antioxidant, and helps to repair damaged DNA and heal the body from other effects of oxidant stress.

Melatonin is also protective against the growth of cancer cells, and disruption of the circadian melatonin cycle has been shown to lead to increased tumor growth in a variety of cancer types. Women who have lower levels of nocturnal melatonin are at greater risk for developing breast cancer. Reduced melatonin levels may also increase the incidence of prostate cancer.

OXIDATIVE STRESS AND DAMAGED DNA

In contrast with Xrays and gamma rays, Microwave radiation does not have sufficient power to directly break covalent bonds in DNA molecules. But microwave RF can produce resonance interactions with ions and with charged macromolecules, and such interactions can significantly alter biochemical functions. A large body of research has shown that microwave RF causes an increased production of free radicals and reactive oxidant species in living tissues, and that this increased oxidant stress damages DNA. This damage can and does occur at power levels well below those levels that could produce damage by thermal mechanisms.

Any chronic exposure to conditions that damage DNA can lead to an increased risk of cancer. Evidence of increased risk of certain types of cancer has been demonstrated in groups with occupational exposure to microwave RF, including radio technicians in private industry, military personnel, commercial airline pilots, and ham radio operators. Elevated levels of cancer have been demonstrated in populations with increased residential exposure to radio transmission towers. And in the last ten years, studies fro Israel, Germany, Austria, and Brazil have documented significant increased in breast cancer and other cancers in individuals living less than 500 meters from cell phone towers, with measured exposure levels much lower than those permitted by current FCC guidelines.

Research has also shown that RF exposure levels well within current guidelines can cause DNA damage and reduced fertility in insects, birds, amphibians and mammals, and can lower sperm counts, sperm motility, and sperm motility in human beings.

RISKS OF CELL PHONE USE

Cell phone use expanded dramatically in Europe and the United States in the late 1990's. Early studies of the cancer risks of cell phone use were hampered by short latency periods of exposure. In general, studies funded by industry have reported lower levels of risk than independently funded studies. But in the last four years, all but the most poorly designed studies have shown an increased risk of brain tumors with more than ten years of use—a level of exposure which appears to double the risk of brain tumor on the side of the head where the cell phone is customarily held. This risk is higher in those who started using cell phones as children.

CONCLUSIONS

Existing scientific research offers strong evidence that the chronic exposure of the public to microwave RF transmissions produces serious acute and chronic health effects in a significant portion of the population. These findings can be summarized in the following precepts:

Basic Precepts for Residential Exposures to RF Transmissions:

- Excessive RF exposure can cause acute problems (headaches, insomnia, fatigue, vertigo, tinnitus, other symptoms of EHS).
- Excessive RF exposure can also cause chronic problems (oxidative stress, cancer, male infertility).
- Constant RF transmission is probably harmful, even at low levels, and should be avoided.
- Frequent and repetitive intermittent transmissions are also probably harmful, and should be avoided.
- Nocturnal exposures are more problematic than daytime exposures, because of RF's potential to suppress nocturnal melatonin secretion and disturb sleep, and because night is the time when we rest and heal from stresses (including oxidative stress).
- Occasional and infrequent daytime exposures are much less likely to cause an increase in chronic problems for the population at large.
- Occasional and infrequent daytime exposures are still likely to provoke acute symptoms in a small percentage of the population.

EWEB should adopt a policy of minimizing their RF footprint in the community.

A recognition of these precepts should lead EWEB to adopting a policy of minimizing their infrastructure's RF footprint in the community as much as possible during regular operations. This doesn't mean that staff would throw away their cell phones and communicate by semaphore. But it would mean that instead of combatting or ignoring the possibility that more RF in the community could cause harm, EWEB should acknowledge the potential risks of excessive residential exposure.

This would mean that such potential risks would be seriously considered in any discussion of the total risks and benefits involved (the "Total Bottom Line"), as EWEB decides *whether* to use RF technology for any given purpose. If, after such a discussion, a considered decision is made to use RF technology, then these same potential risks should be taken into serious consideration in determining *how* to use this technology in a manner that would minimize potential harm to the community.

In other words, don't use RF when you don't have to. Use hard-wired connections wherever it is feasible to do so. And if you do use RF, design the infrastructure in a way that uses as little of it as possible.

In the final section of this report, we discuss the perspectives that such a policy might bring to a consideration of the available AMI technologies.

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PREFACE

This paper represents the efforts of a group of physicians who have been in private practice in Eugene for decades. Our concerns are for the health of our patients as well as for our community as a whole.

When EWEB proposed installing a "mesh" smart meter network we became concerned. We know that there are people in this community who are highly sensitive to electromagnetic fields. The installation of the smart meter mesh would make Eugene a much more hostile environment for these individuals.

We also know that chronic exposures to microwave radio frequency (RF) transmissions can produce adverse long term physiological effects, even in individuals who do not consciously experience acute symptoms from exposure to such electromagnetic fields.

As we considered these issues, we were not sure if the policy makers at EWEB had sufficient current and applicable scientific information upon which to rely, as they evaluated the potential health effects of such an implementation. EWEB may have referred to FCC guidelines, without considering that the FCC regulations on radio frequency (RF) exposure are only designed to protect against the thermal effects of extremely high level RF exposures, and do not attempt to define a safe level of protection against other biological effects.

Because of these concerns, we have undertaken a sixteen month long investigation of the scientific literature, in order to present what we feel is a valid scientific basis for evaluating the potential health effects of a community-wide RF smart meter installation. This paper presents our findings to you.

We have organized this report into six sections:

1. An introduction into some of the issues involved in the "smart meter" Advanced Metering Infrastructure.
2. A review of the scientific research documenting the existence of acute reactions to "non-thermal" levels of RF exposure -- reactions which in their most severe form are called electrohypersensitivity syndrome (EHS).
3. A review of the function of melatonin, of evidence that RF exposure can suppress melatonin, and of the short and long term consequences of melatonin suppression.
4. A review of the long term effects of RF exposure, especially the production of oxidative stress that can lead to DNA damage and increased levels of cancer and infertility.
5. A review of current research regarding relationship of cellular and cordless telephone use to increased risk of brain tumors.
6. A discussion of our conclusions and recommendations to EWEB, based on this review of the scientific literature.

INTRODUCTION

AMI and the Smart Energy Grid

The Advanced Metering Infrastructure (AMI) technology is a key component of the smart energy grid that we heard discussed in very general terms in the 2008 presidential election. During the past two years, EWEB has been actively exploring the possibility of installing AMI in Eugene.

EWEB staff have described several purposes for going to an AMI "smart meter" infrastructure, including the following:

Reducing operating costs

Remote reading of meters would eliminate meter readers, allowing EWEB to save substantial costs in employee time and benefits, vehicle use, and gasoline costs. Smart meters can also be used to turn power on and off remotely, saving labor and travel costs when rentals become vacant or occupied.

Shifting time of use

Smart meters can measure and record total power usage for several intervals during the day. This will allow EWEB to bill customers more for electrical usage at peak use hours, typically the early morning (when people are getting up, taking showers, cooking breakfast) and late afternoon/early evening (when people return home from work, cook dinner, take showers, throw some clothes in the laundry, etc.). Time of use billing could create an incentive for customers to shift elective usage (laundry, recharging the electric car) away from peak usage hours.

Electrical utilities need enough generating capacity to meet peak demand. Reducing or restraining the growth of peak usage could reduce or slow the need to build more power generating capacity into the system.

Training customers to conserve electricity

Smart meter technology can allow home owners to monitor their usage in real time over a home network with the meter. EWEB hopes that this direct feedback will encourage people to reduce their energy consumption.

"Demand/Response" infrastructure

EWEB has invested a great deal in wind power. But the wind tends to blow hardest in the middle of the day and the middle of the night. At dawn and dusk (peak usage times for electrical consumers) the wind is more likely to calm down.

This creates a storage problem for the utility. When wind power production is high during the night, production can exceed demand, generating more electricity than can be used locally or sold interstate.

One way to distribute and store this energy is to put it in your water heater. Two way communication with your Smart Meter could allow the power company to turn your water heater on for 15 minutes in the middle of the night or the middle of the day, at a time when it would otherwise not be on [they can't turn it on for two hours, when it gets to the maximum heat setting the thermostat will turn it off]. EWEB would seek customers willing to volunteer to allow this arrangement.

With "demand/response" control, EWEB could store excess wind power as heat by turn on clusters of water heaters for 15 minutes, then turn them off and turn on other clusters of water heaters, and continue to rotate the usage around the community during the middle of the night.

Solar power generation creates another storage problem. Solar panel output can fluctuate rapidly during the day with changing cloud cover. Too sudden an increase in local production from multiple large panels could overload the grid. The AMI infrastructure would allow the utility to tell Smart Meters to turn off solar panel input into the electrical grid. Again, this requires rapid two-way communication between the utility and the Smart Meter, and between the Smart Meter and the solar panel in the house.

From an engineering point of view, the simplest and cheapest way to install this communications infrastructure is to have the meters communicate with the utility and with the "smart appliances" in the home using *wireless microwave radio technology*.

The use of this wireless technology for AMI communications has generated a good deal of political heat in the last two or three years. To understand where this heat has come from, it is instructive to review the history of the Pacific Gas and Electric Company's smart meter rollout in California.

PG&E in California, 2010 – 2011

In 2010 and 2011 PG&E rolled out an AMI infrastructure in multiple cities in California. The metering technology that they chose to install was the Silver Springs AMI "smart meter". These meters communicate with the utility by forming a "mesh" network in the neighborhood. The meters communicate with each other rather than with a central receiver, and pass data through this MESH network to the central collecting system of the electric utility.

The installation of such technology places a radio transmitter on every house in the community. Concerns about the potential health effects of this residential RF exposure led several members of the California Assembly to request that the California Council on Science and Technology (CCST) perform a study of whether current FCC standards for Smart Meters were sufficiently protective of the public health, and whether additional standards might be needed for such technology.

It should be noted that the regulatory standards established by the Federal Communications Commission are based on defining safe levels against the thermal effects of microwave radio frequency (RF) exposure (i.e. "Will it cook you?") For example, the FCC has established Limits for Maximum Permissible Exposure (MPE). (FCC, 1999, page 15). The FCC has explicitly stated that they do not make any regulations or assurances whatsoever regarding the "nonthermal" biological effects of microwave exposure (other physiologic effect besides heat damage). (Hankin, 2002)

The CCST released a report on "Health Impacts of Radio Frequency from Smart Meters" in January, 2011. (CCST, 2011) This report stated (on page 5) that Smart Metering technology met the FCC standards for "safety against *known thermally* induced health impacts". It also stated (on page 4) that *"To date, scientific studies have not identified or confirmed negative health effects from potential non-thermal impacts of RF emissions such as those produced by existing common household electronic devices and smart meters. Not enough is currently known about potential non-thermal impacts of radio frequency emissions to identify or recommend additional standards for such impacts."* The CCST report concluded that *"There is no evidence that additional standards are needed to protect the public from smart meters."* (page 26)

When the Draft Version of this CCST report was released, several experts in the field of research that studies the biological effects of RF communicated their disagreement with the study's conclusions. It was pointed out that the content of the CCST document was in major part a repetition of a document produced by the industry-sponsored Electric Power Research Institute a few weeks before (Tell, 2010), and that the analysis of AMI smart meter exposure levels in the report was incorrect in its design. (Hirsch, 2011)

These experts offered evidence of multiple scientific studies documenting the nonthermal health impacts of RF. (Sage, 2011b) (Johansson, 2011) Independent research was presented to the CCST documenting that the Silver Springs meters produced levels of household exposures significantly higher than levels shown to have adverse health effects in current scientific research. (Sage, 2011a)

These objections from the scientific community did not alter the CCST's stance on smart meters, which continued to be installed in California.

What happened next in California

PG&E's approach to the AMI rollout didn't involve a lot of public education. They just switched out the meters. And some people found that they were having trouble sleeping, or experiencing headaches, ringing in the ears, vertigo, or other symptoms that hadn't been bothering them before. Soon the internet was awash in anecdotal reports and commentary about these adverse effects. (emfsafetynetwork.org, 2011)

PG&E's public posture was that the meters only transmitted for an average of 45 seconds per day. They asserted that the total power output over time was well below the FCC guidelines for thermal risk, and well below that of other RF exposures in the community. Videos began to crop up on You Tube showing that the picture wasn't that simple (for example, *http://www.youtube.com/user/thisirradiatedlife/featured*).

Finally PG&E was served with a court order to provide clear documentation of what the meters actually were doing. (Yip-Kikugawa, 2011) In the response to that court order, PG&E provided documentation from the manufacturer of the meters that the *average* meter in the mesh network transmitted data signals to the utility 6 times a day, network management signals 15 times a day, timing signals 360 times a day, and beacon signals to the mesh network 9,600 times a day. (Kim et al., 2011) This penciled out to an average of roughly 7 transmissions a minute, 24 hours a day, coming out of every meter in the community.

As reports of provoked symptoms increased, the situation became more and more politically heated. Santa Cruz County banned the installation of smart meters. PG&E continued to install them, and the Santa Cruz County Sheriff's office refused to enforce the ban. Individuals started purchasing refurbished analogue electric meters and swapping them out themselves, attempting to return the smart meters to the utility. PG&E publicly stated (a week or two before Christmas) that they would turn off the power of anyone who removed a smart meter from their service box—but backed down from that threat due to public backlash.

By the end of 2011, multiple cities in California had either banned smart meters or placed a moratorium on their continued installation, and a lawsuit has been filed against PG&E with the California Public Utilities Commission. (Wilner, 2011)

EWEB's Elster MESH AMI Trial

In 2010 EWEB set up a trial of AMI infrastructure, using the Elster REX2 Smart Meter. Like the Silver Springs meter used by PG&E in California, the REX2 operates on a mesh network. The meters upload usage data to a central collection meter 4 to 6 times a day, but transmit short beacon signals to the network several times a minute.

EWEB stated on their website that these meters transmit "less than 10 seconds a day". But they were unable to state how frequently transmissions actually occurred. In our communications with their public relations staff, we were told that Elster was unwilling to release this information. Information on the power output of these meters is available on the ELSTER website. (TUV Rheinland, 2010) But Elster does not discuss the actual frequency of transmission of the meters.

In January 2012 we used a Gigahertz Solutions HF35C analyzer to evaluate the output of one of these Elster meters in a residential neighborhood in Eugene.

Background RF signals coming through the neighborhood were measured in a 360 degree circle around the monitoring position. The background RF averaged around 4 microwatts/square meter ($\mu W/m^2$), increasing to 8 or 10 $\mu W/m^2$ when we aimed our directional antenna at the radio towers on Blanton Heights or at a distant cell phone tower.

The Elster meter's transmission rate was variable. In our observations, they are definitely transmitting several times a minute, sometimes 4 or 5 times a minute, and occasionally in bursts of significantly higher frequency.

At 5 feet from the smart meter, the peak strength of the beacon signal coming off the meter measured from 3800 to 11,000 $\mu W/m^2$. At 20 feet from the meter, the power density of the signal ranged from 362 to 493 $\mu W/m^2$, with occasional bursts at higher power output.

This means that at a distance of 20 feet the power of the signal coming out of the Elster meter was *about 100 times* the power of the ambient background signal coming from any specific direction in the residential neighborhood.

This power density of 300+ to 400+ $\mu W/m^2$ was greater than the signal strength of the cell phone tower at 29th and Amazon, measured from about 200 meters away. So filling a neighborhood with a mesh network of the Elster smart meters would be similar to placing every house in that neighborhood closer than 200 meters from a cell phone tower, each house constantly being pinged by the chatter of multiple beacon signals from the mesh.

This was disconcerting, since recent research has shown that people living within 500 meters of a cell phone tower have increased incidence of headache, concentration difficulties, and sleep disorders, and also a significantly increased risk of some types of cancer. (Khurana et al., 2010) (Levitt and Lai, 2010) (Yakymenko et al., 2011) (Altpeter et al., 2006) (Abdel-Rassoul et al., 2007)

When you put these facts together, it is not so surprising that the installation of mesh smart meter networks in residential neighborhoods in California last year was followed by a surge of anecdotal evidence regarding headaches, insomnia and other health complaints. From a medical perspective, based on a familiarity with current research on the biological effects of RF, this was a predictable consequence of PG&E's smart meter MESH network rollout.

Formation of our Advisory Committee

By late 2011 EWEB staff were working towards setting a specific timeline for installing AMI in Eugene. From our perspective, the potential health risks of such a project did not appear to have received any realistic discussion. EWEB's web site implied that such risks were inconsequential. In January of 2012 EWEB's Public Relations staff started to test a public relations campaign promoting the AMI project. Their initial presentation minimized the possibility any health risks from this exposure.

Some physician members of our group became involved in discussions with EWEB staff. In these discussions, we tried to learn more about the technologies under consideration from EWEB engineers, and in turn we attempted to communicate our concerns about the potential health risks of this technology.

It became clear to us that EWEB staff did not have the time or the expertise to research this issue of health risks in any depth. Our sense of this was confirmed in April of 2012, when EWEB management presented the AMI Business Case to the EWEB Board. The discussion of "Potential Health Risks" in this document quoted government agency reports as if they were scientific studies, and stated that in an *"attempt to discover if there were any credible studies showing any health effect caused by long-term RF exposure in relatively high dosages (e.g. exposures much greater than an AMI meter) . . . no conclusive evidence was found that indicates that this higher magnitude RF exposure has created adverse health impacts."*

EWEB is a locally owned utility with a lot of goodwill in the community. We were concerned that if EWEB continued forward without taking a deeper look at this issue, decisions might be made that would have the potential to cause significant harm to the health of the community, or to create political strife that could significantly damage EWEB's local standing.

In an effort to help EWEB think this problem through in a more complete and considered fashion, we decided to form a group of physicians and other professionals with scientific and engineering expertise. Over the past 16 months, our group has studied the scientific literature on the biological effects of microwave RF. This report is the result of our efforts.

We hope that EWEB's staff and Board will examine this information carefully, and that it will help them to make prudent choices as they consider the various AMI technologies that are currently available to them.

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ELECTROHYPERSENSITIVITY

"MICROWAVE SICKNESS"

Acute symptoms provoked by microwave radiation were first described by Russian medical researchers in the 1950's. They described a constellation of symptoms including headache, ocular dysfunction, fatigue, dizziness, sleep disorders, dermatographism, cardiovascular abnormalities, depression, irritability, and memory impairment. (Liakouris, 1998)

In the years between 1953 and 1978 the Russian government harrassed the U.S. Embassy in Moscow by targeting it with radiation from a microwave transmitter. Concern about health effects led to a detailed study by A.M. Lilienfeld, an epidemiologist at Johns Hopkins University. (Lilienfeld AM, 1979)

The abnormalities found in this study were an embarrassment to the U.S. government, since the levels of exposure experienced by embassy staff were in the order of 2 to 28 microwatts/cm^2, a level dramatically below the described U.S. safety standards for microwave exposure. The conclusions of the study were altered to soft-pedal any abnormal findings. (Goldsmith, 1995b) (Cherry, 2000)

But outside epidemiologic analysis of the Lilienfeld report's published data showed that exposed embassy staff experienced a statistically significant excess of several problems, including depression, irritability, difficulty in concentrating, memory loss, ear problems, skin problems, vascular problems, and other health problems. Symptom incidence increased significantly with accrued years of exposure. (Goldsmith, 1995a) (Cherry, 2000)

THE EMERGENCE OF "ELECTROHYPERSENSITIVITY" AS A DIAGNOSIS

In recent years the buildout of cellular communication networks has created a markedly increased exposure of the public to RF transmissions. Each new generation of cell phone technology has occupied a higher frequency on the microwave scale, with potentially increasing impact on body physiology. (Cherry, 2002) As this has occurred, mounting evidence has pointed to the fact that a percentage of the population experiences adverse reactions associated with these exposures. The term "electrohypersensitivity" (EHS) has been used to describe a constellation of symptoms, including headache, sleep disturbance, difficulty in concentration, memory disturbance, fatigue, depression, irritability, dizziness, malaise, tinnitus, burning and flushed skin, digestive disturbance, tremor, and cardiac irregularities. Sleep disturbance, headache, nervous distress, fatigue, and concentration difficulties are the most commonly described symptoms. (Roosli et al., 2004)

These symptoms are identical to the symptoms of "microwave sickness" described by Russian physicians in the 1950's.

