Public Health Evaluation of Radio Frequency Exposure from Electronic Meters

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Office of Environmental Health

Arizona Department of Health Services

Introduction

A "smart meter" is a term that typically refers to electronic meters that have a two-way communication function between the utility company and the customer. Arizona citizens have been concerned about the potential health effects from exposure to radiofrequency (RF) emitted from Smart Meters. In order to address the customer concerns, the Arizona Corporation Commission (ACC) has requested a review of smart meters used in Arizona. This review is to include a survey of meters used in Arizona to determine whether they emit RF within the Federal Communications Commission (FCC) guidelines, and an evaluation on the potential health risks of RF radiation from the smart meters. In Arizona, there are multiple metering technologies used, and not all types will have and/or utilize the two-way communication function. For the purpose of this report, Arizona Department of Health Services (ADHS) will refer to all wireless communicating meters as electronic meters, regardless of the communication function. The ACC provided comments on the goals and scope of this project, but relied on ADHS and the Arizona Radiation Regulatory Agency (ARRA) for their areas of expertise. The Environmental Toxicology Program in the Office of Environmental Health at the Arizona Department of Health Services conducts risk assessments to determine potential public health impact from site-related contamination. At the request of other agencies or the public, the Environmental Toxicology Program reviews available environmental and exposure data to evaluate potential community exposures to hazardous substances. ADHS does not collect new environmental data, but instead, relies on other agencies or third parties to collect the data.

ARRA houses the nonionizing radiation section, which enforces Arizona Administrative Code Title 12 Chapter 1, Article 14 "The Control of Nonionizing Radiation." These rules address sources of radiofrequency radiation (RF) in the environment, occupational exposure concerns, as well as public exposure. ARRA regulates Class 3B and Class 4 lasers used in the medical, industrial and light show fields, Ultraviolet radiation in tanning facilities, RF radiation sources such as heat sealers and industrial oven, RF radiation in the industrial environment within a frequency range of 0.3 megahertz (MHz) to 100 gigahertz (GHz), and communication sources through a registration/license program. ARRA does not have regulatory authority to enforce rules regarding electronic meters. However, they have the expertise, experience, and ability to measure RF emitting devices including electronic meters.

The goals of this report are 1) to determine whether RF exposure from electronic meters on residences, including single family homes and apartment complexes are within the FCC standards or are at levels to cause public health concern; and 2) to determine whether the current body of peer-reviewed literature has found an association between RF exposure from low level RF exposure and adverse health effects. ADHS reviewed available peer-reviewed literature to summarize potential health effects from radio frequency exposure, including exposure from electronic meters. ADHS also conducted a literature review of standards and guidelines for RF radiation used by a number of countries and health organizations and reviewed the personal anecdotes and journal articles submitted by concerned citizens. Finally, ADHS reviewed RF data collected from various meter types in Arizona to determine if the measured radio frequency is a public health concern.

Background:

What is EMF/RF?

Electromagnetic field (EMF) radiation consists of waves of electric and magnetic energy moving together through space at the speed of light (FCC 2012). Radio waves and microwaves, emitted by transmitting antennas, are one form of electromagnetic radiation and are collectively referred to as "radiofrequency" or "RF" energy or radiation. The most important use for RF energy is in providing telecommunications services. Smart meters, cell phones, Wi-Fi routers, computers, and radio and television broadcasting are just a few of the many telecommunications applications of RF energy.

How is radio frequency measured?

Radiofrequency has two components: an electric and magnetic component. A common unit for characterizing the total electromagnetic field is "power density," which is defined as power per unit area. It is commonly expressed in terms of watts per square meter (W/m^2) (FCC 2012). The quantity used to measure the rate at which RF energy is actually absorbed in a body is called the "Specific Absorption Rate" or "SAR," which is usually expressed in units of watts per kilogram (W/kg). In the case of exposure of the whole body, an adult absorbs RF energy at a maximum rate when the frequency of the RF radiation is approximately 70 MHz. Because of this "resonance phenomenon," RF safety standards are generally most restrictive in the frequency range of 30-300 MHz (FCC 2012).

How do electronic meters use radio frequency?

This report focuses on the usage of electronic meters. Electronic meters give utilities a means to match energy consumption with energy generation, and allow consumers to better manage their energy use. Four general types of meters are used in Arizona. The oldest meter type is analog, which displays energy usage on dials on the face of the meter. Power Line Carriers (PLCs) communicate with the electric company by using power lines, and do not use RF frequencies for communication. Automated Meter Reading (AMR) meters are one-way communicating meters that use RF frequencies to communicate usage data to the electric companies. Advanced Metering Infrastructure (AMI) meters are devices capable of two-way communication, and use RF frequencies for communication purposes. AMI meters send usage data to the electric company, and the electric companies can communicate with the meter, for example, starting and stopping service remotely.

Table 1. Metering technologies evaluated in this study

Type of Meter	Description	Frequency
Analog	The most common type of analog meter is essentially an electric induction motor that drives a series of geared wheels connected to indicators on the meter's face. The utility sends meter readers periodically to each meter, and no RF frequency is used.	N/A
Power Line Carrier (PLC)	Power-line communications usually operate by adding a modulated carrier signal to the existing home electrical wiring system. A PLC carries data on a conductor that is also used simultaneously for alternating current (AC) electric power	57-63 Hz

	transmission or distribution to consumers.	
One-way Communicating [Electronic Meter]	Known as Automated Meter Reading (AMR), these systems consist of small, low-power radio transmitters connected to individual meters that send daily readings to a network of receivers (NYC 2014).	902 – 928 MHz
Two-way Communicating [Electronic Meter] [Smart Meter]	Known as Advanced Metering Infrastructure (AMI), the meters record consumption of electric energy in intervals of an hour or less and communicate that information at least daily back to the utility for monitoring and billing purposes.	902 – 928 MHz

What are some other ways the public might come into contact with radio frequency on a daily basis?

Radio frequency can be from natural sources (e.g. the sun) or from man-made sources (e.g. radios). Some common household items use RF and are regulated by the FCC. The radio frequency ranges emitted from some of the most common RF sources are presented in the diagram below:

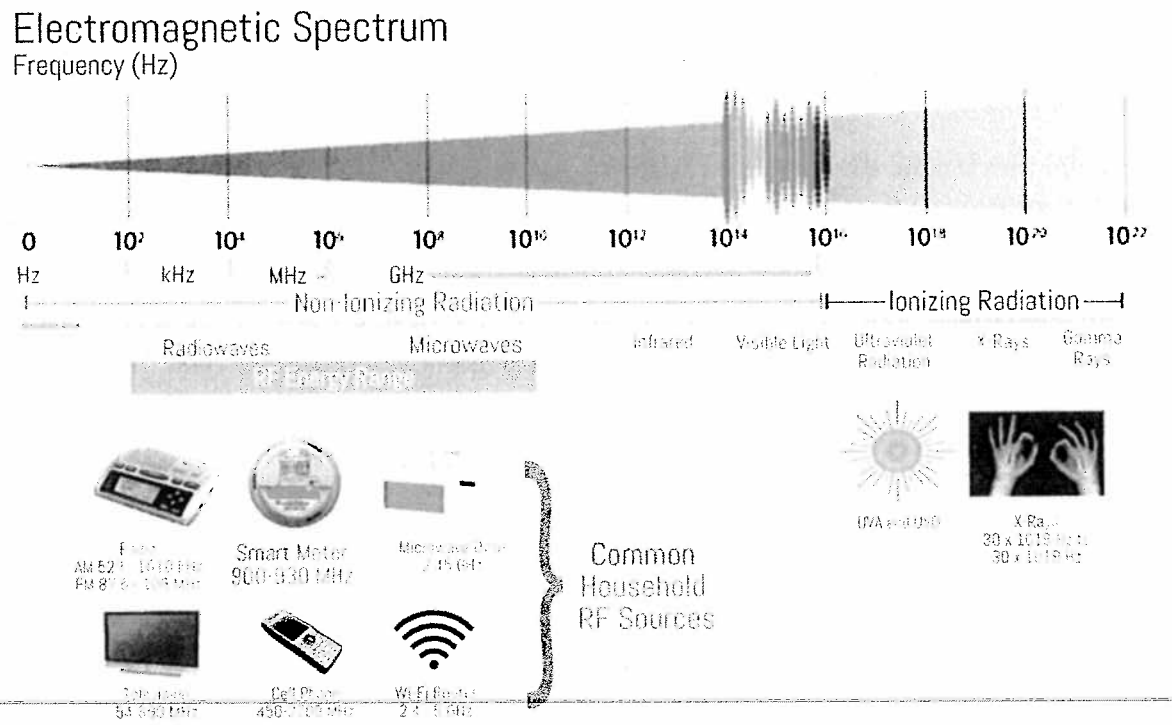


Figure 1. Electromagnetic Spectrum and RF Sources

*Adapted from the National Institute of Environmental Health Sciences Electromagnetic Spectrum

What regulations have been developed to limit RF exposure?

The strength of RF exposure from a source can depend on a number of factors. Some of these are discussed below:

- **Power Density:** Some devices emit radiation at higher power densities than others. For example, cell phones and microwave ovens emit radiation at higher power densities than Wi-Fi routers, radios, and smart meters.
- **Distance from radiation signal:** RF exposure decreases rapidly with distance. For the example of microwave ovens, a person 50 cm from a microwave oven receives about $1/100^{th}$ of the microwave exposure of a person 5 cm away. (WHO 2005)
- **Duration of signal:** Americans spend on average nearly 3 hours per day on their mobile device per day. (Geekwire 2014) In contrast, smart meters in Arizona typically emit RF less than 1/2 hour in total during the day.
- **Attenuation factors:** Attenuation is simply a reduction of signal strength during transmission. Walls, doors, elevator shafts, people, and other obstacles offer varying degrees of attenuation (Moonblink 2014).
- **RF from the Sun:** Humans can also receive RF radiation from the sun. However, this radiation is at a different frequency from radio waves and microwaves.

What are some potential health effects from radio frequency?

Biological effects can result from exposure to RF energy. Exposure to very high RF power densities can result in the heating of biological tissue and an increase in body temperature as a result of thermal radiation (thermal health effects). This can lead to tissue damage, particularly in the eyes and testes (FCC 2012). At relatively low levels of exposure to RF radiation, the evidence for production of adverse health effects is unproven, but there has been concern over non-thermal health effects. A number of individuals have reported a variety of health problems that they relate to exposure to EMF. Some report being so severely affected that they cease work and change their entire lifestyle. This reported sensitivity to EMF has been generally termed "electromagnetic hypersensitivity" or EHS. A survey of occupational medical centers estimated the prevalence of EHS to be a few individuals per million in the population (WHO 2005).

Part 1: Review of Radio Frequency Regulations and Literature

US Regulatory Standard

ADHS searched for regulatory standards developed and/or adopted by the United States Federal Communications Commission (FCC). The Federal Communications Commission (FCC) is an independent agency of the United States government that regulates interstate communications by radio, television, wire, satellite, and cable in the US.

The current exposure limit (Table 2) was determined based on the recommendation made by the International Commission on Non-Ionizing Radiation Protection and the Institute of Electrical and Electronics Engineers, Inc. (IEEE). The ICNIRP and IEEE determined the exposure limits (for occupational and for the general public/community) based on the lowest RF exposure that can cause biological effects. A safety factor was used to derive the values for Maximum Permissible Exposure (MPE) for electric and magnetic field strength and power density. The FCC adopted these values in 1996.

The time-averaging concept can be used to determine the levels of exposure. This means that it is acceptable to exceed the recommended limits for short periods of time as long as the average exposure does not exceed the limit.

Guidelines are more restrictive for lower radio frequencies. Since the smart meters of interest operate between frequencies of 900 and 930MHz, all of the guidelines for power densities presented in Table 2 were calculated assuming a frequency of 900MHz to be most conservative. All standards referenced in this report are based on community exposure, which considered sensitive populations, including children and the elderly. For a discussion of the inclusion of non-thermal effects, see this statement made by the Institute of Electrical and Electronics Engineers (IEEE):

> "Some investigators have reported effects at much lower exposure levels, which are sometimes called 'non-thermal' effects. Each version of the IEEE standard has acknowledged the existence of such reports, while at the same time indicating that they were insufficient to be considered a health hazard or to be used as a basis to develop exposure guidelines. For example, the 1991 standard states that 'research on the effects of chronic exposure and speculations on the biological significance of non-thermal interactions have not yet resulted in any meaningful basis for alteration of the standard. It remains to be seen what future research may produce for consideration at the time of the next revision of this standard.' Other organizations have independently reached this same conclusion" (Ziskin 2005).

Review of Other Standards and Recommendations

ADHS directed a review of standards and guidelines for RF radiation used by a number of countries and health organizations. ADHS found standards for Australia, Canada, ICNIRP, IEEE, New Zealand, and Russia which also included a discussion of how they arrived at their standard.

In North America and most of Europe, exposure standards and guidelines have been based on exposure levels where harmful effects to humans occur. FCC safety factors are then incorporated to determine specific levels of exposure aimed to provide sufficient protection for various segments of the population (including children, the elderly, etc.). Some published limits in other countries have been more restrictive than existing or proposed recommendations for exposure developed in North America and other parts of Europe.

The FCC (USA), Canada, Australia, and New Zealand all based their guidelines on the recommendations of the International Commission on Non-Ionizing Radiation Protection (ICNIRP)'s guideline. The main reason for slight differences in guidelines between these countries is for differences in the safety factors used.