SYMPTOMS PROVOKED BY TRANSMISSION TOWERS

In 2002, Santini reported significant increases in such symptoms in individuals living closer than 300 meters to cell towers. (Santini et al., 2002) (Santini R, 2003)

In Poland, Bortkiewicz found similar increases in symptoms among residents near cell towers. Symptoms showed equal association to proximity of the tower, regardless of whether or not the subject suspected such a causal association. (Bortkiewicz et al., 2004) (Bortkiewicz et al., 2012)

In two studies, Abelin and Altpeter found evidence of disruption of sleep cycle and melatonin physiology by RF transmission during the operation and subsequent shutdown of the short wave radio transmitter in Schwarzenburg, Switzerland. (Abelin et al., 2005) (Altpeter et al., 2006)

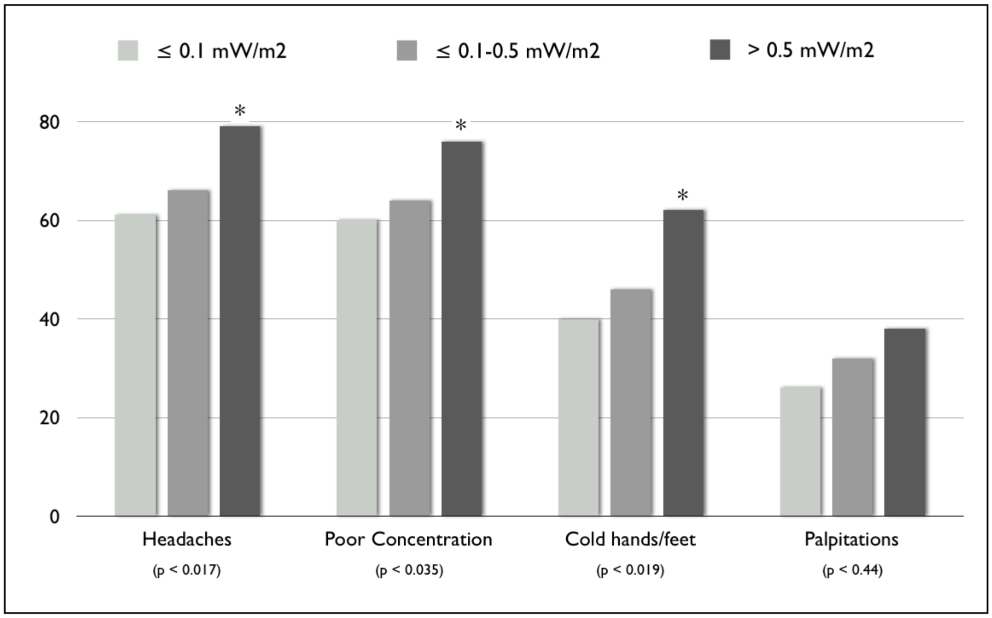

Figure 1: Percentage of subjects reporting symptoms, stratified by RF exposure levels as measured in subject's bedroom. (Hutter et al., 2006)

In a study done in urban and rural sites in Austria, Hutter found a clearly significant correlation between exposed signal power density and headaches and concentration difficulties—despite the fact that maximum measured power densities were only 4.1 mW/m^2 (= 0.41 μW/cm^2, well below established "safe" limits). (Hutter et al., 2006)

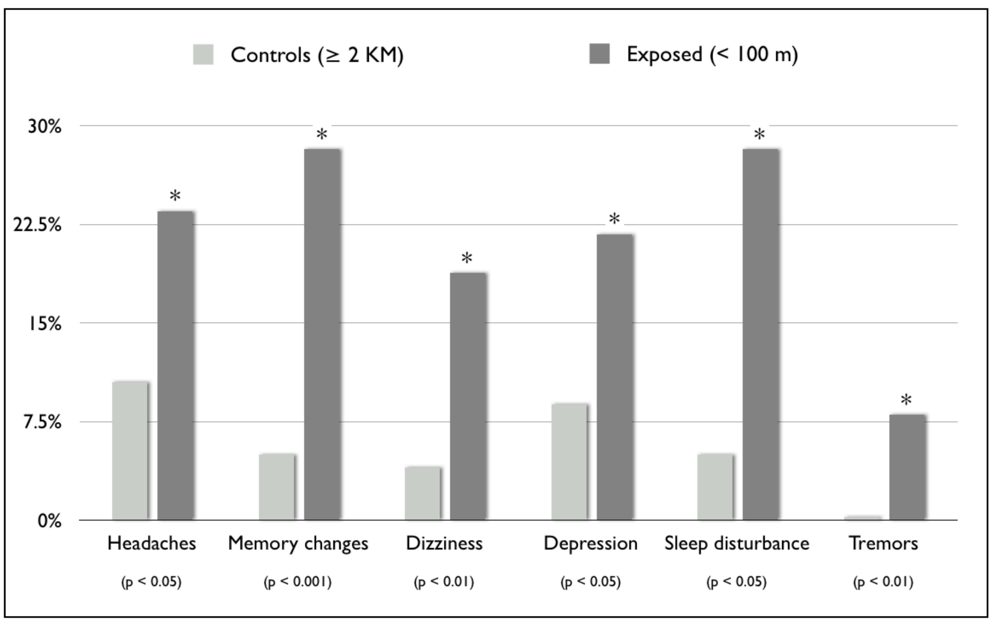

Figure 2: Percentage of subjects reporting symptoms, stratified by proximity to city's first cell phone tower. (Abdel-Rassoul et al., 2007)

In Egypt, a study of inhabitants living near the first cell phone tower in the city of Shebeen El-Kom found a significant increase in headaches, memory changes, dizziness, tremors, depressive symptoms, and sleep disturbance, with lower performance on tests of attention and short-term auditory memory. (Abdel-Rassoul et al., 2007)

Research at the military radar installation in Akrotiri, Cyprus, showed that residents of exposed villages had markedly increased incidence of migraine, headache, dizziness, and depression, and significant increases in asthma, heart problems, and other respiratory problems. (Preece et al., 2007)

Studies in Murcia, Spain yielded similar findings, and based on measured exposures the authors suggested that safe levels of indoor exposure should not exceed 1 $\mu W/m^2$ (0.0001 $\mu W/cm^2$) (Navarro et al., 2003) (Oberfeld et al., 2004)

In a study of residents of Selbitz, Bavaria, researchers found statistically significant increases in multiple health symptoms that demonstrated a dose-response relationship with cell phone tower transmissions. Individuals living within 400 meters of the cell phone tower had significantly more symptoms than those living > 400 meters from the tower. And individuals living within 200 meters of the tower had significantly higher symptoms than those living between 200 and 400 meters from the tower. (Eger and Jahn, 2010)

Two recent reviews provide a detailed overview of research in this area. (Khurana et al., 2010) (Levitt and Lai, 2010)

SYMPTOMS PROVOKED BY CELL PHONE USE

Multiple studies of cell phone users in the last decade found evidence of a similar pattern of symptoms to be provoked in some users. (Chia et al., 2000) (Oftedal et al., 2000) (Santini R, 2002) (Wilen et al., 2003) (Salama and Abou El Naga, 2004) (Al-Khlaiwi and Meo, 2004) (Balikci et al., 2005) (Balik et al., 2005) (Szyjkowska et al., 2005) (Meo and Al-Drees, 2005) (Soderqvist et al., 2008) (Landgrebe et al., 2009) (Hutter et al., 2010)

PHYSIOLOGY OF ELECTROHYPERSENSITIVITY

A variety of research models have demonstrated that RF exposure does not have a uniform effect on people. In many studies, a cohort of individuals has been identified that has a more sensitive response to RF in one way or another.

Reduced heart rate variability

In one study, patients with symptoms consistent with EHS were found to have dereased circadium changes in heart rate variability. (Lyskov et al., 2001) Similar changes in HRV were found in another study where subjects self-identified as having EHS symptoms from exposure to video display terminals, TV screens, fluorescent lights, or other electrical equipment. (Sandstrom et al., 2003) An occupational study of RF plastic sealer workers also found alterations in heart rate compared to normal controls.

Fatigue and reduced melatonin

In the more recent Schwarzenberg study, the effect of RF exposure on producing morning fatigue and reduced melatonin secretion was significantly greater in the subjects whose general quality of sleep was below the median. (Altpeter et al., 2006)

EEG changes

Alterations in EEG have been found in animals and in people with exposure to both magnetic fields and cell phone transmission frequencies. (Marino et al., 2003) (Marino et al., 2004)

Nanou et al found the EEG response to be gender dependent after exposure both to 900 MHz and 1800 MHz signals. (Nanou et al., 2005) (Nanou et al., 2009)

Bachman found EEG changes with 450 MHz microwave exposure in 25 to 30% of healthy volunteers (Bachmann et al., 2005) (Bachmann et al., 2006). In another study, EEG changes were 5 times as common in depressive subjects as in healthy controls. (Bachmann et al., 2007)

Landgrebe found decreased intracortical excitability in EEG after transcranial magnetic stimulation in self-identified EHS patients, as compared with normal controls. (Landgrebe et al., 2007)

Schmidt found alteration in sleep EEG after exposure to a 900 MHz RF signal modulated at two different frequencies, and noted a marked individual variation in sensitivity to this effect. (Schmid et al., 2011)

Loughran found alterations in non-REM EEG after cell phone RF exposure. These alterations were consistently stronger in one subset of his study group, over multiple tests. (Loughran et al., 2012)

Altered Immune Function

Exposure to both GSM and UMTS cellular transmissions at nonthermal exposure levels have been shown to alter DNA repair mechanisms in lymphocytes. (Markova et al., 2005) (Belyaev et al., 2009) Multiple additional studies have demonstrated non-thermal biological effects of RF radiation on immune cell function, as reviewed here. (Johansson, 2007) (Johansson, 2009b)

One of the most intriguing findings is Johannson's research showing that patients with electrosensitivity have higher levels of mast cells in their skin, and that these mast cells migrate closer to the skin surface. (Johansson, 2006) Mast cells are responsible for the itching, burning, and skin flushing that occurs after sunburn exposure. The presence of higher levels of mast cells in EHS patients provides an explanation for the symptoms of flushed, itching, and burning skin on the face and other areas that is described by these patients, who appear to be reacting to RF exposure like others might react to excessive sun exposure. Since mast cells are distributed throughout the body, the presence of mastocytosis in EHS patients may relate to some other symptoms as well.

Hormonal Changes

Chronic exposures to electromagnetic field effects have also been shown to cause alterations in secretion of multiple hormones. A study published in 2007 showed that physiotherapists working with various electromagnetic treatment modalities had significantly elevated secretion levels of the stress hormones cortisol, adrenaline, and noradrenaline. (Vangelova et al., 2007)

Another study measured urinary secretion of the stress hormones adrenaline and noradrenaline, along with levels of dopamine and phenylethylamine, prior to and over the 1 1/2 years following the installation of a GSM cell phone tower in Rimbach, Bavaria. Levels of adrenaline and noradrenaline showed a significant increase over the first six months after exposure, and never returned to baseline levels. Responses showed a proportional relationship to residential exposure levels, and were clearly present at levels as low as 60 to 100 microwatts/m^2 (= 0.006 to 0.010 μW/cm^2). This suggested a chronic stress effect of the GSM microwave signal on the population. (Buchner K, 2011)

Chronic adrenal stress will in time lead to decompensation and symptoms of adrenal fatigue in a certain percentage of the population.

A recently published study evaluated human hormone profiles over six years of exposure to the microwave RF emissions of GSM cell phones or cell phone towers. Findings included highly significant decreases in ACTH, cortisol, both T4 and T3 thyroid hormones. In male subjects, serum testosterone levels gradually decreased with increased time of exposure. In females, alterations in serum prolactin and progesterone levels gradually increased over increased time of exposure. (Eskander et al., 2012)

Current Research

One of us had the opportunity this spring to visit the practice of Dr. Dominique Belpomme, Professor of Oncology at Paris Descartes University, who is conducting research on electrohypersensitivity with the Association for Research and Treatments Against Cancer (ARTAC) in Paris. The ARTAC group has been following several hundred patients with EHS over the last four years, and has documented that these patients have clear and consistent changes in oxidative metabolism, and also in blood flow to the limbic system (as measured by doppler studies). Dr. Belpomme considers these changes in the limbic system to directly correlate with many of the cognitive changes (memory problems, difficulty with concentration, etc.) that are experienced by these patients. The ARTAC group expects to publish a series of papers on their findings during the next year. (Dart, 2012)

PROVOCATION STUDIES

Over the last ten years, many attempts have been made to evaluate the nature of electrohypersensitivity through provocation studies. The limitations of these studies have been discussed in detail in some recent papers. (Loughran et al., 2012) (Regel and Achermann, 2011)

Problems of methodology that have compromised many provocation studies include:

- Many studies have been performed single-blind rather than double-blind.
- Many studies divide the study group and normal controls based on the individual's self-identification as having (or not having) electrohypersensitivity. Since it is certainly possible for people to have reactions to EMF without being aware of this connection, and since the entire population is exposed to EMF at this point in time, it is difficult to be sure that the "control" group is indeed composed of "non-reactors". This will tend to weaken the power of any study set up in this fashion.
- Many studies evaluate whether or not the subject can discern when the RF signal is present and when it is absent. Absence of the ability to make this judgement is taken as evidence that electrohypersensitivity does not exist. This is an extremely illogical assumption. A person can develop a headache during or after an RF exposure without knowing when the signal is "on" or "off", just as they can develop bacterial gastroenteritis without knowing what food was contaminated with the bacteria. Having symptoms from RF and being a reli-

able RF meter are not the same thing.

- Unspecified or inadequate control of background levels of RF/EMF is also a problem with some "negative" studies. For example, one recent study (Kim et al., 2008) was performed with background RF levels in the study area of of 0.5, 0.7, and 0.8 V/m from three different mobile phone service providers. This adds up to a reported 2.0 V/m of background RF, equivalent to several thousand microwatts/m^2, which is well above threshold levels reported to cause symptoms in many sensitive individuals.
- Many studies assume that all patients who complain of EHS will react to any constant RF signal, and that they will react to it every time. Yet some studies have demonstrated that patients vary in which frequencies they respond to, and that patients can react more strongly to the starting and stopping of a signal than they do to the presence of a steady signal.
- Furthermore, the assumption is often made that EHS symptoms will start when a signal is turned on, and stop when it turns off. These assumptions are problematic, since many patients with EHS report having symptoms that continue for a significant time (hours, in many cases) after a triggering exposure. Few studies discuss whether or not an adequate "washout time" was provided for before starting the study, or between provocational challenges. The absence of such washout times seriously weakens the power of these studies.

In order to do a reliable RF provocation study with EHS exposure, it is necessary to isolate the subjects from background RF levels, and to maintain them in this isolation for long enough that they stop reacting to any prior exposures which they have received, before attempting to provoke a new reaction.

Some studies that are designed to address all these methodologic issues have found clear evidence of electrosensitivity. For example, a study done in 1991 that was performed in an isolated EMF environment tested EHS patients with a variety of different frequencies of RF stimulus, to determine their individual reactivity spectrum. 100 patients who identified themselves as having electrohypersensitivity were tested single blind with a variety of RF frequencies. 25 of these 100 patients showed an increase in symptoms of 20% over baseline, with no more than one placebo response.

These 25 patients were retested in a double blind setting with 25 healthy controls. 16 of the 25 patients (64%) reacted to the positive challenges, which were performed at a variety of frequencies.

These 16 patients reacted to 53% of the 336 active challenges, and 7.5% of the 60 blanks. No patient reacted to all tested frequencies. The 25 healthy controls had no reactions to challenges or to blanks.

Finally, these 16 patients were again tested in a double blind setting, each patient challenged with the single frequency to which they were most sensitive. In this phase of the study, the patients reacted 100% of the time to the active transmissions (with both reported symptoms and autonomic changes on iriscorder) and did not report reactions to the sham transmissions. (Rea et al., 1991)

It must be reiterated that having an adverse reaction to a provoking RF signal and having the ability to determine when the signal is "on" and when it is "off" are two completely different things. A recent double blind study demonstrated that a patient can have consistent provocation of symptoms from a signal without having any clear awareness of when the signal is actually present. (McCarty et al., 2011)

These provocation studies involve short term exposures to the RF signal (typically an hour or less). Since a great deal of the physiology research shows a more powerful effect with chronic exposures, these short-term studies are probably not the most effective way to assess the clinical significance of reactions to RF.

PREVALENCE OF EHS

Research in Stockholm County, Sweden in 1997 found that 1.5% of the population reported being hypersensitive to electrical or magnetic fields. (Hillert et al., 2002)

In California in 1998, Levallois et al found that 3.2% of the adult population reported being sensitive to sources of EMF. (Levallois et al., 2002)

In Switzerland in 2004, researchers studying a representative sample of the Swiss population found that 5% of the population had symptoms attributable to EHS, with sleep disorders and headaches being the most common reported symptoms. (Schreier et al., 2006)

In Austria in 2004, 2% of the population was estimated to have electrohypersensitivity. In a survey performed in Austria in 2008, 29.3% of respondents reported having some sort of adverse response to electromagnetic pollution. Of this cohort, 2.1% reported intense disturbance, and 3.5% had experienced enough difficulty that they had consulted a physician about the problem. (Schrottner and Leitgeb, 2008)

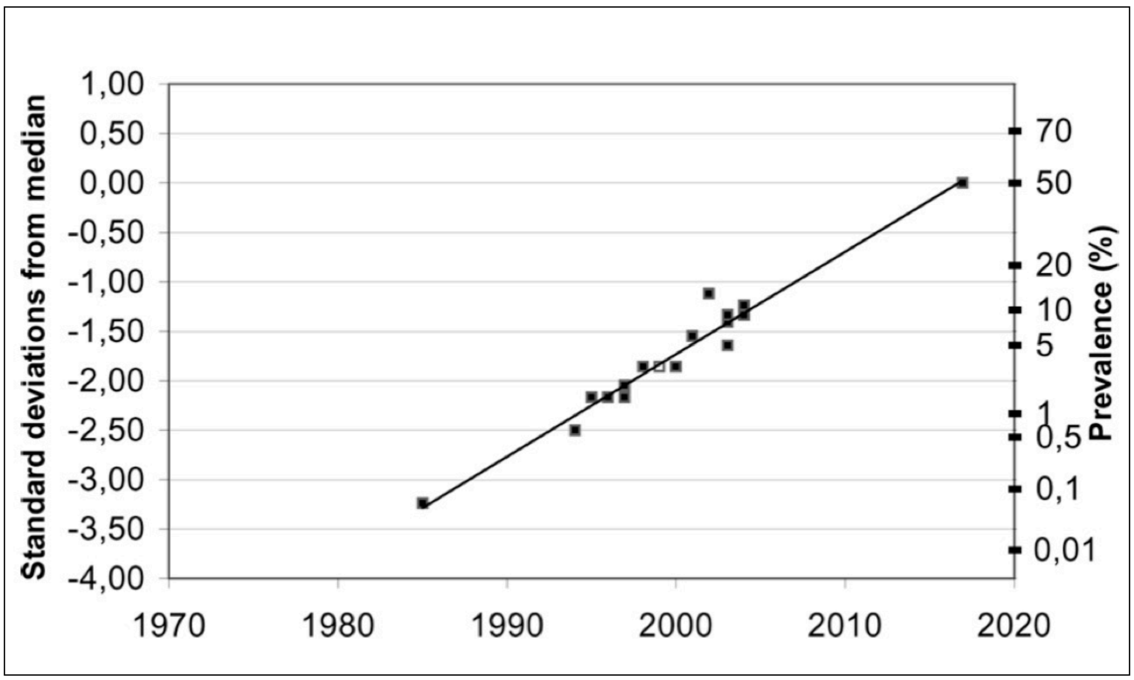

Figure 3: The prevalence of electrohypersensitivity syndrome is increasing. (Hallberg and Oberfeld, 2006

In much of the world, exposure to microwave radio signals has continued to significantly increase since the early 1990's. Reported electrosensitivity also appears to be increasing over time. In 2006, Halberg and Oberfeld reviewed research on this subject from 1985 forward, and estimated that if the trend in increased prevalence continues, fifty percent of the population could be reporting adverse effects from EMF by the year 2017 (Figure 1). (Hallberg and Oberfeld, 2006)

GOVERNMENTAL RESPONSE

The various forms of research described above have provided strong support for the fact that RF/EMF exposures can produce symptoms in human beings and that there is a percentage of the population that is more sensitive to this effect. Continued research is suggesting that this is not a static situation—that the prevalence of electro-hypersensitivity is a growing over time.

By the middle of the last decade, various government agencies were attempting to define the scope of the problem. (Irvine, 2005)

The rollout of mobile phone technology occurred earlier in scandinavia than in other places in the world, and governmental recognition of EHS as a health problem occurred earlier there than in other places. By the year 2000, EHS was recognized as a disability by the Swedish government. (Ministers, 2000)

In Stockholm, individuals with EHS can receive municipal support to reduce the presence of and penetration of EMF/RF into their homes. The construction of a village with houses specifically designed to mitigate this problem is being considered. Patients with EHS have the legal right to receive mitigations in their workplace, and some hospitals have build low EMF hospital rooms for use by such patients. (Johansson, 2006)

Various government reports or reviews on the question of electrohypersensitivity have been commissioned in the last few years. (Aringer et al., 1997) (Irvine, 2005) And legislation to address the problem has been proposed in some countries. (Snoy, 2011) (Parliamentary Assembly, 2011) Many libraries and schools in europe have banned WiFi due to concerns about health effects on employees and on the public.

REGULATORY RESPONSE

Regulations on exposure limits vary dramatically from country to country. In general, exposure limits have been mandated at a lower level in Russia and eastern Europe, where research on the health effects of RF exposure has been performed for a longer period of time. (Repacholi et al., 2012)

The regulatory standards established by the FCC and the World Health Organization are based on defining safe levels against the thermal effects of RF (i.e. damage from being cooked by high levels of microwave exposure). The FCC has not established exposure standards for potential nonthermal or biological effects of microwave exposure. (Hankin, 2002)

For example, the FCC has established Limits for Maximum Permissible Exposure (MPE). For the general population, the permissible level of exposure at 900 MHz is 600 $\mu W/cm^2$, and at 1800 MHz is 1000 $\mu W/cm^2$. (FCC, 1999) These exposure levels were last updated in 1996, and are considered to be protective against thermal effects of microwave radiation. However, current scientific research shows that these permissible levles of exposure are hundreds of times higher than the threshold levels for adverse "nonthermal" biological effects.

For the past ten years, the WHO has consistently equivocated on the issue of recognizing nonthermal biological effects from microwave RF exposure, despite the mounting research evidence of health problems and health risks produced by current levels of public exposure.

The following table shows exposure standards for various countries in 2001. (Firstenberg, 2001)

Country	($\mu W/cm^2$)
New South Wales, Australia	0.001
Salzburg, Austria (for pulsed transmissions)	0.1
Russia	2–10
Bulgaria	2–10
Hungary	2–10
Switzerland	2–10
China	7–10
Italy	10
Auckland, New Zealand	50
Australia	200
New Zealand	200–1000
Japan	200–1000
Germany	200–1000
United States	200–1000
Canada	200–1000
United Kingdom	1000–10,000

Figure 2: RF exposure limits (2001)

PHYSICIAN AND RESEARCHER RESPONSE

In response to this inaction on the part of government and international regulatory bodies over the past decade, a variety of groups of physicians and researchers in the field of RF/EMF health effects have called for regulatory action to address the documented biological consequences of the increasing exposure of the public to RF transmissions.

In 2000, the Salzburg Resolution suggested a total high frequency radiation limit of 100 mW/m^2 (10 $\mu W/cm^2$), and a total emission level of pulse modulated exposure (such as GSM) of 1 mW/m^2 (0.1 $\mu W/cm^2$). (Altpeter et al., 2000)

In 2002 a group of German physicians described a growing problem with adverse clinical effects from RF/EMF, and called for stricter safety limits on RF transmissions, restrictions on cell phone use by children and adolescents, and a ban on cellular and cordless phone use in preschools, schools, hospitals, nursing homes, event halls, public buildings, and vehicles. (2002)

Multiple similar appeals have been made by research groups and medical associations over the past ten years. (Association, 2004) (Leitgeb et al., 2005) (Association, 2012) (Dean A, 2012) (Johansson, 2011) (Johansson, 2009a) (Fragopoulou et al., 2010) (Israel et al., 2011)

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RADIOFREQUENCY EFFECTS ON MELATONIN

THE FUNCTION OF MELATONIN

Many physiologic functions in the human body are entrained in a circadium rhythm, fluctuating through the day/night cycle. The hormone melatonin, secreted by the pineal gland, is a key agent in coordinating these physiologic responses throughout the body. (Zawilska et al., 2009)

The entrainment of melatonin secretion with the day/night cycle is maintained by the suprachiasmatic nucleus in the hypothalamus, which receives input on the presence of light from the retina via the retinohypothalamic tract. In the presence of ambient light, melatonin secretion is suppressed. In the absence of ambient light, melatonin secretion increases. So melatonin secretion is high during the nighttime hours, peaking shortly after midnight. Higher melatonin levels are part of what makes us feel "sleepy" at night. Exposure to light during the nighttime hours will lead to a rapid suppression of melatonin secretion by the pineal gland, and this can cause disruption of sleep and derangement of the circadium rhythm.

Since the length of the day varies seasonally, melatonin also provides our physiology with information and influence produced by the different seasons of the year. This seasonal influence was obviously more profound prior to the widespread introduction of artificial electric lighting.

The circadian rhythm of high nocturnal melatonin levels supports the natural function of sleep, and disruption of this rhythm by bright light at night, night shift work, or travel to different time zones can produce sleep disturbances.

Melatonin is one of the most potent antioxidant molecules in the human body, and acts to reduce reactive oxidative processes in the body. Melatonin can quench the damaging free radical activity produced by inflammation. The presence of elevated melatonin at night is therefore a key factor in the healing and rejuvenating functions that we associate with "a good night's sleep".

Many body processes (serum cortisol levels, body temperature, patterns of digestive function, etc.) have a circadian rhythm that is coordinated by the timing signal of melatonin secretion. Melatonin has a protective effect on the health of the gastrointestinal tract. Melatonin is also protective against the growth of cancer cells, and disruption of the circadian melatonin cycle has been shown to lead to increased tumor growth in a variety of cancer types. (Reiter et al., 2011)

Research has clearly demonstrated that melatonin inhibits the proliferation, invasiveness, and metastasis of human breast cancer cells. Women who have lower levels of nocturnal melatonin are at greater risk for developing breast cancer. (Schernhammer et al., 2008) (Schernhammer and Hankinson, 2009) Breast cancer is more common in industrialized societies, and geographically the incidence of breast cancer is strongly associated with higher levels of "light-at-night". (Kloog et al., 2008) (Kloog et al., 2010)

Current research suggests that disruption of nocturnal melatonin signals by "light at night" can promote both the development and the growth of breast cancer. (Hill et al., 2011) (Stevens, 2009) In 2007 the International Agency for Research on Cancer declared night shift work to be a probable carcinogen. Subsequent epidemiologic research continues to support this finding. (Bonde et al., 2012)

Recent research has also suggested similar associations between "light at night" and the incidence of prostate cancer. (Kloog et al., 2009)

ELECTROMAGNETIC AND RADIOFREQUENCY EXPOSURES CAN REDUCE MELATONIN PRODUCTION IN THE PINEAL GLAND

In the 1990's, the Swiss government conducted a series of studies of sleep quality near the Swiss national short wave radio transmission tower in Schwarzenburg. These studies were initiated after the government received a petition stating that many residents living near the transmitter were experiencing problems including nervousness, headache, sleep disturbance, and fatigue.

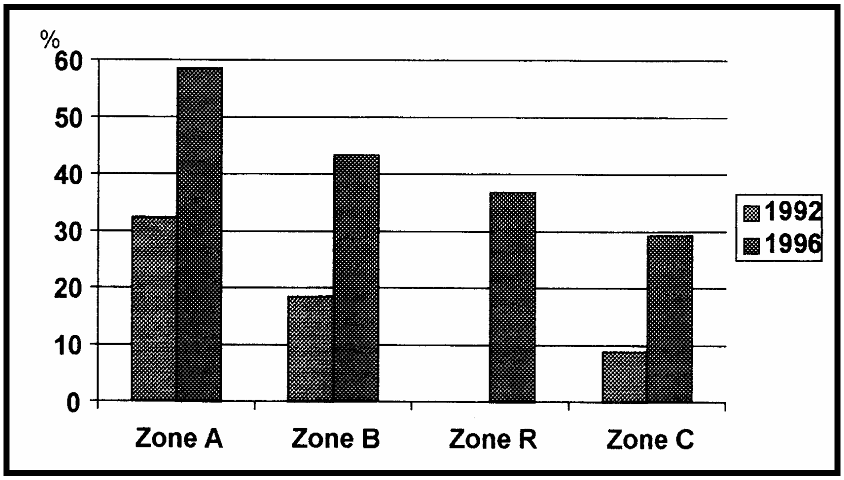

Figure 1: Sleep Disturbance by Proximity Zone in the Schwarzenburg Study. (Cherry, 2002)

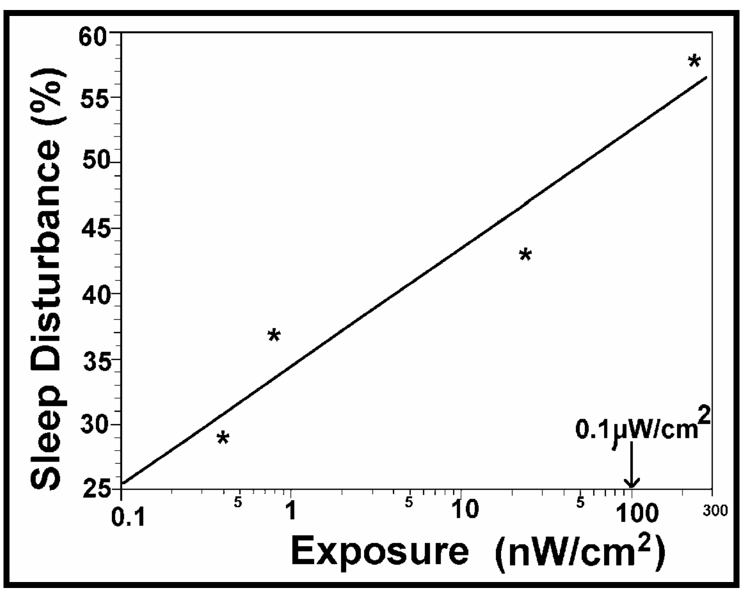

Figure 2: Sleep Disturbance by Exposure Levels in the Schwarzenburg Study. (Cherry, 2002)

In these studies, a statistically significant increase in sleep disturbance was found in residents living closer to the towers. Difficulty in maintaining sleep correlated with transmission field strength, at exposure levels as low as 0.1 nanowatts/cm^2. (Cherry, 2002) (Abelin et al., 2005)

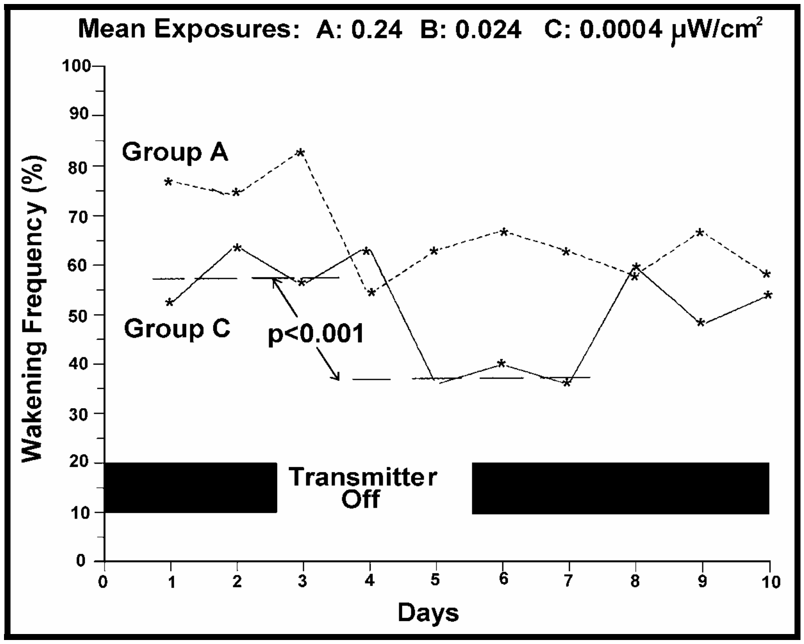

Figure 3: Reduction in Sleep Disturbance with Interruption of Tower Transmission in the Schwarzenburg Study. (Cherry, 2002)

During an interval when the transmitter was turned off for three days, statistically significant reductions in sleep disturbance were found in both the high and the low exposure groups (Figure 3). Note that Group C showed a reduction in sleep disturbance with absence of the signal, despite the fact that signal strength in Zone C averaged only 0.0004 $\mu W/cm^2$ (4 $\mu W/m^2$).

The Schwarzenburg transmission tower was shut down permanently in 1998. In a final research project, sleep quality and salivary melatonin levels were measured in a group of 54 community residents for an interval before and after the end of radio transmission.

Baseline sleep quality was assessed by analysis of sleep diary records, and subjects were stratified into two groups classified as either "poor" or "good" sleepers. Salivary melatonin samples were collected before breakfast, lunch, tea, dinner, and before bed. Subjects recorded morning tiredness and sleep quality, time of falling asleep, and duration of sleep. Exposure levels were calculated for each subjects home.

During the baseline exposure period, scores of morning tiredness directly correlated with increased levels of exposure, and melatonin excretion levels were reduced by a factor of 0.90 for each mA/m of increase magnetic field exposure level. Peak melatonin excretion times were delayed by 4.4 minutes for every 1 mA/m increase in exposure level.

After shutdown of the transmitter, subjects' morning fatigue scores improved by 1.74 units for each 1 mA/m of reduced exposure, and melatonin excretion levels increased by a factor of 1.15 per mA/m of reduced exposure. (Altpeter et al., 2006)

The Schwarzenburg shutdown study's findings were remarkable for two additional reasons. First, there were no other significant levels of short wave radio exposure in the community at the time of the study. So this study provides a true elimination and challenge test of RF exposure effects on a fairly large group of people in their normal environment. Such a study setting was difficult to arrange at that time, and would be even more difficult to achieve today, as the number of sources of RF exposure in our communities have increased markedly with the rollout of the wireless telecommunications infrastructure.

Second, the stratification of the study group into "poor" and "good" sleepers allowed recognition of an important additional finding. Improvements in sleep quality and melatonin secretion levels after transmitter shutdown were significantly greater in "poor" sleepers than they were in "good" sleepers. This evidence supports the hypothesis that some individuals may be more sensitive to the effects of microwave exposure, a condition that has been called "electrohypersensitivity" or EHS.

Multiple additional studies in a variety of settings have demonstrated an effect of various forms of EMF/RF on melatonin physiology. Several comprehensive reviews of this research have been published in the last few years. (Cherry, 2002) (Davinipour and Sobel, 2007) (Davanipour and Sobel, 2009)

Performing large long-term studies of RF effects on humans in a sleep laboratory setting would be prohibitively difficult both logistically and financially. But several recent laboratory studies in animals have demonstrated suppression of melatonin by prolonged pulsed microwave RF exposures.

Kesari et al. exposed Wistar rats to 2.45 GHz mobile phone transmissions, 2 hours daily for 45 days, at a calculated SAR of 0.9 W/Kg. Pineal melatonin levels were significantly reduced in exposed animals. (Kesari et al., 2011)

Kumar et al. repeated this experiment with 2.5 GHz exposures of 2 hours per day for 60 days, at a much lower exposure level (power density of 0.21 mW/cm^2, calculated SAR of 0.014 W/kg). Even at this low level of exposure (= 210 mW/cm^2), serum melatonin levels were significantly reduced in exposed animals. (Kumar et al., 2011)

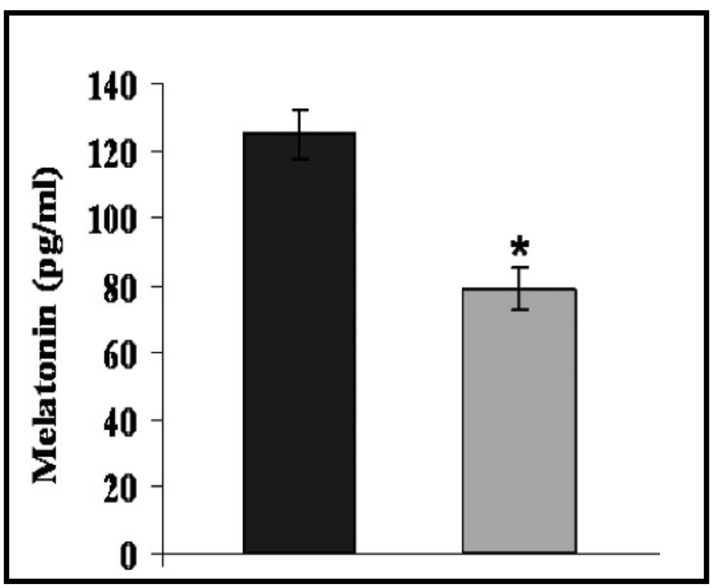

Figure 4: Serum melatonin levels in sham (black) and exposed (grey) Wistar rats after 2 hours daily exposure for 60 days to 2.45 GHz RF transmission at 0.21 milliwatts/cm^2. (from Kumar et al., 2011)

In another study, Kesari found significant reduction in pineal melatonin levels in rats exposed to 2.45 GHz mobile phone transmissions, 2 hours daily for 45 days, at a power density of 0.21 mW/cm^2 (calculated SAR of 0.014 W/kg). (Kesari et al., 2012)

CONSEQUENCES OF REDUCTION OF MELATONIN LEVELS BY MICROWAVE RF EXPOSURE

Reduction of melatonin levels by exposure to radio transmissions could be expected to cause sleep disturbance. Research findings like the Schwarzenburg studies strongly support this conclusion.

But melatonin has also been found to be protective against promotion of some types of cancer. If suppression of melatonin by "light at night" and night shift work can increase risk of breast cancer (as discussed above), then suppression of melatonin by radio transmissions could also be expected to increase cancer risk. Recently published research studies strongly support this conclusion.

A study in Israel found women living within 350 meters of a cell phone tower to have over 10 times greater risk of cancer than the community as a whole ($p < 0.0001$). (Wolf and Wolf, 2004)

A study of cancer patients in Germany found a 3.29 times greater risk of cancer ($p < 0.01$) in patients with residence closer than 400 meters to a cell pone tower. Risk of breast cancer was 3.4 times greater, and average age of diagnosis of breast cancer was 19 years earlier. (Eger et al., 2004)

In a case/control study of cancer patients residing near a cell phone transmission tower in Austria, those with external residential exposures of greater than 1000 $\mu W/m^2$ (> 0.1 $\mu W/cm^2$) had a a breast cancer risk that was 23 times higher ($p = 0.0007$) and brain tumor risk was 121 times higher ($p = 0.001$) than controls. (Oberfeld, 2008)

A recent study from Brazil found a clearly elevated relative risk of cancer mortality at residential distances of 500 meters or less from cell phone transmission towers. (Dode et al., 2011)

Several recent published reviews discuss the multiple epidemiologic studies that have shown an association between residential RF exposure from microwave transmission towers and increased breast cancer risk. (Cherry, 2005) (Khurana et al., 2010) (Levitt and Lai, 2010) (Yakymenko et al., 2011) We will discuss this issue more thoroughly in Section 3.

RAISING THE LEVEL OF RADIOFREQUENCY TRANSMISSION IN RESIDENTIAL NEIGHBORHOODS CARRIES SIGNIFICANT RISKS

Unlike visible light, microwave radio transmissions penetrate walls and human bodies. They are not easily blocked out by window blinds or eye shades. If microwave radio waves can disrupt melatonin secretion in a portion of the population, then a significant increase in nocturnal RF transmission levels in a residential neighborhood would be expected to produce an increase in sleep problems, and over the long run, an increase in the incidence of breast and prostate cancer. The first evidence of such an effect would be a significant increase in complaints of sleep disruption. It might require several years of exposure for the increase in cancer incidence to reveal itself.