Table 2. Standards and Recommended Guidelines for 900 MHz Radio Frequency		
Country/Organization	**Standard/Guideline for Power Density**	**Citation**
Federal Communications Commission (FCC, USA)	6 W/m^2 (Watts/square meter)	OET Bulletin 56: Fourth Edition, August 1999[1]
Australia	9 W/m^2	Radiation Protection Standard, May 2002[2]
Canada	4.5 W/m^2	Safety Code 6, 2009[3]
International Commission on Non-Ionizing Radiation Protection (ICNIRP)	4.5 W/m^2	ICNIRP Guidelines for Limiting Exposure..., 1998[4]
Institute of Electrical and Electronics Engineers (IEEE)	4.5 W/m^2	IEEE Exposure Limits..., 2005[5]
New Zealand	0.5 W/m^2	Radiofrequency Fields Exposure Standard, Feb. 2014[6]
Russia	0.1 W/m^2	Scientific basis for Soviet and Russian Radiofrequency Standards..., July 2012[7]

Links: [1]FCC [2]Australia [3]Canada [4]ICNIRP [5]IEEE [6]New Zealand [7]Russia

International Commission on Non-Ionizing Radiation Protection (ICNIRP):

The ICNIRP is an independent non-profit scientific organization chartered in Germany, which specializes in non-ionizing radiation protection. Their guideline is based on the study: "Biological Effects and Health Hazards of RF and MW Energy: Fundamentals and Overall Phenomenology" by Sol M. Michaelson. Russia's guideline of 0.1 W/m^2 was based on the study: "Biological Significance of Autoimmune Reactions of the Organism After Exposure to Environmental Factors" by G. I. Vinogradov (in Russian).

This study reviewed a number of studies on animals, including rats and rabbits. It was found from this animal data that exposure to more intense fields, producing Specific Absorption Rate (SAR) values in excess of 4 W/kg, can overwhelm the thermoregulatory capacity of the body and produce harmful levels of tissue heating. The sensitivity of various types of tissue to thermal damage varies widely, but the threshold for irreversible effects in even the most sensitive tissues is greater than 4 W/kg under normal environmental conditions. These data form the basis for an occupational exposure restriction of 0.4 W/kg and a community exposure restriction of 0.08 W/kg, which provide a large margin of safety for other limiting conditions such as high ambient temperature, humidity, or level of physical activity (ICNIRP 1998). These values can then be converted from SAR to their equivalent power density.

The Institute of Electrical and Electronics Engineers (IEEE):

The Institute of Electrical and Electronics Engineers (IEEE) is a professional association, whose objectives are the educational and technical advancement of electrical and electronic

engineering, telecommunications, computer engineering, and allied disciplines. The guideline determined by IEEE has a similar rational to that of ICNIRP, but was developed using different processes. Based on its review, IEEE concluded that disruption of food-motivated learned behavior in laboratory animals is the most sensitive biological response that is both well confirmed and predictive of hazard. This effect, known as behavioral disruption, has been observed in laboratory animals ranging from rodents to monkeys exposed to RF fields at frequencies ranging from 225 MHz to 5.8 GHz. Depending on the animal species and RF frequency, the exposure needed to produce behavioral disruption varied from 3.2 to 8 W/kg (Ziskin 2005).

From its literature review, IEEE chose a value of 4 W/kg for the whole body averaged SAR as the threshold for behavioral disruption in animals. It reduced this SAR by a factor of 10 to establish the basic restriction for exposure in controlled environments, and then added another factor of 5 for exposure in uncontrolled environments. The resulting basic restrictions on whole body SAR are 0.4 W/kg for controlled environments, and 0.08 W/kg for uncontrolled environments. These values can then be converted from SAR to their equivalent power density. For 900 MHz radio frequency, the equivalent power density is 4.5 W/m^2.

Russia:

Radiofrequency (RF) standards for both public and occupational health issued by the Russian Federation have always contained exposure limits that were below those in other countries. Their guideline of 0.1 W/m^2 was based on the study: Vinogradov GI, Naumenko GM, Vinarskaya EM, Gonchar NM. 1987. Biological significance of autoimmune reactions of the organism after exposure to environmental factors. Gig Sanit 1:55-58 (in Russian).

This study reviewed a number of studies on animals, including rabbits, guinea pigs, white rats, wistar rats, and female fisher rats. Based on the immunology studies discussed in the article, chronic daily exposure to 1-5 W/m^2 can induce persistent pathological reactions. The threshold exposure for the unfavorable biological effects (0.5 W/m^2) was found in the immunology studies, but these effects were not pathological since the organisms could compensate for the exposure. The authors concluded, however, continual compensation could lead to long-term adverse effects and thus should be protected against. Chronic exposure to 0.1-0.2 W/m^2 did not induce any noticeable biological changes in small laboratory animals. Therefore the guideline in Russia is 0.1 W/m^2.

Other States' Reviews

Four other states have also conducted various types of studies to evaluate the potential health risk from exposure to radio frequency from electronic meters: Texas, California, Vermont, and Maine. ADHS reviewed those studies and some of the literature referenced in those studies. The Vermont study discussed sampling of electronic meters and identified methods that yielded "worst-case" scenarios. The "worst-case" scenarios identified in Vermont's study were as a starting point for a streamlined sampling approach. More on this is described in the methods of the field study section of this report. ADHS also researched whether any of these states

recommended a more stringent RF standard be applied to electronic meters for the protection of public health.

ADHS reviewed similar assessments performed by other US states and organizations on the potential health effects of RF radiation. Their methods and conclusions are discussed below:

California: In 2010, the California Council on Science and Technology (CCST) performed an "independent, science-based study that would help policy makers and the general public resolve the debate over whether smart meters present a significant risk of adverse health effects." They identified and reviewed over 100 publications and postings about smart meters and other devices in the same range of emissions, including research related to cell phone RF emissions. In addition, they contacted over two dozen experts in radio and electromagnetic emissions and related fields and asked for their opinions. They concluded that:

1. The FCC standard provides an adequate factor of safety against known RF induced health impacts of smart meters and other electronic devices in the same range of RF emissions.
2. At this time, there is no clear evidence that additional standards are needed to protect the public from smart meters or other common household electronic devices (CCST 2010).

Texas: In 2012, the Public Utility Commission of Texas wrote a survey report of the existing scientific research and analyses that have been performed to investigate the potential health effects of exposure to low-level radio frequency electromagnetic fields emitted by wireless communication devices including smart meters. They concluded that:

1. Decades of scientific research have not provided any proven or unambiguous biological effects from exposure to low-level radio frequency signals. All available material was reviewed, and no credible evidence to suggest that smart meters emit harmful amount of EMF radiation was found.
2. Smart meters do not emit or utilize ionizing radiation.
3. Smart meters are not intended for, are not designed to, and do not have the capability to harm an individual or direct a person's thoughts or actions (Rivaldo 2012).

Maine:

A. In 2010, a complaint was filed with the Maine Public Utilities Commission focusing on concerns related to health, safety, and security of smart meters. In response, Maine Center for Disease Control and Prevention (CDC) assembled a "smart meters team" to review numerous materials written by the WHO, FCC, NIH, Health Canada, ICNIRP, IEEE and other government agencies and academic organizations. With regards to electromagnetic hypersensitivity (EHS), the smart meters team concluded that the majority of studies indicate that EHS individuals cannot detect EMF exposure any more accurately than non-EHS individuals, and that well controlled and conducted double-blind studies have shown that symptoms were not correlated with EMF exposure. In summary, they concluded that:

1. Agency assessments and studies do not indicate any consistent or convincing evidence to support a concern for health effects related to the use of radiofrequency in the range of frequencies and power used by smart meters.
2. They also do not indicate an association of EMF exposure and symptoms that have been described as electromagnetic sensitivity (Ball 2010).