If we use complaints of sleep disruption as a marker for this effect, we can suspect that the recent installation of MESH-networking smart meters in California and in other municipalities around the world has pushed many residential areas across a threshold, producing chronodysruption in a significantly increased portion of the population. The early evidence for this is that these smart meter rollouts have been followed by a dramatic increase in complaints of sleep difficulties received by physicians, by public utility commissions, and in postings on the internet.

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RADIOFREQUENCY EXPOSURE INCREASES OXIDATIVE STRESS AND DAMAGES DNA

Over the past 20 years, a great deal of research evidence has accrued which demonstrates that EMF and RF can alter cellular physiology.

INDUCTION OF STRESS PROTEINS

When cells are stressed in a way that damages DNA in cells, an early response of the cellular physiology is to increase the production of proteins involved in the repair of these structures. These repair proteins are called stress proteins or "heat shock" proteins (since early research models used heat to stress the cells). Increased production of these proteins are direct evidence of physiologic stress and damage to cell DNA, as they represent the effort of the cell to protect against and repair that damage.

The physiologic stressors that trigger this response stimulate specific regions on the cell's chromosome. These regions initiate the transcription of the stress response genes that encode for these repair proteins.

In the late 1990's research demonstrated that EMF exposures can produce these stress proteins. (Lin et al., 1997) (DiCarlo et al., 1998)

Further research demonstrated that EMF/RF stimulation promotes gene transcription at different promotion sites than those triggered by heat stress (Lin et al., 1998) (Lin et al., 1999), and that this promotion by EMF/RF can occur at power levels that are not high enough to produce thermal changes in the cells. (DiCarlo et al., 1999) (Weisbrot et al., 2003) (Blank and Goodman, 2004) (Blank, 2007)

Subsequent research has shown that at DNA transcription sites activated by low level EMF and RF exposure, higher levels of exposure can lead to single or double strand breakage of the DNA chain. (Blank and Goodman, 2009)

Current research confirms production of the stress protein response by microwave signals in the 900 MHz and 1800 MHz bands. (Cao et al., 2011) (Jiang et al., 2012) (Calabro et al., 2012)

DNA DAMAGE

Many research studies performed in the last decade have demonstrated that radio frequency radiation at nonthermal levels can produce fragmentation of DNA.

In 2003, Ivancsits reported that intermittent low frequency EMF could cause single and double strand breaks in DNA at magnetic flux densities as low as 35 microtesla, well below levels producing thermal effects. Effects were time and dose dependent. (Ivancsits et al., 2003)

This work was confirmed in 2004 in a study showing that 24 to 48 hour exposures to a 0.01 mT 60 hz magnetic field could produce single and double strand DNA cleavage, apoptosis, and necrosis of brain cells in rats. These effects could be blocked with antoxidants, suggesting that free radicals played a role in the damage process. (Lai and Singh, 2004)

Subsequent research demonstrated that these effects also could be produced by nonthermal effects of radiofrequency microwave exposures—at power levels that were below the levels producing thermal effects—and that this nonthermal damage could be prevented by administration of antioxidant free radical scavengers. (Adlkofer, 2006)

The results of in vitro studies on DNA damage from EMF/RF are variable, since different cell types have different sensitivities to these effects. (Schwarz et al., 2008) Several detailed reviews of these studies have been published in the last five years. These reviews document multiple studies showing production of DNA damage at low power densities, with more prolonged exposure times producing more significant effects. (Lai, 2007) (Ruediger, 2009) (Phillips et al., 2009) (Levitt and Lai, 2010)

Current research continues to validate these findings. For example, Cam and Syhand found an increase in the production of single strand DNA breaks in hair root cells following 15 to 30 minutes of mobile phone use. (Cam and Seyhan, 2012)

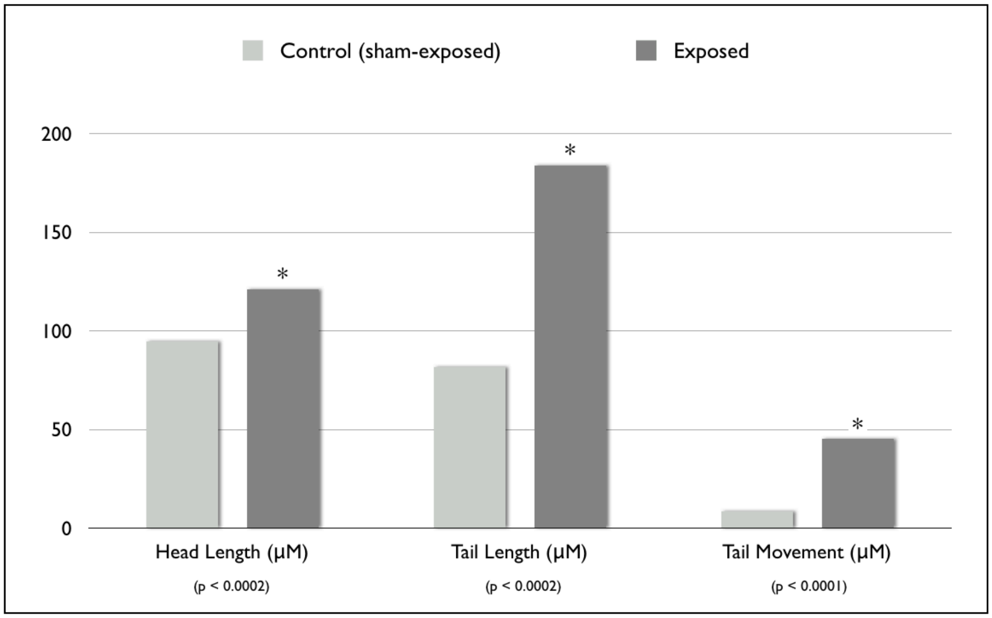

Figure 1: Comet Assay of DNA fragmentation in rat brains, produced by prolonged exposure to microwave RF. (Kesari et al., 2010a)

Kesari et. al. exposed Wistar rats to 2.45 GHz frequency at 0.34 mW/cm^2 power density (340 µW/cm^2, whole body SAR ~ 0.11 W/Kg), 2 hours a day for 35 days, and demonstrated increased double strand DNA breakage ($p \leq 0.0002$) in brain tissue. This was accompanied by decreased activity levels of glutathione peroxidase ($p < 0.005$) and superoxide dismutase ($p < 0.006$), and increased catalase activity ($p < 0.006$) suggesting that the microwave exposure produced severe oxidative stress. (Kesari et al., 2010a)

Kumar et. al. exposed Wistar rats to 50 GHz continuous source microwave transmission, 2 hours a day for 45 days, with a power density of 0.86 µW/cm^2 (calculated SAR 8.0 x 10^{-4} W/kg). Other rats were exposed to 10 GHz, 2 hours a day for 45 days, power density 0.214 mW/cm^2 (214 µW/cm^2, SAR 0.014 W/kg). Both forms of exposure produced significantly altered levels of reactive oxygen species, antioxidant enzyme activity, and blood cell micronuclei formation, demonstrating the production of oxidative stress with genotoxic effects. (Kumar et al., 2010)

RF EXPOSURE PRODUCES OXIDATIVE STRESS

It is a truism among apologists for the telecommunications industry that microwave radiofrequency transmissions cannot possibly cause cancer, because the energy of a photon of this wavelength is not powerful enough to directly break an ionic bond the way an xray can, and therefor could not possibly cause mutations in DNA. Such an argument sounds like good physics, but it isn't good biology. Ionizing radiation is only one way to cause the mutations in DNA that can produce cancer.

Chronic inflammation can cause cancer. Cigarette smoke can cause cancer. Toxins and autoimmune disease can cause cancer. One common pathway shared by these causes is that they produce an inflammatory response in the body that increases the activity of free radicals (reactive oxygen species). These free radicals produce oxidative damage in the tissues.

This oxidative activity is the tool that our bodies use to destroy foreign bacteria, which can be completely broken up—DNA and all—and digested by our immune system. Free radicals are an important defensive weapon for our bodies, but an excess of oxidative activity can lead to damage of our own tissues. Such excesses have been associated with many chronic problems including autoimmune disease, heart disease, and some forms of cancer. Every week another article is published suggesting that taking antioxidants may be protective against some of these problems.

The mechanisms through which EMF/RF increase oxidative stress in living tissues have not been clearly elucidated, although some ideas have been proposed. (Liboff, 2010) (Georgiou, 2010)

But in the last decade, the scientific research clearly established that EMF and RF exposure cause an increase in reactive oxygen species in living tissues, leading to oxidant damage of DNA. (Shiroff, 2008)

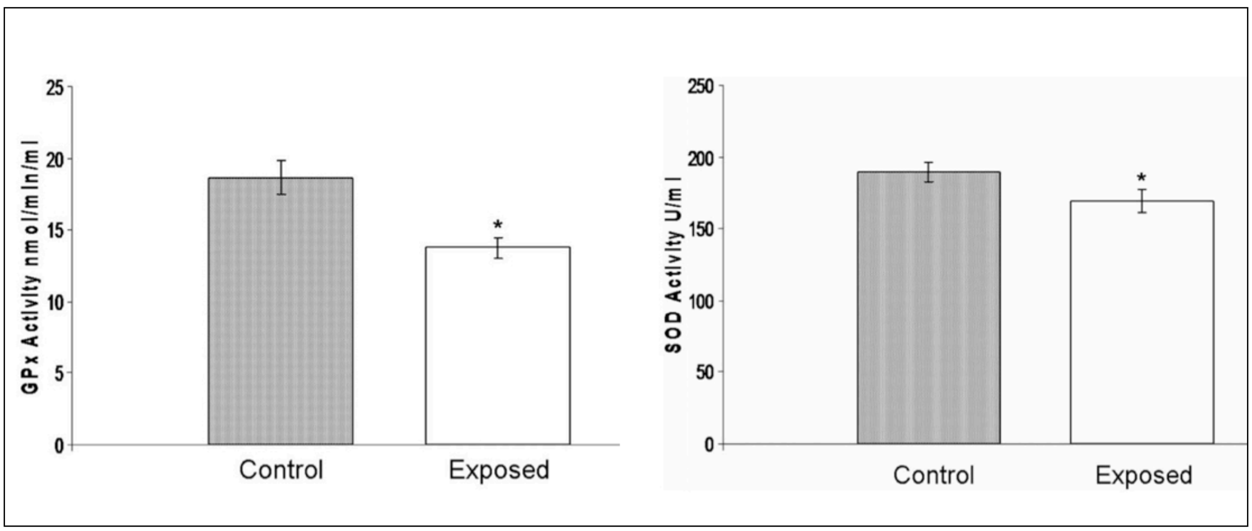

Figure 2: Depletion of antioxidants in RF-exposed rat brains, after exposure to 2.45 GHz, 2 h a day for 35 days at 0.34 mW/cm2 power density, 2.45 GHz frequency. (Kesari et al., 2010a)

Studies cited above document that microwave RF exposures at very low power densities produce oxidant stress accompanied by DNA damage. (Kesari et al., 2010a) (Kumar et al., 2010)

Other recently published studies also show that RF exposure can increase oxidant stress and tissue damage in brain tissue (Maaroufi et al., 2011) (Avci et al., 2012), liver tissue (Guler et al., 2012), white blood cells (Lu et al., 2012), and human salivary glands (Hamzany et al., 2012).

SUPPRESSION OF MELATONIN SECRETION COMPOUNDS THE PROBLEM.

The problems caused by increased oxidative stress from EMF/RF are compounded by the fact that EMF/RF can also suppress melatonin secretion by the pineal gland, since melatonin is one of the most potent antioxidant molecules produced in the body.

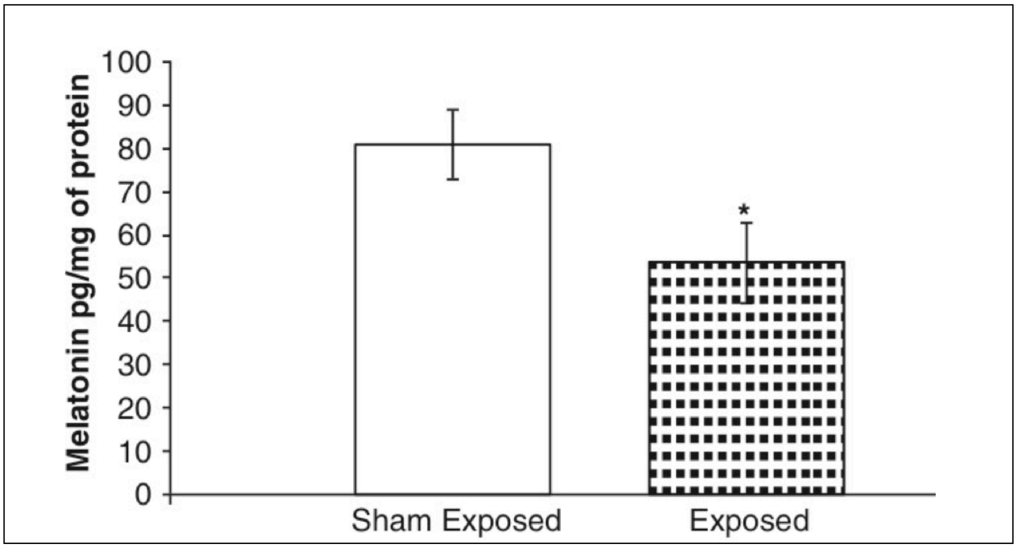

Figure 3: Suppression of melatonin secretion by 2.45 GHz RF, 2 hours a day for 45 days at 0.21 mW/cm2. (Kesari et al., 2012)

In recently published study, Kesari et. al. exposed Wistar rats to 2.45 GHz microwave radio transmission, 2 hours a day for 45 days, at a power density of 0.21 mW/cm^2 (210 $\mu W/cm^2$, whole body SAR ~ 0.14 W/kg). Pineal melatonin was significantly decreased in the exposed group. (Kesari et al., 2012)

Multiple studies have documented that exposure to microwave RF can reduce melatonin levels in animals and in people. (see Section 3).

CONSEQUENCES OF OXIDATIVE DAMAGE TO DNA

EVIDENCE FOR CANCER

When DNA is damaged, the body attempts to repair it. Errors in DNA coding sequence produced during the repair process can produce mutations. And it is hypothesized that such mutations in DNA are a major cause of cancer.

So if radio frequency (RF) and microwave (MF) exposure increase oxidative damage to DNA, we would expect to see evidence that chronic RF exposure increased the rate of some forms of cancer. A significant body of epidemiologic research in a variety of exposure settings suggests that this is indeed the case.

Electronics technicians

In the 1980's, Milham published evidence of increased leukemia in electrical workers (Milham, 1985b)

Another study of workers in the electronics industry found an increased risk of brain tumor associated with exposure to microwave radio transmission, with a highly significant increase in risk in those with more than 20 years of exposure. (Thomas et al., 1987)

A case/control study of brain cancer deaths in Maryland found a threefold greater brain cancer incidence in electrical or electronic engineers and technicians, compared to the reference population. (Lin et al., 1985)

A study of leukemia rates in different occupational groups in the U.S. Navy showed increased leukemia risk in electrician's mates. (Garland et al., 1990)

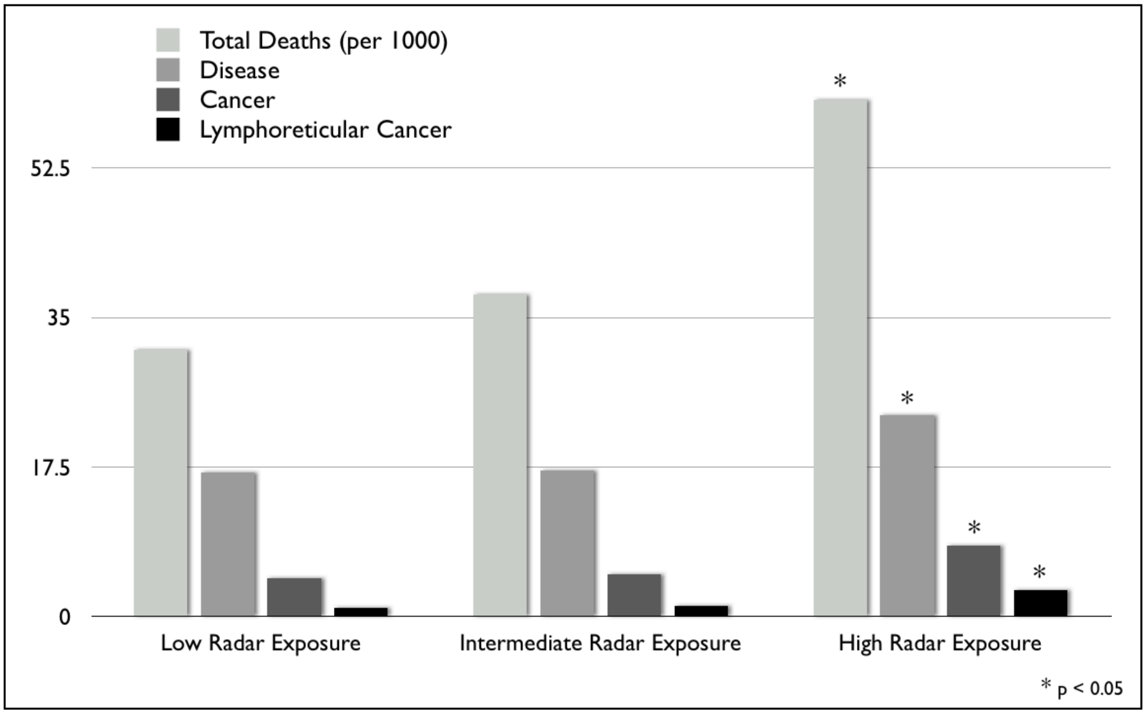

Figure 4: Mortality (1950–1974) in U.S. Navy Korean War Veterans, stratified by in-service levels of occupational radar exposure. (Cherry, 2002a, after Robinette, 1980)

A study performed for the U.S. military published data comparing a cohort of 20,000 Korean War veterans with higher occupational exposure levels to RF/MW exposure to 208,000 Korean war veterans with minimal occupational exposure during their service years. Mortality statistics were reviewed for the interval between 1950 and 1974. (Robinette et al., 1980) This data shows that the group with the highest rated occupational exposure level (aviation electronic technicians) had a significantly higher total death rate during the study period, and a higher death rate from disease, from malignancy, and from lymphatic and hematopoetic malignancies. (Goldsmith, 1997a)

A study of Polish career military personnel from 1971 – 1985 showed double the risk of cancer in personnel with occupational exposure to RF/MW transmission, as compared other personnel. The exposed cohort had higher morbidity rates for GI cancers (Observed versus Expected Ratio = 3.19 – 3.24), brain tumors (OER = 1.91), and hematopoetic malignancy (OER = 6.31), including chronic myelocytic leukemia (OER = 13.9), acute myeloblastic leukemia (OER = 8.62), and non-Hodgkin's lymphoma (OER = 5.82). (Szmigielski, 1996)

Radio Operators

Increased rates of acute myeloid leukemia and of other lymphatic malignancies have been found in large population based studies of amateur radio operators (Milham, 1985a) (Milham, 1988a) (Milham, 1988b).