B. In 2013, True North Associates was retained by the Office of the Maine Public Advocate to "measure the maximum and average power output of a sample of smart meters and other system components using the mesh network, and compare these readings to existing safety standards." True North focused its efforts on a selection of the most active meters and elements within the mesh network and included all system components involved in broadcasting data within the network. Three residential meter locations were tested. The results obtained through the effort indicated that the measured exposure levels were well below current FCC exposure limits" (C2 Systems 2013).

Vermont:

A. In 2012, the Vermont Department of Health measured RF from smart meters. They stated, "The readings from these devices verify that they emit no more than a small fraction of the RF emitted from a wireless phone, even at very close proximity to the meter, and are well below regulatory limits set by the Federal Communications Commission (FCC). After extensive review of the scientific literature available to date and current FCC regulatory health protection standards, we agree with the opinion of experts:

1. The thermal health effects of RFR are well understood, and are the current basis for regulatory exposure limits. These limits are sufficient to prevent thermal health effects.
2. Non-thermal health effects have been widely studied, but are still theoretical and have not been recognized by experts as a basis for changing regulatory exposure limits" (Vermont 2012)

B. In 2012, the Vermont Department of Public Service aimed to assess compliance of smart meter signal intensities with regulations established by the FCC that prescribe limits for safe exposure to humans. In total, Vermont conducted measurements at 37 different locations in the state, including 18 residential sites, six banks of smart meters, two data collection points, one isolated meter, and 14 general environmental measurement sites. Field measurements were accomplished with a spectrum analyzer based selective radiation meter (Narda model SRM-3000), which permits direct measurement of the intensity of RF fields expressed as a percentage of the FCC maximum permissible exposure (MPE) values. Using the highest indicated results from the measurements performed in the study, it was concluded that:
1. Potential exposure of individuals to RF fields associated with currently deployed smart meters is small when compared to the limits set by the FCC.

2. Any potential exposure to the investigated smart meters will comply with the FCC exposure rules by a wide margin (Tell 2013).

Scientific Publication Review

Review Articles

ADHS performed a literature review of the potential health effects caused by exposure to RF radiation. ADHS searched two different literature databases of peer-reviewed articles. ADHS searched for review articles and articles that discussed an association between RF exposure and any of the top five health concerns from community members (see below). Preference was given to review articles that 1) discussed radiation from electronic meters, and 2) were published within the last 5 years if they could be found.

ADHS found that most experts agree that exposure to RF at high enough strengths for long enough time can result in adverse health outcomes from thermal effects. However, when discussing non-thermal adverse health outcomes, the literature is not clear.

Some study designs reported in the literature provide higher levels of evidence than others. For example, human epidemiology studies are of primary importance in health risk assessment because they can provide direct information on the health of people exposed to an agent. When examining human epidemiology data, systematic review articles which conduct meta-analyses (a statistical technique for combing the findings from independent studies) are the strongest literature. These studies aim for a complete coverage of all relevant studies. They look for the presence of differences, and explore the robustness of the main findings among peer-reviewed scientific studies.

Other literature ADHS reviewed discussed potential changes on the cellular level which provide knowledge of the basic interaction mechanisms of RF with cellular structures. These studies are important hypotheses generating studies. They provide evidence that RF may have the potential to affect human physiology. However, these studies cannot conclude that the cellular changes necessarily lead to disease. Other studies concluded exposure to RF from a variety of sources was associated with adverse health outcomes. However, these studies had several limitations ranging from recall bias to a lack of details, e.g. power densities of exposure or differentiating between exposure to electronic meters and other types of RF emitting devices. Sometimes a study that suggests an exposure is associated with an adverse health outcome is countered by another similar study that suggests there is no adverse health outcome at that exposure level.

ADHS considered articles' study design, exposure parameters, and relevance to this current review. The study design and exposure parameters vary widely from study to study. ADHS attempted to concentrate on those studies that addressed the questions relating to community exposure to RF from electronic meters.

It is generally well understood that RF exposure can cause tissue heating or "thermal effects," leading to potential adverse health effects. More recently, concern has been raised that exposure to lower power densities of RF may lead to adverse health effects without tissue heating, also known as "non-thermal effects." Several studies in the last decade have concluded that RF exposure at lower power densities than those required to cause thermal effects may cause adverse health effects including genotoxicity, decreased sperm count, headaches, sleep problems, concentration problems, and hyperactivity in children. The studies that draw these conclusions are largely based on exposure to cell phones and Wi-Fi devices held close to the human body such as a laptop on a man's lap leading to decreased sperm quality/count. In addition, many of these conclusions were based on results that showed biologic changes. Biologic changes do not always lead to the expected adverse health outcome. The National Aeronautics and Space Administration (NASA) describes the difference of biologic and adverse effects as follows:

> "Biological effect — A biological effect is an established effect caused by, or in response to, exposure to a biological, chemical, or physical agent, including electromagnetic energy. Biological effects are alterations of the structure, metabolism, or functions of a whole organism, its organs, tissues, and cells. Biological effects can occur without harming health and can be beneficial. Biological effects also can include sensation phenomena and adaptive responses.
>
> Adverse health effect — A biological effect characterized by a harmful change in health." (NASA, 2014)

For example Juutilainen, et. al. reviewed *in vitro*, *in vivo*, and human studies on a variety of adverse health outcomes. The authors stated, "the studies discussed in this review indicate that there may be specific effects from amplitude-modulated RF electromagnetic fields on the human central nervous system. The effects reported (changes in EEG, cerebral blood flow and performance in a memory test) are relatively minor, and do not at present allow conclusions concerning possible adverse health effects." They went on to say:

> "Further studies are warranted to determine how the effects depend on modulation characteristics and exposure level, and to investigate possible mechanisms and relevance to human health. Also, animal studies with suitable experimental models would be valuable to shed light on the mechanisms of the modulation-dependent effects on the central nervous system.
>
> No consistent evidence has been found for modulation-dependent effects on carcinogenesis or genotoxicity. Some in vitro studies have provided suggestive evidence of modulation-specific effects at the cellular level. Follow-up of the positive findings would be helpful for

understanding the mechanisms of any specific effects of modulated RF energy."

An international group of researchers reported in L. Verschaeve et. al. the endpoint, exposure conditions, and conclusions for 82 genotoxic endpoints from *in vitro* (lab studies, eg. cells in a petri dish), 29 animal, and 17 human from various studies on RF exposure. The authors concluded that the majority of studies that showed positive results (RF exposure lead to an adverse outcome) reported high exposure levels and the effects were likely due to thermal effects. They also stated that although there were some studies that suggested adverse outcomes from lower level exposure to RF, this apparent association might be due to many factors including poor study design, errors, or incorrect assumptions regarding exposure conditions. Their overall conclusion was "overall, taking into account these different factors the evidence to date that exposure to non-thermal levels of RFR is genotoxic is very weak." The authors also stated, "the weight of scientific evidence from 45 peer reviewed investigations shows that RFR-exposure up to lifetime duration (2 years) does not adversely affect body mass, survival and carcinogenic processes (initiation, promotion or co-promotion) at whole-body dose rates up to 4W/kg and localized dose rates up to 2.3W/kg.

Kundi et al. (2010) reviewed nine epidemiological studies conducted by various countries: US, Sweden, Denmark, Finland, and Germany. These studies investigated the relationship between the use of cell phones and cancer, mainly brain tumors. They concluded that, based on the available information, an elevated cancer risk associated with cell phone use cannot be ruled out because increased cancer risks were observed in epidemiological studies. Yet, all studies have some methodological deficiencies: (1) short exposure duration: the duration of cell phone use were too short to be helpful in risk assessment, (2) exposure was not rigorously determined, and (3) there is a possibility of recall and response error (recall bias) in some studies. Recall bias occurs when the participants recall exposure differently. For example: cancer cases may try harder to recall prior exposure because they think the exposure might be related to their disease. Parents of children with birth effects may try harder to recall any drugs, exposures they had during pregnancy than parents of children without birth defects.

Roosli (2008) conducted a systemic review of electromagnetic sensibility (i.e. the ability to perceive low levels of EMF) and electromagnetic sensitivity (i.e. the development of health symptoms attributing to exposure to EMF such as headache, sleep disturbance, fatigue, dizziness, and concentration difficulties.) Meta-analytic techniques were used to analyze and integrate the information from peer-reviewed articles published before 2007. For electromagnetic sensibility, the author reviewed seven studies including a total of 182 self-declared electromagnetic hypersensitivity (EHS) individuals and 332 non-EHS individuals. The results indicated that there was no evidence that EHS individuals could detect presence or absence of EMF better than other persons. For electromagnetic sensitivity, the review from eight laboratory studies (including 194 EHS and 346 non-EHS individuals) showed that there was little evidence that short-term exposure to a mobile phone or based station causes non-specific symptoms. Four population-based studies were reviewed. Two studies observed slightly

increased, but not significant, complaints while the other two studies found there is no association. Overall, this review concluded that: the large majority of individuals who claim to be able to detect low level of radio frequency EMF are not able to do so under double-blind conditions.

In another study, Karaca et. al. (2012) stated that "the results of our study support the proposition that cell phones may have a potential to cause hazardous effects on the genome; however, in *in vivo* conditions, the duration of exposure and the capacity of DNA repair may prevent the development of cancer to an extent."

Vigjayalaxmi compiled the conclusions on the biological effects of RF exposures from various national and international expert groups. Below is a summary table of these conclusions (2014).

Organization	Conclusions
IARC	No increased risk for meningioma and glioma with mobile phone use.
IEEE	Public health officials should continue to use RF safety limits of international organizations.
ICNIRP	Impossible to disprove non-thermal effects. Poor evidence for chronic/low-level effects. Studies with adequate RF exposure assessment did not reveal any health-related effects.
EU	No consistent evidence on cognitive function. No clear effect on neurological diseases. Inadequate evidence for cancer and neurological diseases.
Australia	No substantiated evidence for health risk for people living near base stations. Insufficient evidence for higher risk for children. No need to reconsider exposure limits.
Belgium	No proven health risks. Long-term health risks cannot be ruled out.
Canada	Cell phone towers are not dangerous. No evidence of adverse effects from WiFi.
Finland	Mobile phone use is not detrimental to health.
France	No new proven health effects.
Germany	Discrepancy between scientific evidence and risk perception. No overall risks. Risk perception is linked to media coverage.
Latin America	Insufficient evidence for adverse health effects from in vitro and in vivo studies.
Netherlands	Insufficient and inconsistent association of tumors in brain and other regions of head.
New Zealand	No health problems when complied with international guidelines.
Nordic Countries	No scientific evidence for adverse health effects.
Norway	No evidence that weak RF fields cause adverse health effects. Uncertainty in risk assessment is small.
Spain	No scientific evidence that exposure to low emissions levels produces adverse health effects in school children.
Sweden	Overall data do not support increased cancer risk in mobile phone users.
Switzerland	No new confirmed health effects.
Tanzania	No substantial evidence for harmful health effects. Many benefits of modern technology.
UK	No convincing evidence in adults or children for adverse effects below the

	recommended/guideline levels.
USA	Studies have not shown a consistent link with cancers of the brain, nerves, or other tissues of the head and neck cancers.

Source: Vijayalaxmi. "International and National Expert Group Evaluations: Biological/Health Effects of Radiofrequency Fields." International Journal of Environmental Research and Public Health: Volume 11, Issue 9. September 10, 2014.

Another review article summarizes that excessive exposure to magnetic fields from power lines and other sources of electric current increases the risk of development of some cancers and neurodegenerative diseases. Excessive exposure to RF radiation increases risk of cancer, male infertility, and neurobehavioral abnormalities. Smart meters usually produce atypical, relatively potent, and short-pulsed RF microwaves whose biological effects have never been fully tested and may, in fact, be more hazardous than other waveforms. Electronic meters can add significantly to aggregate RF exposure.

However, at further study of the article, the article states that a typical electronic meter with a 5% duty cycle at a distance of 20 cm (= 0.656 ft) emits 11 $\mu W/cm^2$ of RF radiation. This is equal to 0.11 W/m^2, which is well below the FCC community guideline of 6 W/m^2. The article seems more focused on the dangers of cell phone radiation, which is a separate issue (Carpenter, 2013).

Whether a person experiences an adverse health outcome from RF depends on many factors. Factors include how strong the power density is, how far the person is from the RF field, how often the person is exposed, and the individual health of the person exposed.

Individual Health Effects

ADHS conducted a literature search of peer-reviewed articles on the potential effects of RF radiation. Special attention was given to articles that discussed the health concerns most noted by Arizona citizens. These health effects are: headaches, insomnia, cancer, ear pain/tinnitus, and fatigue. Preference was given to articles that 1) discussed radiation from electronic meters, and 2) were published within the last 5 years.

The articles ADHS found discussed RF from sources other than electronic meters. A number of the articles discussed the potential health effects listed above from RF radiation emitted from cell phones. Electronic meters use a very similar wireless technology to cell phones, and the electronic meters in Arizona use a frequency of 900-930 MHz, which is within the frequency range of cell phones (450-2700 MHz). However, strength of the RF field and exposure to electronic meters and cell phones differ.

Most of the studies concluded that there was no association between RF exposure at low levels and adverse health outcomes. A couple of articles found weak associations. Some studies called for additional research (Mohler, 2012; Lowden 2011; Heinrich 2010; Mortazavi 2014; Poulsen 2013; Swerdlow 2011; Kwon 2012; Choi 2014; and Frei 2012).