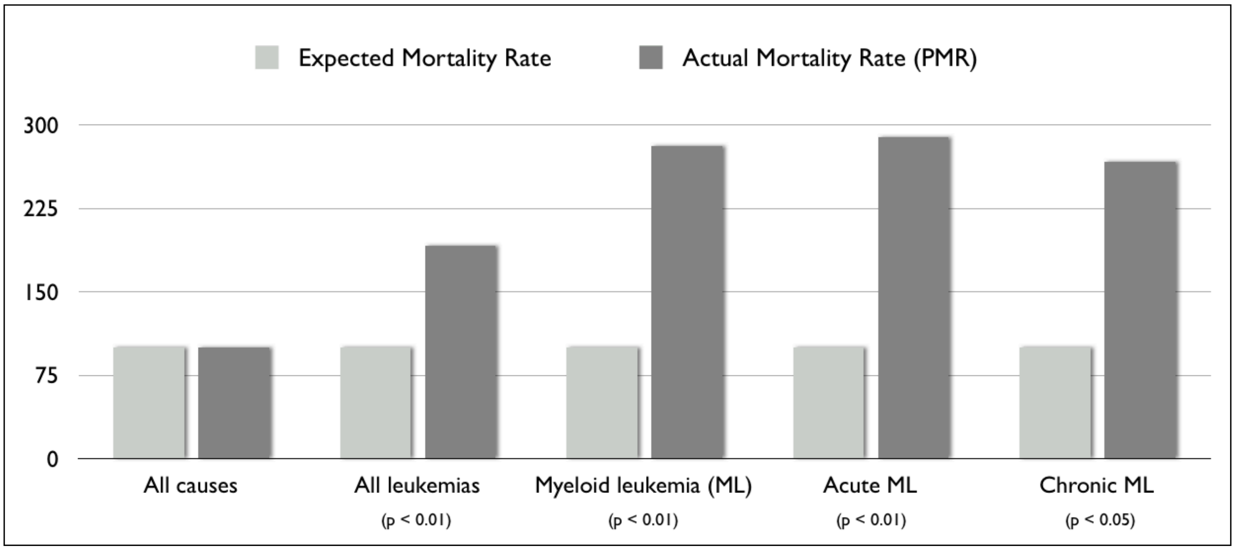

Figure 5: Analysis of leukemia deaths in male members of the American Radio Relay League resident in Washington and California, 1971 – 1983. (Milham, 1985a)

Another study of female radio and telegraph operators in Norway found an increased incidence of breast cancer in this group as compared to the standardized incidence rate in the female population of that country. (Tynes et al., 1996)

Police radar operators

Two studies have shown increased rates of testicular cancer (Davis and Mostofi, 1993), and of testicular cancer and melanoma (Finkelstein, 1998) in police officers with occupational exposure to handheld radar.

Airline pilots

Airline pilots have significant occupational exposure to RF/MF (radio frequency and microwave frequency) transmissions.

A study of U.S. Air Force personnel showed an increased risk of brain tumors associated with increasing rank, and associated with estimated exposures to both microwave radio and low frequency radio transmissions. No increased risk associated with exposure to ionizing radiation was found in this study population. (Grayson, 1996)

A study of commercial airline pilots in Iceland found an increased risk of malignant melanoma. (Rafnsson et al., 2000) Another study with Danish pilots showed increased risk of total cancer, melanoma, other skin cancers, and acute myeloid leukemia in commercial airline cockpit crews. (Gundestrup and Storm, 1999) Neither of these studies specifically controlled for RF/MF exposures as compared to other exposures (cosmic rays, tropical sun on the beach, etc.) incurred by flying personnel.

However, an extensive study of German commercial airlines crews (including 6,017 cockpit and 20,757 cabin crew members) showed an increased brain cancer risk for cockpit crew and an increased all cancer risk for cockpit crew with more than 30 years employment compared to those with under 10 years of employment. Notably, these increased risk were not found in cabin crew members, who share equal exposure to cosmic rays and tropical beaches, but are farther from the radios. (Zeeb et al., 2010)

U.S. Embassy Moscow 1953 – 1976

From the 1950’s to the mid-1970’s the U.S. Embassy in Moscow was exposed to a constant low intensity radar signal, as a form of harassment by the Russian government. The exposure level on the outside of the west facade of the building was measured at 5 microwatts/cm^2, and was present for 9 hours a day. Since the wall and windows attenuated the signal, inside exposure levels were likely to be in the range of 0.02 to 0.1 μW/cm^2.

The State Department contracted an epidemiologic analysis potential health effects on exposed personnel and their dependents, which was performed by A.M. Lilienfeld M.D., and epidemiologist at John's Hopkins University. This report was published including all of the tabulated raw data. (Lilienfeld AM, 1979)

The report as finally released stated as a conclusion that personnel "suffered no ill effects" from the microwave exposure. However, the published conclusions differed from the original conclusions written by Dr. Lilienfeld, and evidence suggests that the final conclusions were "whitewashed". (Goldsmith, 1997b) One can presume that this might have been done to avoid embarrassment of the federal government, since any harm, if produced, would have been produced at levels of exposure orders of magnitude less than those exposure levels permitted by United States FCC guidelines.

A hematologic study performed on employees at the Moscow embassy was submitted to the U.S. government in October, 1976. This study showed significant abnormalities in hematologic parameters in this group, in comparison with studies of foreign service workers in the United States. (Goldsmith, 1997a)

The published data from the Lilienfield study of Moscow embassy workers and their dependents has subsequently been analyzed by other epidemiologists and found to show a statistically significant increase in total adult and childhood cancers, in breast cancer, and in childhood leukemia. (Goldsmith, 1995) (Cherry, 2002a)

Residential exposure to Radio/TV Transmission towers

By the late 1990's, a significant body of epidemiologic literature had accumulated that demonstrated an association between exposure to radar and RF radiation and the occurrence of certain types of cancer.

Evidence for association between radio transmission tower exposures and adult and/or childhood leukemia has been reported in studies from Hawaii (Maskarinec et al., 1994) and Australia (Hocking et al., 1996).

A study from England shows an increased risk of adult leukemia in those residing within two kilometers of the transmission tower, and decreased risk of leukemia, skin cancer, and bladder cancer with increased distance of residence from the tower. (Dolk et al., 1997b) A follow-up study involving multiple other sites in England also showed a statistically significant decline in risk of adult leukemia with increasing distance of residence from transmission sites. (Dolk et al., 1997a) (Hocking et al., 1998)

A study in Rome evaluated the incidence of adult and childhood leukemia as a function of residential proximity to the Vatican Radio transmission tower. Pediatric leukemia cases were more common than expected at less than 6 kilometers from the tower, and significantly elevated in adult men living within 2 km of the tower. Adult male leukemia mortality and childhood leukemia rates showed a significant decrease with increasing distance between tower and residence. (Michelozzi et al., 2002)

A study of cancer incidence in proximity to the Sutro radio/TV tower in San Francisco also showed a strong correlation of exposure and incidence of several types of childhood cancer. (Cherry, 2002b) This study was notable for its rigor in analyzing the actual exposure levels around the tower in relation to the data set. Power density/

exposure levels around UHF and VHF broadcasting antennae are not distributed in a simple and symmetrical regression ("with the square of the distance"). Transmission exposure levels form a series of peaks and valleys around these antennae, and the antennae can be arranged to focus more power in one direction than another, aiming a stronger signal at the target audience in a population center. Studies that fail to take this distribution into account and assume that exposure is in direct ratio to distance will mix higher and lower exposure groups together, diluting the power of the study and underestimating true risk in relation to exposure.

In another paper, Dr. Cherry analyzes this issue in detail, and uses his more rigorous approach to review and refine the analysis of data from many of the earlier studies on health effects of radio/TV broadcast towers. His analysis strengthens the evidence for increased cancer risk from these exposures. (Cherry, 2002a)

A large population case/control study in south Korea looked at 1928 leukemia patients and 956 brain cancer patients under 15 years of age who were diagnosed between 1993 and 1999 at 14 large hospitals in Korea. These cases were matched with 3082 age matched patients who received respiratory disease diagnoses (primarily asthma) at the same hospitals during the study period. Case and control exposure levels were calculated for 31 transmitters in South Korea that had a transmission power greater than 20 kW, using a mathematical model that was correlated with field testing. Children residing within 2 kilometers of a transmission tower had a significantly increased risk of leukemia as compared to children with residence greater than 20 km from the tower (OR 2.15, 95% CI = 1.00 to 4.67). (Ha et al., 2007)

Residential Exposure to Cell Phone Tower (Base Station) Transmissions

With the dramatic rollout of commercial cell phone service in the 1990's, large segments of the population became exposed to significantly higher levels of microwave RF exposure due to the installation of cell phone towers in urban areas. Several recent papers have reviewed the significant evidence for ill effects from these urban exposures. (Khurana et al., 2010) (Yakymenko et al., 2011) (Kumar, 2010)

Netanyu, Israel

Wolf and Wolf studied rates of cancer incidence during the second year of operation of a 1500 watt 850 MHz cell phone tower in Netanya, Israel. The study group was composed of 622 individuals who had lived in area A, within 350 meters of the tower, for the previous 3 to 7 years. A control group of 1,222 individuals living in an outlying area B was also studied.

During the study year, 8 cases of cancer occurred in the study group, and 2 cases occurred in the control group. The cancer rate for the entire town was 31 cases per 10,000. Relative cancer rates for females was 10.5 for the study group, 0.6 for the control group, and 1.0 for the town as a whole ($P < 0.0001$).

Signal power densities of the tower's transmissions in the homes of the cancer cases ranged from 0.3 – 0.5 $\mu W/cm^2$. [note that FCC limits are 600 – 1000 $\mu W/cm^2$.]

In the year following the close of the study, another 8 new cases of cancer occurred in area A, and another 2 cases occurred in area B. (Wolf and Wolf, 2004)

Naila, Germany

A cell phone transmission tower was placed in the town of Naila, Germany, in 1993. Eger, Hagen, et. al. reviewed the medical health records from 1994 to 2004 for around 1000 residents of the municipality (roughly 90% of the population). All included patients had been living at the same address during the entire 10 years of observation.

Over the course of the entire study period, patients living in an inner area within 400 meter of the transmission tower had 2.27 times the relative risk of cancer incidence, compared to patients living more than 400 meters from the tower ($p < 0.05$). Cancer patients in the inner residential area also developed cancer an average of 8.5 years earlier in life than did cancer patients residing in the more distant area.

For the years 1999 to 2004 (after 5 years of tower operation) the relative risk of cancer incidence in residents less then 400 meters from the tower increased to 3.29 ($p < 0.01$). Relative risk of breast cancer was 3.4 in the inner area, where average age of diagnosis was 50.8 years, compared to 69.9 years in the outer area. (Eger et al., 2004)

Hausmannstätten and Vasoldsberg, Austria

Oberfeld performed a case/control study of cancer patients in the municipalities of Hausmannstätten and Vasoldsberg, Austria. All subjects had resided within 1,200 meters of an analogue cell phone tower that operated between 1984 and 1997 in the municipalities.

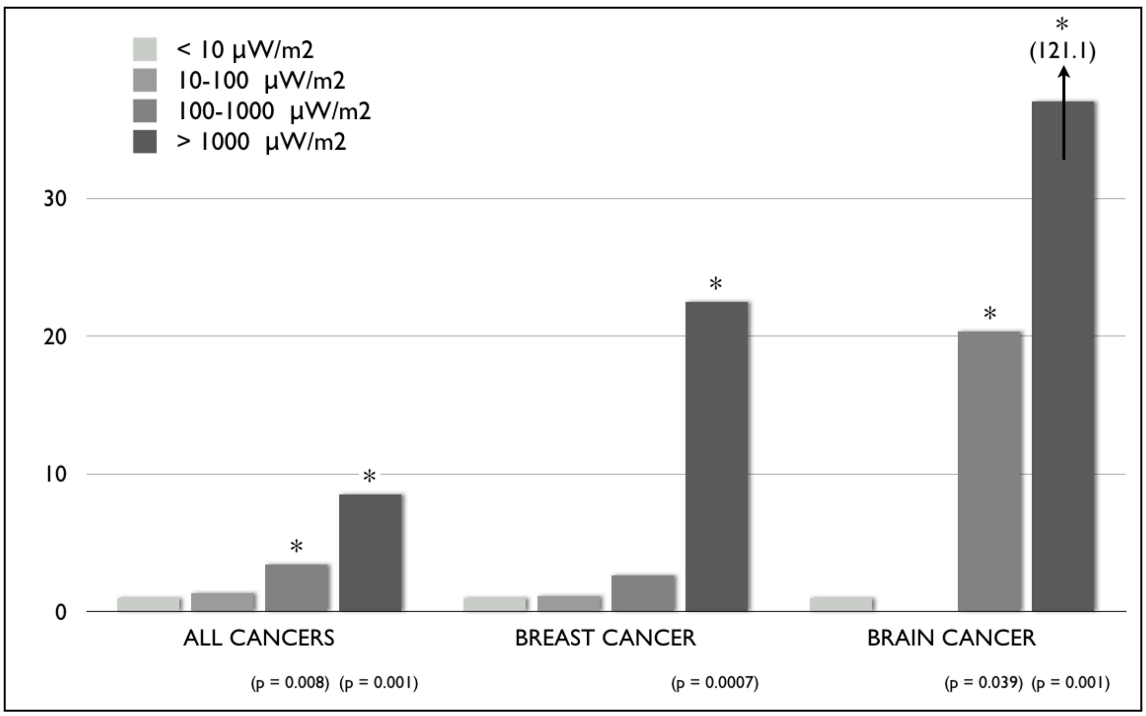

Figure 6: Odds ratio of cancer incidence, stratified by exposure levels (exterior to dwelling) in µW/m². (Oberfeld, 2008)

Residential outdoor exposure levels were measured, and three different case/control groups were assessed, for case exposure levels outside the residence of 10 – 100 µW/m² (= 0.001 – 0.01 µW/cm²)), 100 – 1000 µW/m² (= 0.01 – 0.1 µW/cm²), and greater than 1000 µW/m² (> 0.1 µW/cm²). respectively. The reference exposure level for the control group was less than 10 µw/m² (= 0.001 µW/cm²). [Note that FCC thermal safety limits are 6,000,000 to 10,000,000 µW/m².]

Cancer risk for all cancers was significantly elevated for all three elevated exposure categories, and was 5 to 8 times higher in the >1000 µW/m² (> 0.1 µW/cm²) category (p=0.001). In this highest risk group, breast cancer risk was 23 times higher (p = 0.0007) and brain tumor risk was 121 times higher (p = 0.001). (Oberfeld, 2008)

Belo Horizonte, Brazil

Dode et. al. studied deaths from cancer in the city of Belo Horizonte in southern Brazil from 1996 to 2006. This city of over 2 million inhabitants was rated by the United Nations in 2007 as having the best quality of life in Latin America. The researchers used the database of deaths by neoplasm of the City Health Department, the database of cell phone base station sites from the Brazilian Telecommunications Agency, and a database of the city census and demographics. Exposure duration was calculated from the date of installation of the first antenna to which the individual had been exposed, and residential distance from that exposure was calculated in 100 meter increments.

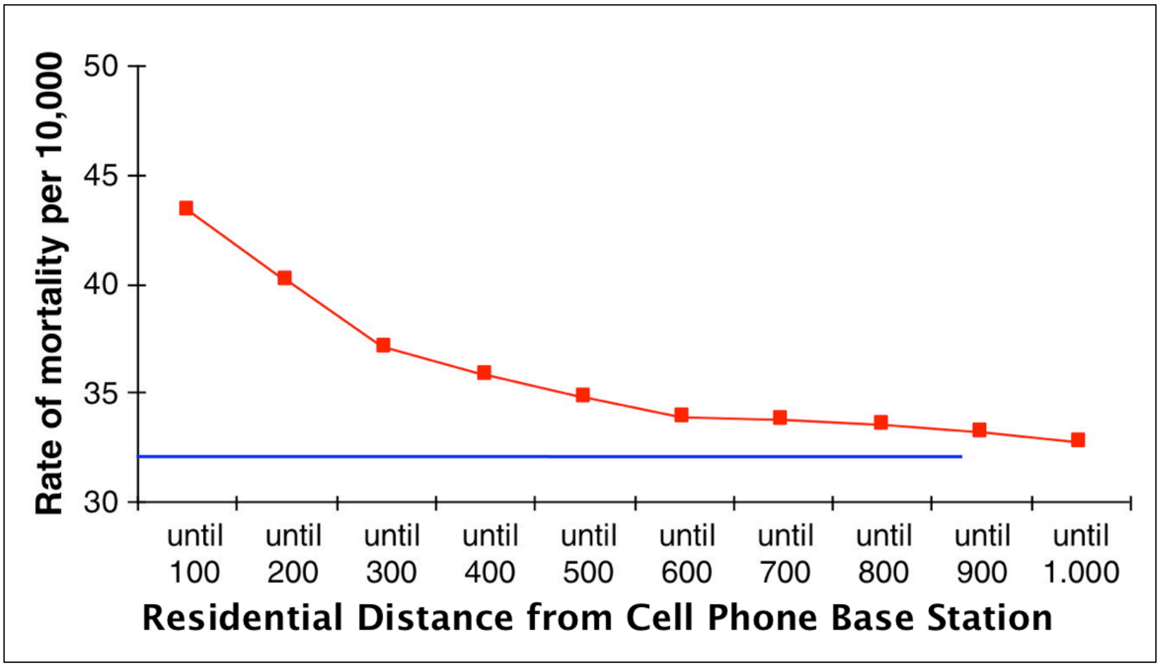

Figure 7: Cancer death rate as function of residential proximity to cell phone transmission towers in meters. Horizontal line = null hypothesis. (Dode et al., 2011)

The highest concentration of base stations was in the south central part of the city. In 2008, environmental monitoring of microwave radiation was performed at 400 sites, measuring frequency bands between 800 MHz and 1800 MHz. Signal intensity averaged 7.32 V/m (~ 14.2 μW/cm^2), with a range from 0.4 to 12.4 V/m (~ 0.04 to 40.7 μW/cm^2). These intensity levels are well below the ICNIRP guidelines for microwave radiation exposure, which are based on protection against thermal effects.

Analysis of the data showed that cancer mortality rates were higher near the cell phone transmission towers. Within the range of 100 meters of a tower, the mortality rate was 43.42 persons per 10,000 (compared to a rate of 32.12 per 10,000 for the city as a whole), with a relative risk of 1.35.

The mortality rate reduced in proportion to residential distance from cell phone tower. Relative risk of cancer mortality was clearly elevated at residential distances of 500 meters or less from a cell transmission tower (base station, or BS) as illustrated in Figure 7. (Dode et al., 2011)

Taiwan

Li et. al. performed a case/control study of 2606 children age 15 or less who were diagnosed with a neoplasm in Taiwan between 2003 and 2007. Each case was matched with 30 controls. Residential exposure of cases and controls was calculated based on the annual power density in watt-years per kilometer squared for each of the 367 townships in Taiwan, averaged out for the 5 year period prior to diagnosis in the township where the subject resided at time of diagnosis.

This study is notable for the large number of cases and controls, which should increase the power of the study. On the other hand, if elevated microwave exposure is associated with cancer risk, assuming that power density of cell phone tower transmissions is constant throughout each township would serve to minimize the effects of higher exposure levels closer to the towers, minimizing the distinction between higher and lower cohorts, and diluting the power of the study.

Case/control analyses were performed for "all cancer types", for leukemia, and for brain neoplasm. Odds ratio for cases of "all cancer types" with calculated exposure greater than median exposure value of controls were significantly elevated at 1.13 (95% CI = 1.01 to 1.28). Odds ratio for cases of leukemia with calculated exposure greater than median exposure value of controls were elevated at 1.23 (95% CI = 0.99 to 1.52). Odds ratio for cases of brain neoplasm with calculated exposure greater than median exposure value of controls were slightly elevated at 1.14 (95% CI = 0.83 to 1.55). (Li et al., 2012)

EVIDENCE FOR IMPAIRMENT OF FERTILITY

Toxic exposures that damage DNA can cause cancer. They can also cause damage to the production of healthy eggs and sperm, leading to infertility. If microwave RF exposure causes oxidative damage to DNA, this should lead to measurable alterations in function of reproductive function and fertility. Current research is beginning to prove the presence of this effect.