Submissions from the Community

Arizona residents have submitted a plethora of information to the Arizona Corporation Commission's eDocket relating to RF exposures from electronic meters. ADHS reviewed the documents submitted from August 2011 to August 2014 that discussed health-related concerns. ADHS also reviewed direct communication received before October 1, 2014 from community members across the state. The types of information submitted by residents included news articles, websites, peer-reviewed studies, documents released by governmental regulatory or advisory bodies, anecdotal descriptions of how residents believed electronic meters were affecting their health, and personal opinions. ADHS reviewed the peer-reviewed studies and government documents. A discussion on some of these is included in the literature review section described above. ADHS created a table of the reported health effects, and made note of how many times each effect was mentioned. ADHS determined the top 5 mentioned health effects and searched peer-reviewed literature databases (described above) for peer-reviewed studies that looked for associations between RF exposure and the reported health effect. A list of the reported health concerns can be found in Appendix A.

ADHS reviewed all 38 journal articles assessing health implications that were submitted to the ACCs eDocket. ADHS provides a summary and response to the three were most often mentioned articles in Appendix B.

Health Concerns Mentioned in Submissions to the ACC eDocket		Number of times mentioned
Top Five Concerns	Headaches	28
	Insomnia	27
	Cancer	15
	Fatigue	14
	Ear pain/ringing (tinnitus)	14

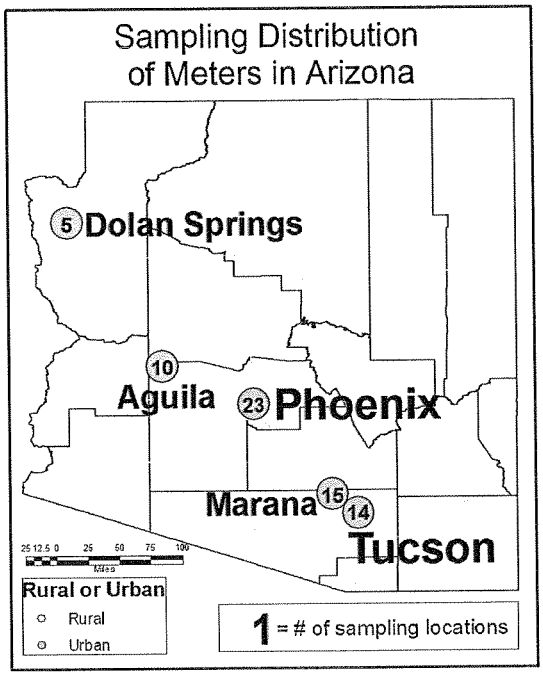
Part 2: Field Study

ADHS worked with ARRA to design a field sampling plan that would measure different meter technologies in urban and rural areas. The agencies used their expertise and referred to previous studies to identify a scientifically sound method. The agencies approached the field study by attempting to capture a worst case scenario as a screening process. If a measurement was captured at or above the screening value, a more in depth evaluation would be necessary. The field study was not intended to strictly follow FCC's recommendations for evaluating human exposures to RF, but rather capture the worst case scenario. The FCC guidelines consider percent Maximum Permissible Exposure (MPE) and duty cycle when comparing the measured RF exposure to the standard. This study measured peak and average power densities at 5, 10, and 15 minutes without regard to duty cycle.

It was decided that ARRA would test the RF emitted from a variety of meter technologies: analog, PLC, AMR and AMI. The Arizona Radiation Regulatory Agency (ARRA) conducted the field sampling analyzed in this report. ADHS used the measured RF levels to determine if there is a public health concern associated with exposures to electronic meters in Arizona. Sampling was conducted from June to September 2014 by ARRA. Only outdoor sampling was conducted at residential locations for single-family homes and apartment complexes.

Selecting sampling locations

Sampling locations were selected by the technology of the meter used by the electric companies for the three technologies: AMI, AMR, and PLC. 2010 U.S. Census Bureau definitions were used to identify whether a city was considered urban or rural. Locations that were serviced by each the three technologies were randomly chosen to identify five zip codes for testing (3 urban zip codes and 2 rural zip codes). The following cities and zip codes were selected for field sampling: Phoenix (85023), Aguila (85320), Tucson (85712), Dolan Springs (86441), and Marana (85658). ADHS contacted the electric companies for the zip codes selected for field sampling. ADHS requested all addresses within the zip code that have the technology being sampled. This was to ensure the chosen sampling locations would be operating as regularly scheduled. ADHS randomly selected addresses on the lists provided by the electric companies to create a description of neighborhoods (street names and names of apartment complexes) for ARRA to sample. ARRA then selected addresses from the neighborhood descriptions provided by ADHS.



Number of samples

ACC and ARRA worked together to determine the scope of the sampling. ARRA tested as many sampling locations in each of the zip codes as was feasible for the scope of the project. There were a total of 66 sampling locations: 10 locations were apartments, 2 locations were part of duplexes, and 54 were single- family residences.

Radiofrequency Sampling Device

The Tenmars TM-195 is a radio frequency (RF) field strength meter. It is designed for measuring and monitoring RF electromagnetic field strength over the frequency range of 50 megahertz through 3.5 gigahertz. This meter self-calibrates at power up levels but has a functionality to be manually adjusted to detect more sensitive frequencies inside of multiple frequency fields. Field strength meters will display excessive values if hand-held or moved during measurements from electrostatic charges. To counter this, the TM-195 should be used on a tripod or held as steady as possible while avoiding speaking or moving during measurements. The electrical specifications are as follows:

Under the following conditions:
Ambient temperature +23°C ± 3°C
Relative Humidity 25% - 75%
Frequency range 50 megahertz – 3.5 gigahertz
CW signal (f>50 megahertz) 0.01V/m to 20.0 V/m
0.1 mA/m to 532.6 mA/m, 0.01W/m² to 106.94mW/m²
Dynamic range: Typically 75 dB
Absolute error at 1 V/m and 2.45GHz ± 1.0 dB

Frequency response:
Sensor taking into account typical CAL factor
± 2.4dB (50 Mhz to 1.9 GHz)
± 1.0 dB (1.9 GHz to 3.5 GHz)
Isotropy deviation: Typically ± 1.0 dB (f 2.45GHz)
Overload limit: .042 mW/cm²
Overload limit: (0 to 50°C); ± .2 dB

The Arizona Radiation Regulatory Agency uses this meter during routine use to ensure that industrial registrants registered to operate radio frequency devices do not exceed the maximum permissible exposure (MPE) limits as defined in the Arizona Administrative Code Title 12, Chapter 1, Article 14. Calculations of the MPE are published in IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz.

Sampling Design

The measurements of RF can be affected by various factors: traffic on the meter network, proximity to other meters, background RF, direct sunlight, barriers between the meter and the RF sampling device/person. These factors were considered in the design of the sampling plan.