Laboratory studies in insects

In 2004, Panagopoulos et. al. demonstrated that exposure to a modulated GSM 900 MHz cell phone signal for 6 continuous minutes daily for two days decreased the fertility of both male and female fruit flies (Drosophila melanogaster). Exposure power density was ~ 0.436 milliwatts/cm^2 (= 436 µW/cm^2). (Panagopoulos et al., 2004)

In a later study, Panagopoulos et. al. exposed Drosophila fruit flies to a cell phone transmitting GSM 900 MHz at 0.40 mW/cm^2 (= 400 µW/cm^2—Group 1) or GSM 900 MHz at 0.29 mW/cm^2 (= 290 µW/cm^2—Group 2), or DCS 1800 MHz at 0.29 mW/cm^2 (= 290 µW/cm^2—Group 3). Transmission exposures were 6 consecutive minutes per day for six days. The exposure induced fragmented DNA during oogenesis. Cell death scores in the ovaries of female flies were 63% in Group 1, 45% in Group 2, and 39% in Group 3, as compared to 7.8% in the sham and control groups. (Panagopoulos et al., 2007)

Subsequent research exposed Drosophila fruit flies to GSM 900 MHz or DCS 1800 MHz signals for signal durations of 1 to 21 minutes a day for five consecutive days, at a power density of 10 µW/cm^2. Impairment of fertility increased linearly with duration of exposure (see figure 2). Even at 1 minute of exposure a day, fertility was significantly decreased in exposed versus sham exposure specimens ($p < 0.00001$). (Panagopoulos and Margaritis, 2010)

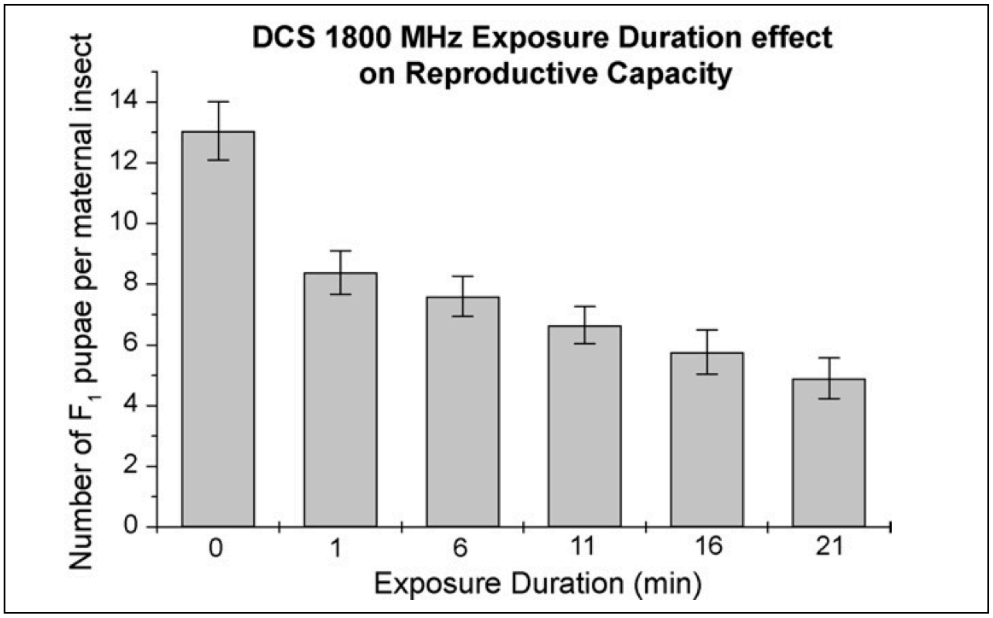

Figure 8: Decreased fertility of fruit flies at exposure level of 10 μW/cm².
(Panagopoulos and Margaritis, 2010)

In another study using a GSM 900 MHz cell phone signal at 0.35 mW/cm² (= 350 μW/cm²), six minutes of daily exposure was divided into one, two, or three minute segments, spaced 10 minutes apart. This was compared with one 6 minute constant exposure and with two 3 minute exposures spaced 6 hours apart. DNA damage and cell death in the intermittent exposures sequenced 10 minutes apart was essentially the same as with the constant 6 minute exposure ($p > 0.92$), and markedly higher than in the sham group ($p < 10^{-8}$). The group with divided exposures 6 hours apart had less cell death than the more frequently exposed group, but still showed significantly higher infertility than the control group ($p < 0.002$). (Chavdoula et al., 2010)

In yet another study, the Panagopoulos group evaluated influence of GSM 900 MHz and 1800 MHz cell phone transmissions on Drosophila fertility using exposures of 6 minutes per day for 6 days, at exposure distances varying from 0 to 100 cm. They were able to demonstrate an adverse effect on fertility for all exposures at all power densities greater than or equal to 1 μW/cm². (Panagopoulos et al., 2010)

Recently Panagopoulos published another study demonstrating that exposure to a GSM 900 MHz modulated cell phone transmissions at ~0.35 mW/cm² (= 350 μW/cm²) for 6 minutes during ovarian development can seriously retard ovarian maturation and reduce final size of ovaries in Drosophila fruit flies. (Panagopoulos, 2012)

Laboratory studies in animals

Magras and Xenos placed caged mice at various locations in an antenna park in Thessaloniki, Greece, at locations with RF power densities ranging from 168 nW/cm² (= 0.168 μW/cm²) to 1053 nW/cm² (= 1.053 μW/cm²). The mice lived in these locations for six months, during which time they were mated repeatedly. Numbers of newborns per litter decreased progressively, and ended with complete infertility by the fifth mating cycle. This infertility was not reversible with removal to an unexposed laboratory environment. (Magras and Xenos, 1997)

Meo et. al. exposed Wistar rats to cell phone transmissions for either 30 or 60 minutes a day for 3 months, and then measured serum testosterone levels. Testosterone levels decreased with increased duration of exposure, and the difference in testosterone level between subjects and controls was statistically significant in the 60 minutes per day group ($p < 0.02$) (Meo et al., 2010)

Otitoloju et. al. evaluated sperm head morphology in laboratory rats that were exposed to cell tower transmissions at two locations with mean RF exposure levels of 489 ± 43 mV/m (~ 0.6 μW/cm^2) and 625 ± 25 mV/m (~ 0.10 μW/cm^2). A control group was held in a laboratory with RF exposure levels of 59 ± 17 mV/m (~ 0.001 μW/cm^2). After six months of exposure, exposed rats showed mean sperm head abnormalities of 40% and 46%, versus 2% in control animals. (Otitoloju et al., 2010)

Kesari and Behari exposed male Wistar rats to 50 GHz continuous microwave radiation at a power density of 0.86 μW/cm^2 (calculated SAR 8 x 10^{-4} W/kg), 2 hours a day for 45 days. Sperm cells showed significant reductions of glutathione peroxidase and superoxide dismutase activity ($p \leq 0.05$) and increased catalase activity ($p < 0.02$), consistent with a significant increase in oxidative stress. Histone kinase activity was also increased ($p < 0.016$), and and significantly increased apoptosis (programmed cell death) and alteration in phases of sperm development were also present. (Kesari and Behari, 2010)

In a similar study, Kesari et. al. confirmed a significant increase in cell death through apoptosis, reduced sperm count, and reduced protein kinase C activity in male Wistar rats exposed to cell phone transmissions 2 hours daily for 35 days. Exposure power densities ranged from 0.1 – 2.0 mW/cm^2 (= 100 – 2000 μW/cm^2, calculated SAR 0.9 W/kg. (Kesari et al., 2010b)

In 2011 and 2012 Kumar and Kesari published four additional papers documenting the adverse effects of 10 GHz microwave exposure (2 hours daily for 45 days at power density of 0.21 mW/cm^2 (= 210 μW/cm^2, SAR 0.014 W/kg) on fertility in male Wistar rats. These studies document significant levels of pathological change including increases in reactive oxygen species, increased apoptosis (cell death) in sperm cells and altered sperm cell cycle (Kumar et al., 2011), increased free radical formation, decreased activity of glutathione peroxidase and superoxide dismutase, increased activity of catalase and malondialdehyde, decreased histone kinase (Kesari et al., 2011), reduced testosterone levels, shrinkage of seminiferous tubules and testicular size, distortion of sperm structure, decreased number and weight of progeny (Kesari and Behari, 2012), formation of micronuclei bodies in lymphocytes, DNA strand breakage, altered levels of histone kinase, altered percentage of spermatogenic phases, and (again) reduced testosterone levels and shrinkage of seminiferous tubules. (Kumar et al., 2012)

In 2012, Atasoy et. al. published a study of rats exposed to a WiFi router (802.11.g, 2.437 GHz) for 20 weeks, 24 hours a day. Histological and immunohistochemical examinations of the rats' testes showed evidence of DNA damage compared to controls ($p < 0.05$) and decreased activity levels of antioxidants (catalase and glutathione peroxidase, $p < 0.05$). (Atasoy et al., 2012)

Other animal studies

Experimental laboratory evidence clearly demonstrates that microwave RF radiation can adversely effect reproduction in insects and animals. Some evidence to support this is also available from studies of animals exposed to RF in their natural environment.

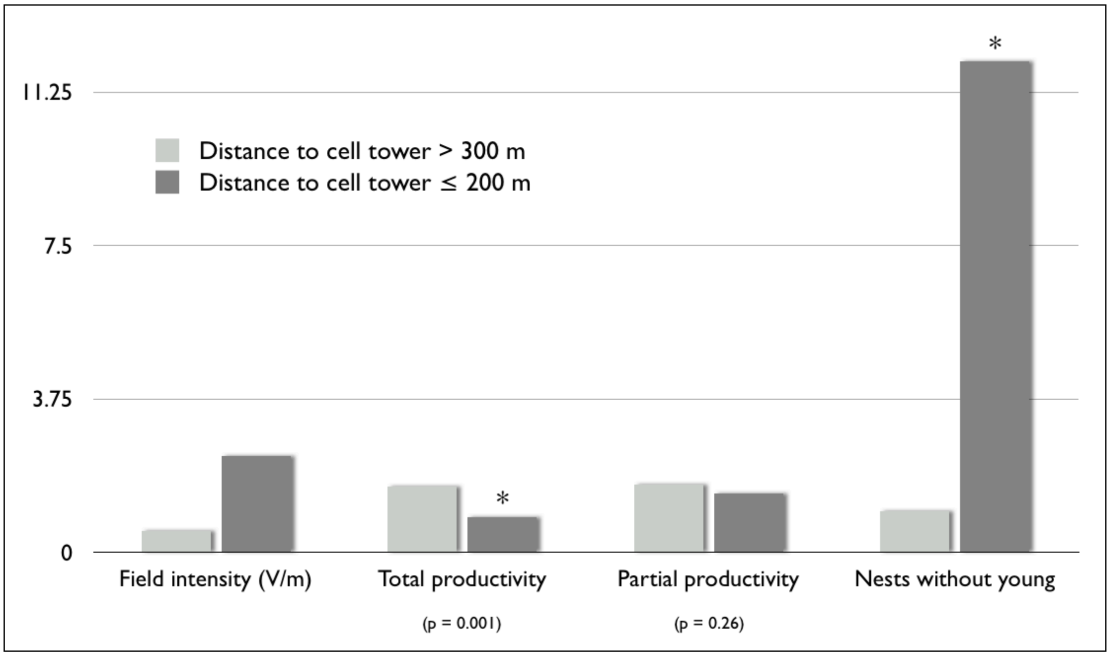

Figure 9: Impaired fertility in white storks nesting near cell phone towers. (Balmori, 2005)

Balmori studied a white stork population that was nesting near a cluster of cell phone towers in in Valladolid, Spain. Power densities at ground level ranged from 10 μW/cm^2 at 50 meters from the towers to 1 μW/cm^2 at 100 meters distance and a tenths of a μW/cm^2 at 150 to 200 meters distance. Total breeding productivity was significantly reduced at nests closer than 200 meters, compared to nests farther than 300 meters from the towers. (Balmori, 2005)

Balmori performed bird counts at 30 locations during 40 visits to Valladolid, Spain, over the interval between October 2002 and May 2006, and measured mean electric field strength at each counting site. Bird population density declined significantly over the observation period ($p = 0.0037$), and population density was significantly lower in areas with higher electric field strength ($p = 0.0001$). (Balmori and Hallberg, 2007)

Balmori also studied reproductive success of common frogs (Rana temporaria) at a breeding site 140 meters from a cluster of cell phone towers. Electric field intensities measured at 1.8 to 3.5 V/m (~0.9 to 3.2 μW/cm^2). Some eggs were in enclosures that were permeable to microwave radiation, and others were shielded in grounded Faraday cages. Exposed eggs showed asynchronous growth with varying tadpole size and a 90% mortality rate, while shielded eggs developed synchronously with a 4.2% mortality rate. (Balmori, 2010a)

Much more work needs to be done on in vivo studies of the effects of microwave cellular transmissions on animals and plants. Two reviews of the existing research have been published. (Balmori, 2009) (Balmori, 2010b)

Human studies

Human sperm counts have been declining for decades. In 1992 Carlsen et. al. published a meta-review of 61 studies published between 1938 and 1991, with 14,947 subjects. They found a decreased in mean sperm count from 113 million/ml to 66 million/ml ($p < 0.0001$) between 1940 and 1990, with a decrease in seminal volume from

3.40 ml to 2.75 ml ($p = 0.027$). Additionally, the percentage of men with sperm counts < 20 million/ml increased over this time period, while the percentage of men with sperm counts > 100 million/ml decreased. The incidence of testicular cancer increased between two and fourfold during this interval. (Carlsen et al., 1992)

Carlsen's analysis produced controversy initially. But subsequent analysis has shown that their results were essentially correct. Analytic approaches to their data set that refined the analysis to adjust for bias of various kinds have continued to support the validity of their conclusions. (Swan and Elkin, 1999)

In another meta-analysis, Swan et. al. looked at 54 of the most robust studies in the Carlsen data set, and at 47 additional studies, covering studies from 28 countries over a total time interval from 1934 to 1996. They found a rate of decrease in sperm counts of 0.80 million/ml per year in North America and 3.13 million/ml per year in Europe/Australia. (Swan et al., 2000)

And more recent studies have shown that this downward trend in sperm counts is continuing. Jorgensen et. al. found decreasing levels in sperm concentration, total sperm count, and percentage of morphologically normal sperm in Finnish men born in 1987 versus 1982 – 83 versus 1979 – 1981. (Jorgensen et al., 2011) Sperm counts in New Zealand sperm donors decreased 50% between 1987 and 2007, an average of 2.5% per year. (Shine et al., 2008)

In the early 1990's, it was hypothesized that this decrease in sperm counts and increase in testicular pathology might be due to exposure of male embryos to exogenous estrogens (DES, pesticide residues, plasticizers like Bisphenol A, etc.) early in development. (Sharpe and Skakkebaek, 1993) (Carlsen et al., 1995) (Irvine, 1997)

In 1994, Abell et. al. described higher sperm counts in members of a Danish organic farmer's association, as compared with Danish men who had occupational exposures to xenoestrogens. (Abell et al., 1994) Jensen et. al. found a 43.1% higher sperm concentration ($p = 0.033$) in 55 members of Danish organic foods associations who ate at least 25% organic foods, as compared with 141 normal controls. (Jensen et al., 1996)

Multiple studies in animal models have shown that in utero exposures to estrogenic chemicals can alter testicular health and function. Regional variations in sperm count and testicular cancer rates suggest the possibility of environmental influences. A recent paper by Nordkap et. al. reviews current perspectives on this subject. (Nordkap et al., 2012)

On the other hand, estrogenic xenobiotic chemicals have been present in the food chain since the 1950's. Adverse clinical effects of these exposures have been discussed since the early 1960's. (Randolph, 1962) Unless the human body burden of these chemicals has continued to significantly increase over the last 50 years, we would expect the influence of this effect on sperm counts to plateau.

But sperm counts have not plateaued. They have continue to decrease throughout the developed world. A recent study of 26,609 french partners of totally infertile women seeking in vitro fertilization found a 32.2% decrease in sperm concentration between 1989 and 2005, with projected sperm counts for a 35 year old man dropping from 73.6 million/ml to 49.9 million/ml. (Rolland et al., 2012)

This continued trend should be a cause for significant alarm. The World Health Organization defines sperm counts above 20 million/ml as normal. But studies have shown that couples take longer to get pregnant at sperm counts below 40 to 55 million/

ml. (Bonde et al., 1998) (Guzick et al., 2001) (Slama et al., 2002) In Israel, a recent study of sperm donors showed that over the last 10 to 15 years the average sperm count has dropped from 106 million/ml to 68 million/ml, an average decrease of 2.5 million/ml (0.8%) per year. 15 years ago, 66% of sperm donations were of acceptable quality; using the same criteria, at the current time only 18% of donations would be of acceptable quality. (Haimov-Kochman et al., 2012)

As discussed above, studies in insects and animals have demonstrated that microwave radio exposure at remarkably low power densities can have an adverse effect on male fertility. With the rollout of cellular and WiFi infrastructure, exposure to these radio frequencies has increased dramatically in the last 20 years. Would it be reasonable to ask if such exposures have played a role in the continued decrease in male fertility that has occurred during this time period? The result of several recent studies suggests that the answer to this question is "Yes".

Erogul et. al. split human sperm samples and exposed one part to signal from a 900 MHz cell phone. They found statistically significant decreases in motility of sperm in the exposed samples. (Erogul et al., 2006)

Fejes et. al. measured semen quality in a cohort of 371 subjects where confounding factors had been excluded, and found a significant decrease in sperm motility ($p < 0.01$) in individuals with talk time > 60 minutes/day versus talk time < 15 minutes/D. Decreased sperm motility also correlated with increased duration of cell phone ownership in months. (Fejes et al., 2005)

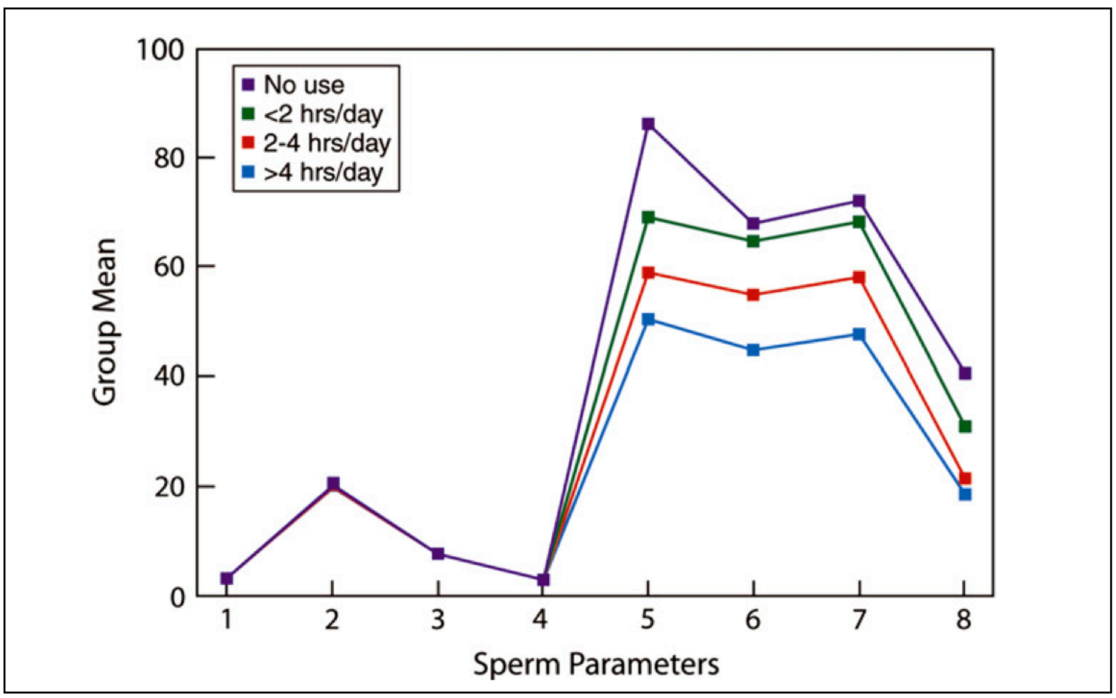

Figure 10: Decrease in sperm count (5), motility (6), viability (7) and normal morphology (8) with increased cell phone talk time. (Agarwal, 2008)

Agarwal et. al. studied semen quality in 361 subjects, divided into four groups based on daily cell phone usage (no use, < 2 hours/day, 2 to 4 h/D, > 4 h/D). They found that sperm count, motility, viability, and percent normal morphology all decreased with increased cell phone use. (Agarwal et al., 2008)