Trial Sampling Event

A trial sampling event was conducted at a residential, single-family home and an apartment complex to determine the feasibility of various sampling parameters. At this event, two distances (three feet and nine feet), use of attenuation and no attenuation, and time intervals (readings every 15 minutes for one hour) were considered. It was determined that spending one hour at each location would significantly limit the number of total sampling locations in the final review. In order to 1) sample more locations, 2) measure the same location multiple times at different times of the day, and 3) sample locations across the state, it was decided to adjust the sampling parameters to measure the maximum radiofrequency a person may be exposed to from the electric meter, the worst-case scenario.

Vermont's Study

Richard Tell Associates, Inc. conducted a field study of electronic meters deployed in Vermont. During this field study, they sampled a residential meter to assess the potential exposure and directionality to electronic meter RF fields at various distances, heights, and horizontal directions. Readings were taken at four distances between one foot and 10 feet, with the highest reading occurring at a distance of one foot. For height, the measurement at four feet above the ground (the height of the face of the meter) was the highest reading, suggesting that emissions are mainly directed horizontal to the meter. In the horizontal plane, the highest readings occurred at zero degrees, or forward from the face of the meter. Measurements were also taken inside the home to account for attenuation. Attenuation refers to the concept that RF exposure is less if there is a material between the RF emitting device and the person being exposed.

The findings of Vermont's report were considered in determining the parameters of the "worst case scenario": measurements at one foot, height of the face of the meter, and the sampling device probe aimed at the front of the face of the meter, without any attenuation.

Readings from the TM-195 were taken at five minute intervals, over a 15 minute period. Readings were also taken at three different times during the day to determine if there is any difference in RF transmission throughout the day. Background RF was also measured near sampling locations. This background location was chosen to have as little RF transmission signals as possible, such as being away from overhead power lines, street lights, houses, etc. Background measurements were taken for all sampling locations.

Field Measurements

ARRA completed all field sampling and recorded data on the sampling form created by ADHS see Appendix C. ARRA mutually agreed upon sampling protocols.

Sampling device setup

The TM-195 was secured to a tripod and adjusted to the same height as the center of the face of the meter. For single meters, the probe was directed at the center of the electric meter. For a bank of meters, the probe was directed toward the center of the bank of meters and raised to the height of the middle of the bank of meters. The sampling device was placed one foot away from the electric meter (s), perpendicular to the front face of the meter.

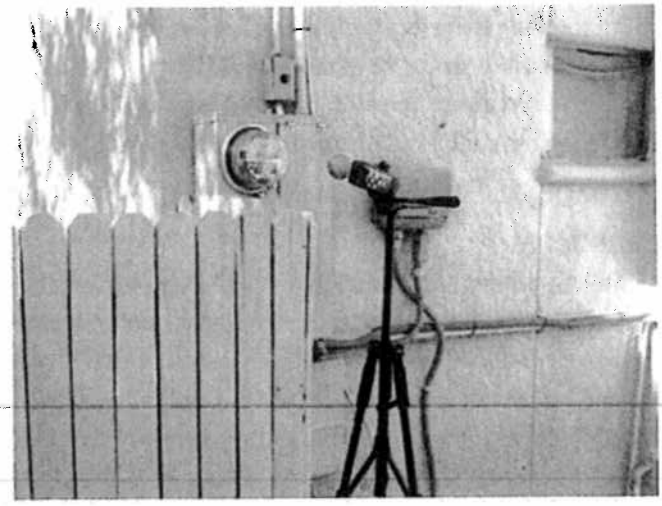


Figure 2. TM-195 placement at a single-family residence.

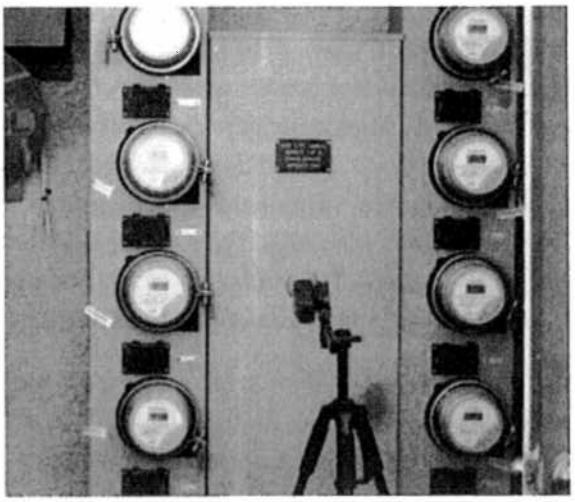


Figure 3. TM-195 placement at a bank of meters.

For each sampling location ARRA:

1. Recorded address location, address type (single family home or apartment complex), zip code (urban or rural area) and meter details [single meter or bank of meters (record number of meters in the bank)], location of meter(s) on the home (garage or living space) and the meter model.
2. Recorded background readings in the shade and sun to the corresponding sampling address location. Recorded average and peak reading over a five minute time interval.
3. Took all measurements at one foot, without attenuation.
4. Recorded the average and peak readings every five minutes for a total of 15 minutes.
5. Sampled at three different times during the day (for example, morning, midday, and afternoon).

For each reading time ARRA:

1. Recorded weather condition (sunny, partly cloudy, or mostly cloudy.)
2. Recorded whether or not the readings were taken in the shade.
3. Recorded dates and times of readings.

Results and discussion

On-site Readings of Radio Frequency Electromagnetic Fields

The RF electromagnetic field emissions associated with the usage of electronic, PLC, and analog meters were measured by using a RF field strength meter, Tenmars TM-195, as described in the Methods section. This field investigation examined the strengths (measured by power density in watts per square meter, W/m^2) of the RF fields emitted by different types of meters under normal operating conditions because the electric companies were not notified when the investigation was conducted. This was determined by the study group (i.e. ACC, ARRA, and ADHS) to prevent bias.

The amount of transmitting activity of an electronic meter varies throughout the day. It depends on the prescribed data-collecting times and the interaction with other meters. In addition, the typical emission of an electronic meter consists of very brief spurts of pulses of RF energy lasting less than one-tenth of a second. To represent the overall exposure throughout a day, power density measurements were taken at three different times during the day (for example, morning, midday, and afternoon) for each sampling location. Both the average and instant peak values of field power density were measured. The measurements were taken at 1 foot away from the meter without attenuation. The measurements represented the maximum RF emission a person (i.e. worst case scenario) can be exposed to from the meters at the sampling time.

ADHS compared the levels of RF power density measured in front of different types of meters (Table 3). As expected the measured RF levels are higher for AMI and AMR meters because they communicate via radio frequency. ADHS compared the levels of RF power density measured in front of single and multiple meters (Table 4.) As expected the measured RF levels are higher for multiple meters. ADHS also compared the levels of RF power density measured at urban and rural areas (Table 5.) Overall, the RF levels are higher in urban area. These results indicated that, under the sampling scenario, people will receive higher levels of RF exposure from multiple meters. Yet, as discussed later, none of the measured RF power density are at levels of public health concern.

Table 3 shows the readings of power density from different types of meters.