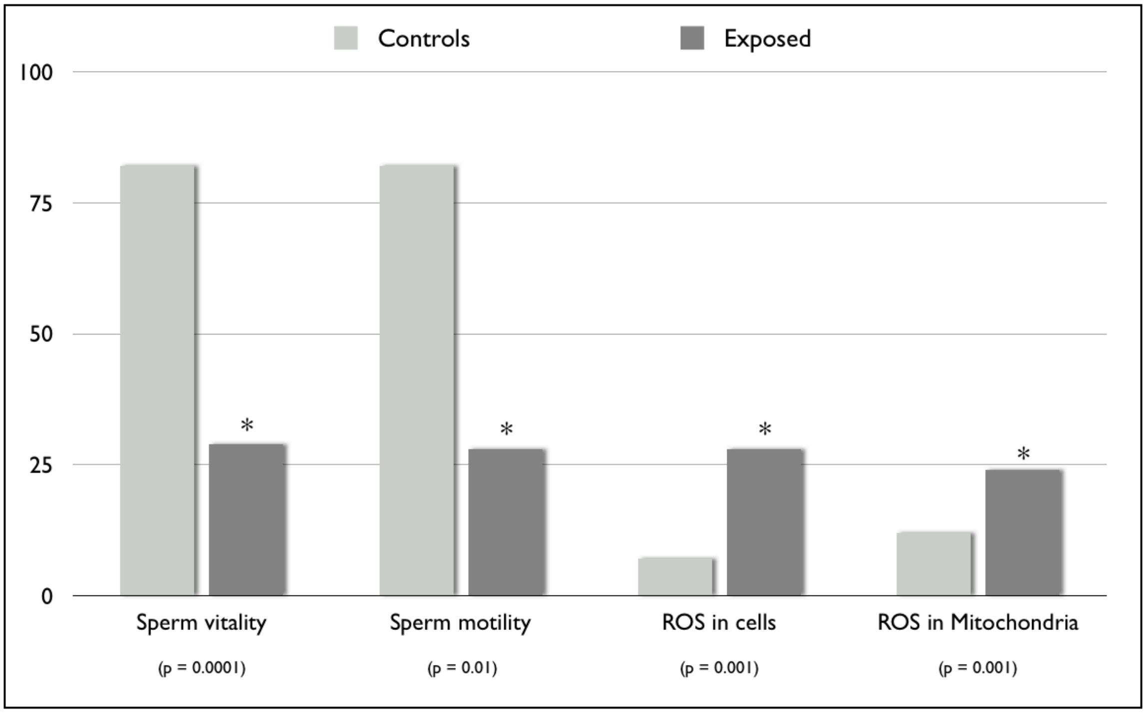

Figure 11: Sperm exposed in vitro to 1.8 GHz (SAR = 27.5 W/kg) for 16 hours @ 21°C (isothermal conditions). (De Iuliis et al., 2009)

De Iuliis et. al. exposed human sperm to 1.8 GHz microwave radio transmissions. Statistically significant decreases in sperm motility and vitality were demonstrate at exposure levels as low as 1.0 W/kg ($p < 0.01$). This study also found an increase in reactive oxygen species, oxidative damage to DNA, and DNA fragmentation, that was not dependent on thermal effects. (De Iuliis et al., 2009)

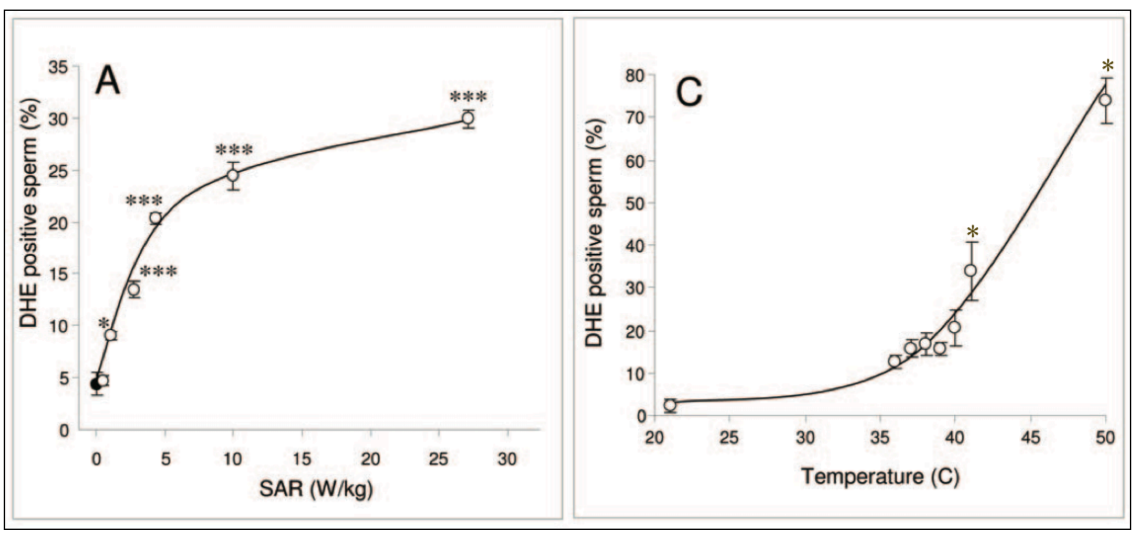

Figure 12: A) Production of ROS with increasing levels of microwave RF .
B) Production of ROS with increasing levels of temperature.
(De Iuliis et al., 2009)

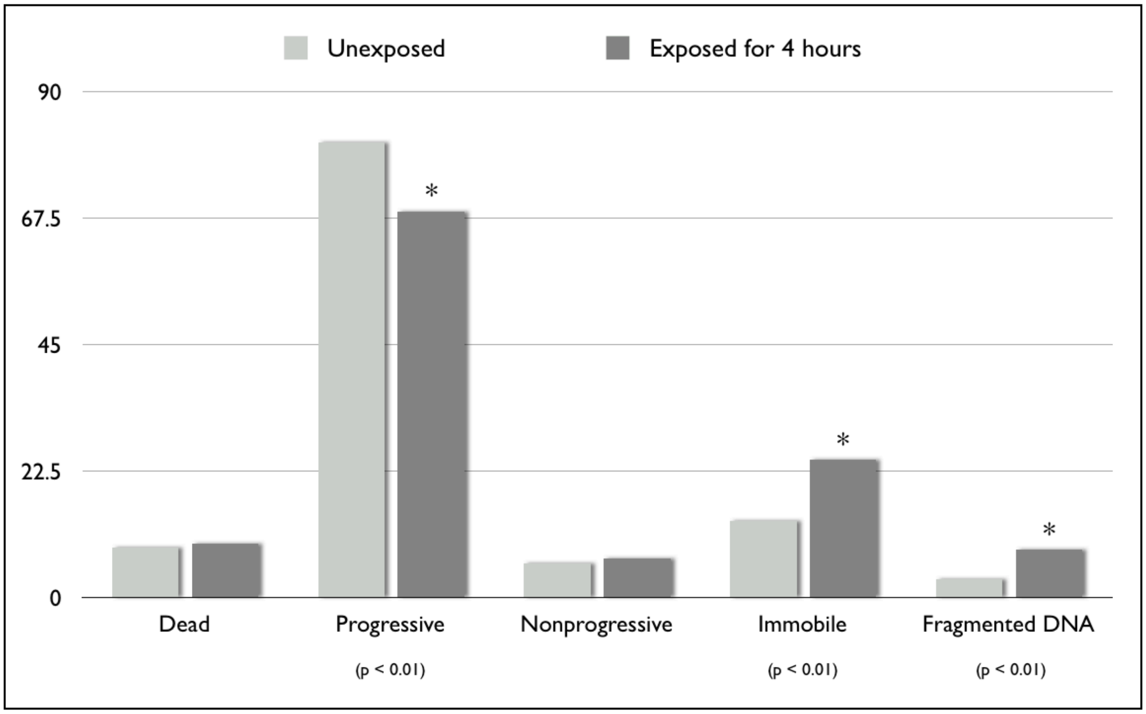

Figure 13: Sperm damage from exposure to laptop computer WiFi transmission. (Avendano et al., 2011).

Another recent study the effects of exposing motile sperm to 4 hours of WiFi transmission at a position 3 cm beneath a laptop computer, at power densities between 0.45 and 1.05 μW/cm². Temperature was maintained at a constant 25ºC. Exposed specimens showed a statistically significant decrease in sperm progressive motility, and a significant increase in non-motile sperm and in sperm DNA fragmentation. (Avendano et al., 2011)

The fact that multiple recent studies have demonstrated the ability of microwave RF exposure to cause nonthermal damage sperm function and sperm DNA with short exposure times and quite low exposure levels—the FCC exposure limit is 1000 μW/cm²—should be a source of grave concern. The presence of constantly transmitting WiFi networks in homes and schools may be much less innocuous than is generally supposed.

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CURRENT RESEARCH ON CELL PHONE USE AND BRAIN TUMOR RISK

INTRODUCTION

To be complete, any review of the health hazards of microwave radio exposures must include a discussion of the research on possible associations between cell phone usage and brain tumors.

This research is a hot topic politically. Cell phone use has permeated our society, and no one wants to think that use of a cell phone is going to increase their personal risk (or their child's personal risk) of acquiring a terrifying disease.

The rollout of the cellular communications infrastructure has also created an extremely profitable industry. The telecommunications industry made $3.1 trillion in gross profits in 2010. (Plunkett Research, 2012) This industry has a powerful incentive to downplay the health effects of EMF, and has funded a good deal of research that serves to further that aim. Some studies regarding cell phones and brain tumors have been funded in large part by the telecommunications industry. These industry-designed studies have generally concluded that the use of cell phones does not create a health hazard. And these negative reports have received wide coverage in the news media. However, the study designs funded by industry are more likely to use unblinded protocols and to underestimate risk, as compared to studies funded by public bodies. (Levis et al., 2012)

When powerful financial interests are at play, industry funding of favorable research studies is often used to influence the political and scientific playing field. We've seen this play out in pharmaceutical research, where several recent scandals have highlighted the distorting effects of corporate financing on research outcomes. In the past few decades the production of research providing favorable (to corporate interests) results has become something of a science in itself, with corporations essentially gaming the academic system, funding studies designed to produce favorable outcomes for their products, and hiding studies that do not support their interests. The peer review process of the scientific journals has not proved to be an adequate defence against this problem. (Smith, 2005)

In the research on cell phones and brain tumors, the situation is further confounded by the fact that cell phone usage has only become wide spread in the last 15 years or so. The first digital cell phone infrastructure was pioneered in Scandinavia, and the first research that raised concerns about cell phone cancer risks was produced in Sweden in the late 1990's. But environmental influences that promote cancer generally take years to do so.

Take the question of the potential risk of cell phone use by teenagers. Does this cell phone use increase the risk of brain tumors later in life? The mass market for cell phone use by teenagers really started after 1995, and extended use of cell phones to surf the web ballooned after the introduction of the iPhone in 2007. Looking for brain cancer today in 30 year olds who started using a cell phone in 1997 would be similar to looking for lung cancer today in 30 year olds who started smoking in 1997 (and who would be most likely to develop lung cancer in their 50's or 60's).

This means we cannot find great reassurance in "negative" cell phone cancer risk studies performed 8 or 10 years ago. And similarly, any "positive" findings of cell phone cancer risk to date should produce real concern, since it is possible that they are identifying only the early cases of a larger problem.

Three major and ongoing research studies have been performed in the last 10 years. One is the INTERPHONE Study, which is funded in major part by the telecommunications industry. A second study which received much recent media attention is the "Danish Cohort" study. A third body of research has been produced by the Hardell group in Sweden, a research group with no financial support from the telecommunications industry.

THE INTERPHONE STUDY

The INTERPHONE Study is a large standard protocol study of brain and salivary gland tumor risk in relation to mobile telephone use, with branches of the study being performed in 13 countries, and combined together to increase the statistical power of the results. This study was funded in major part by the wireless communications industry.

The first major summary of this research was published in 2010. This "case-control" study looked at patients with brain tumors (2708 glioma cases, 2409 meningioma cases) and matched controls, and compared their estimated cell phone usage to determine if regular cell phone usage increased the odds of being a brain tumor patient. The authors concluded that "Overall, no increase in risk of either glioma or meningioma was observed in association with use of mobile phones." (Group, 2010)

This reported result was then widely quoted by the press and government agencies like the World Health Organization (IARC, 2010) as demonstrating the lack of risk of wireless technology.

However, this study defined a member of the risk group as any subject who *"had an average of at least one call per week for a period of 6 months"*. This definition of "regular cell phone use" diluted the risk pool out with lower risk individuals to the point that no difference between risk and control groups was visible in the study.

Interestingly, the study did report its statistics stratified by total time of reported use, and the top decile (greater than 1640 hours use over a ten year interval, averaging out as greater than 3 hours a week) had an increased risk of certain tumors. Individuals who accrued that greater than 1650 hours of use over a 1 to 4 year interval (ranging from 8 to over 30 hours a week) had a markedly higher odds ratio of meningioma (OR 4.80) or glioma (OR 3.27).

In the discussion of their data showing increased risk within the higher usage group, the authors failed to consider the possibility that this data showed a real risk. Instead, they discounted this trend of increased risk in the heavier users, stating that various "biases and errors limit the strength of the conclusions we can draw from these analyses and prevent a causal interpretation." And it is this "biases and error's" comment that has been quoted by industry apologists in subsequent publications, rather than the study's actual statistical findings of increased odds of brain tumor with cell phone talk time greater than 3 hours a week over a ten year period, or greater than 8 hours a week over a 1 to 4 year period.

The discrepancy between actual data and concluding discussion in this study was not highlighted by mass media coverage of this study. One must assume that reporters read the abstract rather than the complete article, and accepted the author's conclusions without question. Other researchers in the field were more critical in their assessments of the INTERPHONE project as compared to other published literature on the subject (Morgan, 2009), and pointed out that the INTERPHONE data really did document an increased risk, consistent with studies published by researchers in the field that were more independent from industry funding sources. (Hardell et al., 2011a) (Levis et al., 2011)

A more recent study from the INTERPHONE group found an increased risk for acoustic neuroma in individuals with > 1640 hours of talk time over up to 5 years of exposure (OR = 2.79, 95% CI = 1.51 – 5.16). For those subjects who routinely used their cell phone on the same side of the head where they had the acoustic neuroma, the odds ratio was 3.74 (95% CI 1.58 – 8.83). (Cardis and Schüz, 2011)

The most recent study from the INTERPHONE group showed increased odds ratio of glioma and meningioma with greater than 10 years of mobile phone use. The author's conclusions acknowledged this finding, but stated that "the uncertainty of these results requires that they be replicated before a causal interpretation can be made". This is an interesting comment, considering that this study result itself was essentially a replication of the actual findings of the earlier INTERPHONE study. (Cardis et al., 2011)

THE DANISH STUDY

A study from Denmark on the risk of mobile phones and brain tumors was published in the British Medical Journal in 2011. The conclusions of this study were that "there were no increased risks of tumors of the central nervous system, providing little evidence for a causal association". (Frei et al., 2011)

This study was widely quoted in the media and by government organizations as refuting the link between cell phones and brain tumors, with headlines like BBC News: "Mobile phone brain cancer link rejected." (Triggle, 2011)

In this case-control study, the risk group was composed of native Danes who had acquired a cell phone contract prior to 1995. However, any prior to 1995 corporate users were excluded from the risk group (this was 32% of the original cohort). Also excluded were all prior to 1995 subscribers who were less than 18 years old at the time they obtained their first subscription. The study did not determine how often members of the risk group used their phones, or make any determination as to exposure to portable phones in the home for risk or control group members.

The control group was composed of all Danes aged 30 or older and born after 1925 in Denmark. This of course means that the control group included all the early corporate subscribers (whom we might call the "power users"), and also included the 85% of Danes who obtained a cell phone *after* 1995.

This contamination of the control group with large numbers of cell phone users made the conclusions of the study essentially meaningless. To the BMJ's credit, letters that pointed this out were printed in the same issue with the original article (but apparently not read by the members of the press). (Khurana, 2011) (Philips and Lamburn, 2011)

The net result of all this was that the public was falsely reassured by media reports of a peer reviewed article in a prestigious medical journal, when the negative conclusions of that article were essentially meaningless. (Soderqvist et al., 2012)

THE HARDELL GROUP STUDIES

The first digital cell phone network (2G) was launched in Finland in 1991, and the cell phone communication infrastructure expanded widely in Scandinavia during that decade. In the late 1990's case reports of brain tumors in cell phone users lead to the first of multiple studies produced by the Hardell research group in Sweden. In this case control study of data collected between 1994 and 1996 from 233 living patients with biopsy-verified brain tumors, no clear distinction could be established between cell phone users and nonusers in the patient population, but a trend was observed of increased odds of tumor presence in the temporal or occipital lobe on the same side of the head habitually used to listen to the cell phone. (Hardell et al., 1999)

In 2002 Hardell et al. published another and larger case control study of 649 brain tumor cases diagnosed between January 1997 and June 2000. This study (and subsequent studies by the Hardell group) looked at exposure from both cellular phones and mobile (cordless) phones connected to land lines. Cumulative hours of cell phone use was calculated from questionnaires about phone usage habits. Increased risk of brain tumor was found for ipsilateral use (phone habitually on same side of head as brain tumor site) with both analogue and digital cellular phones and for cordless phones. Increased risk was also seen for increased duration of exposure. (Hardell et al., 2002)

Another expanded case control study with 1617 brain tumor patients diagnosed between 1997 and 2000 was published later that year showed similar findings, with the highest calculated risk being for ipsilateral acoustic neuroma in analog cellular phone users (the older technology). (Hardell et al., 2002)

Hardell et al. analyzed this same data set of 1617 patients for incidence of vestibular schwannoma (VS), and found an increased odds ratio for VS associated with the use of analogue cell phones. They found that the incidence of VS in Sweden had significantly increased during the time period from 1960 to 1998, with more of this increase occurring during from 1980 to 1998. All other brain tumors taken together had also showed a significant yearly increase between 1960 and 1998. (Hardell et al., 2003) (Hardell et al., 2003)

In 2006 and 2007, Hardell et al. published several more studies of brain tumor patients diagnosed between 1997 and 2003. Cell phones had been in wide use for a longer interval of time, and their data allowed evaluation of latency periods of > 10 years duration, and risk for subjects with first cell phone use at < 20 years of age. Cumulative lifetime use of > 2,000 hours showed elevated odds ratios for analog, digital, and cordless phones, and increased risk for malignant tumors with ipsilateral exposure. Risk of malignant tumors was more pronounced in individuals with first cell phone use at less than 20 years of age. (Hardell et al., 2006) (Hardell et al., 2006a) (Hardell et al., 2006b) (Mild et al., 2007)

Later in 2006, Hardell et al. published a pooled review of their data from all six of their previous case control studies. (Hardell et al., 2006) And they have subsequently published three more papers updating and consolidating their earlier findings. (Hardell and Carlberg, 2009) (Hardell et al., 2010) (Hardell et al., 2011b)

CRITIQUES AND REVIEWS

In 2004 Kundi et al. published a review of 9 existing epidemiologic studies on the relationship between cell phone use and brain tumor risk, and found that all studies approaching reasonable latencies of exposure time showed an increased relative risk (range 1.3 to 4.6) of brain tumor in cell phone users, with highest overall risk for acoustic neuroma (RR 3.5) and uveal melanoma (RR 4.2) (Kundi et al., 2004)

In 2007 Hardell et al. published a meta-analysis of two cohort studies and 15 case control studies on the association between long-term use of cell phones and brain tumor. They found increased risk for acoustic neuroma and glioma with ≥ 10 years of exposure, with higher risk of tumor on the exposed side of the head. (Hardell et al., 2007a)

Hardell, Mild, and Kundi published exhaustive reviews of the existing literature on this subject in 2007 in the Bioinitiative Report. (Hardell et al., 2007b) (Kundi, 2007)

In 2008, Hardell et al. published two meta-analyses of the existing case control studies in the literature including ten studies on glioma and nine studies on acoustic neuroma. They found "a consistent pattern of association between mobile phone use and ipsilateral glioma and acoustic neuroma using ≥ 10 years latency period". (Hardell et al., 2008)

In another meta-analysis published in 2009, Hardell et al. again found "a consistent pattern of an increased risk for glioma and acoustic neuroma after > 10 year mobile phone use . . . with highest risk found in the age group < 20 years at time of first use of wireless phones." (Hardell et al., 2009)

In a 2009 review, Ahlbom et al. stated that existing studies "do not demonstrate an increased risk within approximately 10 years of use for any tumor of the brain". In a way, this statement is a somewhat backhanded acknowledgement of the fact that the published research to that date clearly does show increased risk with greater than 10 years of use. (Ahlbom et al., 2009)

In 2009 Khurana et al. published a metanalysis of the eleven existing long-term epidemiologic studies on cell phone use and brain tumor risk that met these criteria: Publication in a peer reviewed journal; inclusion of subjects with greater than 10 years of cell phone use; analyzing "laterality" of cell phone usage in relation to brain tumor incidence. Their conclusion was that "using a cell phone for ≥ 10 years approximately doubles the risk of being diagnosed with a brain tumor on the same ("ipsilateral") side of the head as that preferred for cell phone use". (Khurana et al., 2009)

In 2011 the WHO/International Agency for Research on Cancer (IARC) classified radiofrequency electromagnetic fields as "possibly carcinogenic to humans (Group 2B), based on an increased risk for glioma, a malignant type of brain cancer, associated with wireless phone use". (WHO, 2011) (Baan et al., 2011)

In 2012, Levis et al. published an analysis of published case control studies, pooled analyses, and meta-analyses on head tumor risk with mobile phone use. They found that "in studies funded by public bodies, blind protocols give positive results revealing cause-effect relationships between long-term latency or use of mobile phones (cellulars and cordless) and statistically significant increases of ipsilateral risk of brain gliomas and acoustic neuromas, with biological plausibility. In studies funded or co-funded by the cellphone companies non-blind protocols give overall negative results with systematic underestimation of risk; however, also in these studies a statistically significant increase in risk of ipsilateral brain gliomas, acoustic neuromas, and parotid gland tumours is quite common when only subjects with at least 10 years of latency or exposure to mobile phones (only cellulars) are considered." (Levis et al., 2012)

CONCLUSIONS

The current epidemiological research shows that greater than 10 years of cell phone use incurs a significantly increased risk of ipsilateral brain tumor (glioma or meningioma). This risk is greater in individuals that start using cell phones as children.

This means that the RF exposure guidelines for cell phone use cannot be considered to be adequately protecting the public.

In light of these findings, current public policy that essentially ignores biological or "nonthermal" levels of RF exposure need to be reconsidered and revised, in order to significantly reduce the risk to the public health that is produced by these technologies.

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CONCLUSIONS AND RECOMMENDATIONS

ADVERSE BIOLOGICAL EFFECTS—THE SCIENTIFIC EVIDENCE

In the previous sections we have reviewed the increasingly robust body of scientific evidence that excessive RF exposure can cause both acute and chronic adverse biological effects:

ACUTE EFFECTS

In susceptible individuals, excessive RF exposure can provoke acute symptoms. The most common symptoms are sleep disturbance, headache, irritability, fatigue, and concentration difficulties. Other symptoms may include depression, dizziness, tinnitus, burning and flushed skin, digestive disturbance, tremor, and cardiac irregularities.

As physicians, some of us have seen patients who are experiencing this problem, and are aware of the connection with RF exposure. Research suggests that 3 to 5% of the population fit into this category. If this is the case, there may be 4,700 people in Eugene who react to RF exposure in some way, and know it.

These symptoms are not uncommon in the population, of course. And in all probability there are many other people in Eugene who are having problems with insomnia or fatigue--problems provoked by EMF exposures--but are unaware of the connection between cause and effect.

Any significant increase in RF exposure in our residential areas will make these individuals more symptomatic. Such increases are likely to push additional individuals above their tolerance threshold, producing new cases of these problems. If increased RF levels from repeated daily transmissions between smart meters and their control towers pushed an additional 1% of the community into acute reactivity to RF exposures, this would mean an additional 1500 people in our city with insomnia, headaches, fatigue, ringing in the ears, or other debilitating symptoms.

CHRONIC EFFECTS

Chronic exposure to RF can also cause chronic physiologic changes, including altered endocrine function (both melatonin and other hormones), and increased oxidant stress that can lead to increased levels of cancer and male infertility. The public is already being subjected to increased levels of RF from wireless communications. Increasing the total load of transmission further will increase the occurrence of these adverse consequences.

PERSPECTIVE AS WE MOVE FORWARD

At the beginning of the last century, people began to use vehicles powered by internal combustion engines that burned gasoline. Gasoline power was cheap and convenient, and greatly increased the mobility of the population. And the companies that sold the gas and the cars made a lot of money.

This use of fossil fuels has had long term consequences--increased atmospheric CO2 which through the greenhouse effect would lead to global climate change. Initially, these consequences went unrecognized. Then the scientific community began to predict and measure them.

Public acknowledgement of these consequences has gone through several stages. First, the science was ignored. Then the science was attacked or denied by those whose economic interests were threatened by it. Public recognition of the problem is only arriving as the long term consequences of climate change are beginning to be felt.

The use of wireless communications technology is following a similar trajectory. Wireless communication is convenient, and increases our mobility. The installation of wireless networks is also significantly cheaper than installation of hard-wired networks. And the companies that provide these networks and the tools that we use to access them are making a great deal of money.

For decades, the biological consequences of this form of communication went unrecognized by both the public and the scientific community. As scientific evidence of biological and health effects began to emerge, this evidence was initially ignored by government regulating bodies, the media, and the public. As this evidence is getting harder to ignore, it is now being attacked or denied by the telecommunications industry. Wide public recognition of the problem and the science that describes it will arrive as the problem becomes more severe, and more people get sick.

The previous sections of this report describe the increasing body of science that clearly demonstrates the existence of adverse biological effects from chronic RF exposure. It is important for EWEB's Board and staff to recognize that this science is real, and that the science isn't going to go away. As the wireless communications infrastructure continues to grow, the magnitude and duration of public exposure are going to continue to increase, and the number of people with acute or chronic effects from this exposure will continue to grow. As recognition of the problem by the public increases, exposures and infrastructure that are currently unquestioned will become politically unacceptable.

EWEB has moved slowly in the process of investigating AMI technology. Recognition of the potential health effects of excessive RF exposure to the public should cause this appraisal to become even more deliberate and circumspect. EWEB needs to avoid investing millions of dollars on infrastructure that becomes part of the problem. Instead, EWEB needs to think about making engineering choices that recognize this problem, and seek to become a part of its solution.

RECOMMENDATIONS

BASIC PRECEPTS FOR RESIDENTIAL EXPOSURES TO RF TRANSMISSIONS

- Excessive RF exposure can cause acute problems (headaches, insomnia, fatigue, vertigo, tinnitus, other symptoms of EHS).
- Excessive RF exposure can also cause chronic problems (oxidative stress, cancer, male infertility).
- Constant RF transmission is probably harmful, even at low levels, and should be avoided.
- Frequent and repetitive intermittent transmissions are also probably harmful, and should be avoided.
- Nocturnal exposures are more problematic than daytime exposures, because of RF's potential to suppress nocturnal melatonin secretion and disturb sleep, and because night is the time when we rest and heal from stresses (including oxidative stress).
- Occasional and infrequent daytime exposures are much less likely to cause an increase in chronic problems for the population at large.
- Occasional and infrequent daytime exposures are still likely to provoke acute symptoms in a small percentage of the population.

Based on our review of the existing science, we suggest that the above basic precepts be considered when thinking about residential exposures to microwave RF transmissions. We consider this to be important for the population at large, and even more important for those in our community who suffer from symptoms of electrohypersensitivity. For all of us, our homes are the place where we rest and where we sleep, where we rejuvenate ourselves from the stresses of the wider world. It is important that our residential environments be a place where this can occur. Our homes need to be part of the solution, not part of the problem.

EWEB SHOULD ADOPT A POLICY OF MINIMIZING THEIR RF FOOTPRINT IN THE COMMUNITY

A recognition of these precepts should lead EWEB to adopting a policy of minimizing their infrastructure's RF footprint in the community as much as possible during regular operations. This doesn't mean that staff would throw away their cell phones and communicate by semaphore. But it would mean that instead of combatting or ignoring the possibility that more RF in the community could cause harm, EWEB should acknowledge the potential risks of excessive residential exposure.

This would mean that such potential risks would be seriously considered in any discussion of the total risks and benefits (the "Total Bottom Line") in deciding <u>whether</u> to use RF technology for any given purpose. If, after such a discussion, a considered decision is made to use RF technology, then these same potential risks should be taken into serious consideration in determining <u>how</u> to use this technology in a manner that would minimize potential harm to the community.

In other words, don't use RF when you don't have to. Go hard-wired wherever it is feasible to do so. And if you do use RF, design the technology to use as little of it as possible.

Current engineering choices in AMI technology have not been designed with these goals in mind, since the industry has not had an practical incentive to recognize the problem and to "work the problem". But EWEB as a purchaser of technology could choose to push vendors towards designing and providing hardware options that would address these goals. This would put EWEB in the position of being part of the solution rather than just another part of the problem.

FLAWS IN THE CONCEPT OF "OPTING OUT"

It has been suggested that people who have problems with EHS or concerns about health exposures to RF can be taken care of by creating an "opt out" program, allowing them to decline the installation of a smart meter on their home. This suggestion overlooks some obvious and important problems:

- You can't "opt out" of exposure to your neighbor's meter, that is ten feet away from your bedroom window.
- You can't "opt out" of all the meters on the wall of your rental apartment complex. Or the ones on the wall of the complex right across the alley from your apartment.
- You can't "opt out" of exposure to the meter on the other side of your bedroom wall if you are a baby in a crib.
- You can't "opt out" of exposure to transmissions from the radio tower 100 meters from your house.

The idea of an "opt out" program is an effort to address the concerns of people who are personally worried about RF exposures, either because they are aware of having acute reactions to these exposures, or because they have a general concern about the acute or chronic effects from such exposure.

But a voluntary "opt out" program does not protect the community at large from adverse effects that they are unaware of and unconcerned about. For example, the current research shows that cancer rates are higher in residences near cellular transmission towers. Most people don't know this. How does a voluntary "opt out" program help the person who develops breast cancer three years after installation of a transmission tower across the street from her house? She didn't know it was a problem . . .

DISCUSSION OF THE TECHNOLOGY OPTIONS

How would adopting these precepts and goals play out in practice? Several factors come into consideration:

- The scientific evidence on biological effects of RF, summarized in the basic precepts listed above.
- The various possible functional goals of the AMI program:
  - Reducing operating costs by reading and switching meters remotely.
  - Training customers to conserve electricity.
  - Shifting time of use by measuring and billing time of day usage.
  - Absorbing fluctuations in renewable energy supply by "demand/response" control of usage.
- The different AMI technologies that are available.

When our committee puts our best understanding of these three factors into consideration, and look at each choice in AMI technology through this combined frame of reference, the discussion runs something like this:

MESH Network

From a biological point of view, AMI meters that are transmitting several times a minute can be considered to be an essentially constant source of RF exposure. Where these networks have been established in the last two years, large increases in reported acute symptoms have occurred. We think it is medically probable that that this technology will be found to cause an increase in chronic health problems, including increased cancer, once sufficient time has passed for this to occur.

EWEB staff has already explored and tested a MESH option and chosen not to go forward on that path. We applaud EWEB's decision to steer away from this technology.

Powerline Communications (PLC)

From a public health point of view, PLC is less problematic than an RF AMI communication technology. And PLC could be used to reduce operating costs, train customers to conserve electricity using in-house monitors, and record and transmit time of day usage measurements to the utility.

EWEB has turned away from the choice of PLC for two main reasons. Firstly, because it won't allow measurement of water meter readings, limiting the reduction of operating costs from elimination of meter reading. Secondly, because PLC as currently designed does not have the bandwidth to sustain rapid "demand/response" control communications.

There are some other technical considerations that make PLC infrastructure more awkward to set up in an environment where some transmission wires are on poles and others are underground.

If "demand/response" was not on the table, and if a Total Bottom Line analysis of the options included the potential health costs of using RF technology, the financial analysis of the PLC option might look different than it did in the AMI Business Case prepared by EWEB staff last April. A decision to read the water meters once every 3 months rather than monthly could also realize additional savings, if this option was under serious consideration.

Fiber Optic Communications

Fiber optic communication between the utility and the house meter is an ideal solution from a health/environmental point of view, providing ample bandwidth without RF transmission. However, this technology would be quite expensive to install, especially in the parts of Eugene where the power grid is underground. The cost might be prohibitive for EWEB at this point in time. Like PLC, fiber optics would not communicate with the water meters.

Tower Communications Network (SENSUS)

The engineering system that EWEB is currently considering is the SENSUS company's technology, where central towers communicate directly with the meters on the houses. SENSUS owns the sole rights to a certain transmission frequency on the communications bandwidth. This allows them to use more powerful radios on the smart meters, strong enough to communicate directly with a transmission tower without requiring that the message be passed from meter to meter across a MESH network. The community would be divided into about 13 zones, each of which would have a communication tower placed on an existing EWEB property within the zone, and these towers would communicate directly with the house electric meters and with radios on the house water meters.

With 88,000 electric meters and 52,000 water meters in the city, an average zone would have 6770 electric meters and 4000 water meters in the zone. How long a transmission interval would be required for a tower to collect the data from 10,770 meters? We don't know the answer to this question, and EWEB engineers may not know either, until they set up a trial system and test it out. But clearly, the RF footprint created by this sort of system could vary significantly, depending on how the system was used.

It is routine for utilities to collect data from these systems four times a day. But this routine was developed without consideration of the potential health risks of excessive RF transmission in the community. And usage data does not need to be collected this frequently to achieve the main goals of the AMI program. From a practical point of view, the utility will continue to bill once a month, and in theory could remotely collect that usage data once a month, minimizing the community's exposure to frequent and repetitive RF transmissions.

We think usage data should be collected from these meters at an interval of once every two to four weeks, with transmission occurring during the daytime hours. Transmission events at this level of infrequency would represent a minimal increase in the RF exposure to the community, and would be unlikely to significantly increase the risk of chronic health problems in the community.

Each data transmission event would still be likely to provoke acute symptoms in individuals with EHS who lived near these transmission towers. But if these events occurred at an interval of once every two weeks or longer, and at a predictable time of day, this might be a manageable level of exposure for those individuals.

In our informal discussions with EWEB engineers, we have been told that they have looked into the issue of data collection frequency, and that the longest that they could go between data collection events with the SENSUS system would be about three and one half days.

This would appear to be a case where the technology has not been designed with an eye to minimizing RF transmission. Six daily time-of-use intervals times 30 days equals 180 intervals of usage data. We think that if an iPod can store 64 gigabytes of music, it ought to be possible to give a smart meter enough memory to store 180 readings before transmitting them to the utility. We would recommend that EWEB ask their potential vendors to provide a meter with enough memory to store two to four weeks of data, to enable the minimal RF footprint that we are recommending.

Tower communications and the water meters

Water usage is billed once a month, and a single monthly reading of the meters would collect this data with minimal RF exposure to the community. Again, this data collection should occur in the day time, not in the middle of the night.

Tower communications and "demand/response"

From a public health perspective, the use of the system for "demand/response" load control is more problematic. As we understand it, a lot of this transmission would occur at night, when wind power production is high and demand is low. Towers would be transmitting every 15 minutes, to turn one cohort of water heaters on and another cohort off. And the protocols required by the grid would require a two way communication with each meter in the cohort, acknowledging that house's participation in the cohort at that time.

This will involve a good deal of transmission in the system every 15 minutes, both from the towers potentially talking to hundreds of meters across the neighborhood, and from the 2 watt radios on each house in the cohort talking back to the tower.

Communication of this frequency from the towers would be a significant additional layer of frequent nocturnal RF signal exposure to the residences within a few hundred meters of the towers.

And enough cohorts of houses are involved, the transmissions from the meters on the houses could also increase the signal density in the residential areas enough to disrupt melatonin and sleep in a percentage of the population.

We think that this frequent level of activity in the demand/response system would be a significant additional RF burden on the community. It would make life in the residential area significantly more difficult for those individuals in the community that is currently already having acute problems. It would probably cause the onset of acute symptoms in a small percentage of the population who are not currently experiencing them. And it would be likely to further increase the incidence of chronic adverse RF effects in our community.

Demand/response and the in-home "Zigbee" network

Once the AMI smart meter on the house gets a demand/response signal from the control tower, it must tell the water heater in the house to turn on. Existing technology does this through wireless communication over a "Zigbee" WiFi network in the home. This network is maintained by constant transmissions of signals between the meter and the Zigbee appliances in the home network, 24 hours a day.

The research that we've reviewed above shows that biological effects can be produced by low power levels of RF exposure, and that prolonged, constant exposures can have effects even at extremely low exposure levels.

For demand/response to work in the community, at least 20% of the homes in the community will need to volunteer for the program, and have it set up in their houses. In undertaking to install demand/response infrastructure in its current form, EWEB would be making several presumptions:

- A presumption that the Zigbee system is low enough in power that it won't cause any harm.
- A presumption that public acceptance should be good, since the public at large isn't really concerned about the health effects of RF at this time.
- A presumption that since most people have WiFi now anyway, they aren't going to be concerned about the additional exposure.
- A presumption that because the system will be voluntary, so no one can or will complain about involuntary exposure.

While it may be true that the public isn't that worried at present, and that many people have WiFi in their homes and aren't worried about it at all, we do not think that EWEB can assume that this will continue to be the case throughout the investment lifetime of the installed demand/response infrastructure.

As we've discussed in the prior sections, signals of WiFi power are strong enough to cause severe symptoms in individuals with EHS. Several hours of WiFi exposure has been shown to cause damage to healthy sperm. The general public is unaware of these facts. But we think that this is less likely to be the case 8 or 10 years from now, much less 20 years from now. As increased exposure to wireless RF communications causes more health problems in the population, and the scientific evidence of this effect continues to become more robust, public attitudes about this exposure are going to change. Within 20 years, the public—especially parents with young children—will be much less open to having constant WiFi signal in their homes. If this assumption is correct, the purchase of many millions of dollars in demand/response infrastructure that is based on wireless in-home communications would appear to be an unwise investment.

The "demand/response" infrastructure is still immature

We think that the "demand/response? infrastructure is still immature. This technology may be mature from an engineering point of view, in that "it works". But from a public health perspective, it is completely immature. We state this because the technology has been designed around RF communications (because this infrastructure is quicker and cheaper to set up than a hard wired system) without any consideration of the health effects of exposure to excessive or prolonged RF transmissions, and without any considered effort to engineer the hardware or the software protocols in a way that would minimize such exposures.

The Zigbee network is a case in point. In modern construction, most electric meters are sitting on the outside of the circuit breaker box. Within that breaker box, there are dedicated circuits with hard-wired connections to the electric water heater, the electric stove, and the electric clothes drier.

Why not set up communications between these utilities with powerline communications protocols over these hard-wired connections? All it would take would be some intelligent technology in the 220 circuit breakers for the appliances, and a smart switch at the other end of the circuit, and connections to the network controls in the smart meter that is plugged into the breaker box. All this could be done without putting any RF transmission into the house?

Why hasn't this been done yet? Because a wireless solution is easier to install? Because changing the hard wiring would require changing electrical codes? Because no one thinks it's necessary to get this clever, since no one is worried about RF exposures?

Solutions like this could be created, if industry and government had enough incentive to work the problem, rather than to deny the existence of the problem. Until such alternatives to constant in-home RF exposure are developed, we think that EWEB would be wise to avoid getting married to this technology. Developing demand/ response using a constantly transmitting in-home RF network will mean investing a great deal of money in infrastructure that is likely to become extremely unpopular within the next 10 to 15 years. What we look at now as "quick and cheap" will come to be viewed as "quick and dirty".

Other communication options

We've been told that the powerline communication option is not a feasible solution for demand/response control, since it lacks the bandwidth necessary for rapid communications between server and meters.

We think that serious consideration should be given to the potential use of broadband internet connections for demand/response communications. We understand that EWEB does not have the financial power to build their own fiberoptic network at this time. But in 2010, 82% of the households in our part of the state had broadband internet connections, and this proportion continues to grow. Would it be technically possible to use these wired internet connections to communicate with the vast majority of the electric meters in our city, rather than building a new wireless infrastructure to do the job? Broadband internet communications would certainly have the bandwidth to do this, and a demand/response system is not expected to require the participation of every household in the community. If we acknowledge the health risks of RF communication (especially the robust night-time communication expected for demand/ response control), then an internet-based demand/response control system should be given serious consideration.

IN CONCLUSION

We hope that our report and recommendations will be helpful to EWEB staff, the EWEB Board of Governors, and to members of our community. We think that review of this information should allow a more realistic appraisal of the health risks involved in establishing an AMI network that utilizes microwave RF communication. Such a measured and realistic appraisal is a necessary part of the Total Bottom Line Analysis that EWEB has promised to bring to any major initiative in our community.

This is a lengthy document, and discusses complex issues. We would welcome the opportunity to meet with EWEB staff and members of the Board, in order to give a more extensive audiovisual presentation and clarification of this material, and to answer any questions that you wish to ask us about this research.

We hope to be part of an ongoing dialogue about the potential health effects of RF technology, as EWEB continues to deliberate on the various choices that they face with the AMI program.