Meter Type	Number of meters measured	Range of 5-min average (W/m^2)	Highest reading measured (W/m^2)
Analog	3	0.0000035 – 0.0000879	0.000129
PLC	13	0.0000131 – 0.0000936	0.001084
AMR	17	0.0000021 – 0.000747	0.001435
AMI	33	0.00001 – 0.0016017	0.0025

Table 4 shows the readings from residences with single meters or multiple meters.

Meter Type	Number of meters measured	Range of 5-min average (W/m^2)	Highest reading measured (W/m^2)
Single meter	54	0.000021 – 0.0003	0.0025
Multiple meters	12	0.00001347– 0.0016017	0.0017679

Table 5 shows the readings from urban and rural areas.

Meter Type	Number of meters measured	Range of 5-min average (W/m^2)	Highest reading measured (W/m^2)
Urban	49	0.0000021 – 0.0016017	0.0025
Rural	17	0.0000043 – 0.000163	0.000163

Public Health Implication Based on the On-site Readings

ADHS generally follows a three-step methodology to assess public health issues related to environmental exposures. First, ADHS obtains representative environmental data for the site of concern and compiles a comprehensive list of site-related contaminants or concerns. Second, ADHS identifies exposure pathways, and then uses standards or guidelines to find those exposures that do not have a realistic possibility of causing adverse health effects. For the remaining exposures, ADHS reviews recent scientific studies to determine if exposures are sufficient to impact public health.

These on-site readings were compared to standards and guidelines, which are often used as screening tools to evaluate environmental data relevant to exposure pathways. The standards and guidelines are quite conservative, and include safety factors that account for sensitive populations (such as infants, young children, and elderly.) Adverse health effects are not expected to occur if an exposure level is below a health-based guideline. However, an exposure level at or above the health-based guideline does not mean adverse effects will occur. Rather, it means that there is a need to conduct a site-specific exposure scenario evaluation. The health risk for an individual depends on individual human factors (e.g. personal habits, occupation, and/or overall health), and site-specific environmental exposure factors (e.g. duration and amount of exposure). Therefore, the health-based guidelines should not be used to predict the occurrence of adverse health effects without looking at site-specific conditions.

ADHS typically uses standards and guidelines as follows: if an exposure is never found at levels greater than its standard or guideline, ADHS concludes the levels of corresponding exposure do not pose a risk to human health. If, however, an exposure is found at levels that are greater than its standard or guideline, ADHS examines potential human exposures in greater detail.

Meters communicate via radio frequency (i.e. AMI and AMR meters):

Measured power densities were compared to health-based guidelines (Table 6.) The 30-minute averages were calculated by using the top six 5-minute averages from a sampling location. This approach provided an estimation of the possible maximum 30-minute exposure throughout a day. The overall averages were calculated by using all 5-minute averages from a sampling location. This provided an estimation of the overall exposure throughout a day. ADHS used guidelines developed by FCC, ICNIRP, IEEE and Russia to evaluate the potential adverse health effects associated with exposures to radio frequency from AMI and AMR meters.

Short-term Exposure: FCC, ICNIRP and IEEE guideline values was determined based on established adverse thermal health effects. The purpose of these guidelines are to prevent whole-body heat stress and excessive localized tissue heating. The 30-minute averages ranged from 0.000021 to 0.000465 W/m^2 for AMR meters, and from 0.000028 to 0.001101 W/m^2 for AMI meters. None of these values exceeded the FCC (6 W/m^2), or ICNIRP/IEEE (4.5 W/m^2) guideline values (Table 6.)

Long-term Exposure: FCC does not have an established standard for non-thermal health effects because of insufficient information. Our review of US and most internal government assessments, and scientific publications indicated that there is no consistent or convincing evidence to support a cause-and-effect relationship related to the exposure to the RF frequency (900 – 930 MHz) used by the smart meters. The majority of the scientific studies concentrated on the possible health effects from mobile phone exposure. When compared to mobile phones, smart meters represent lower RF exposure sources because of the attenuation factor of the building structure (for example: walls), and the distance from radiation signal source (i.e. location of the smart meters and mobile phones in relation to the human body.) Based on these, it appears to us that exposures to smart meters would indicate even less association to non-thermal effects.

Our review indicated that Russia has developed a standard for radio frequency between 450 to 2,700 MHz for mobile phones. This standard was determined based on non-thermal health effects. We do not have access and do not have the ability to review the original paper (in Russian). The source indicated that this value was set based on an animal study consisting of 110 rats exposed to 900 and 1,800 MHz at 5 and 20 W/m^2. The results showed changes in the immune status of animals exposed to 5 W/m^2. A safety factor was applied to obtain the Russian standard of 0.1 W/m^2 for the general public. This limit was set to ensure that no exposure would cause any possible biological consequences among the exposed population. ADHS used the Russian standard as a comparison to ARRA's measurements. The results showed that none of the overall average readings of AMI (ranging from 0.000025 to 0.000888 W/m^2) or AMR (ranged from 0.000016 to 0.000377 W/m^2) meters exceeded the standard (Table 6.)

In this field investigation, ARRA measured the RF emission levels based on the worst case scenario. Such measurements do not necessarily reflect personal RF exposure (they tend to overestimate the RF exposures) because they are not always taken at the distance from the RF source that the person would typically be from the source (for example: inside the house.) Therefore, with the available information, exposures to AMI and AMR meters are not likely to harm the health of the public.

Table 6 shows the readings of power density from electronic meters communicating via radio frequency.

Meter Type	Number of meters measured	30-min average (W/m^2)	Highest reading measured (W/m^2)	Standards/ Guidelines (W/m^2)	
AMR[1]	17	0.000021 – 0.000465	0.001435	6	FCC
AMI[2]	33	0.000028 – 0.001101	0.0025	4.5	ICNIRP/IEEE

1. AMR: Automated Meter Reading
2. AMI: Advanced Metering Infrastructure
3. FCC: U.S. Federal Communications Commission OET Bulletin 56, 47 CFR § 1.1310

4. ICNIRP: International Commission on Non-ionizing Radiation Protection
5. IEEE: Institute of Electrical and Electronics Engineers (IEEE)

Meter Type	Number of meters measured	Overall average (W/m^2)	Standards/ Guidelines (W/m^2)	
AMR[1]	17	0.000016 – 0.000377	0.1	Russian
AMI[2]	33	0.000025 – 0.000888		

1. AMR: Automated Meter Reading
2. AMI: Advanced Metering Infrastructure

Meters that do not communicate via radio frequency (i.e. PLC and analog meters):
As described in previous sections, analog meters are not expected to emit any radio frequencies. The PLC meters communicate via power lines. During the data transmission process, a power frequency field of 60 Hz is produced. Power frequency is considered as a type of extremely low frequency (ELF) electric and magnetic field ranging from 3 to 3,000 Hz. In this range, electric and magnetic fields do not interrelate as higher-frequency waves (such as radiofrequency), and they are characterized separately. Electric field strength is measured in unit of volts per meter (V/m), and the magnetic field strength is measured in units of gauss (G) or tesla (T.) The strength of power radio frequency was not measured since it is not within the scope of this investigation. A detailed discussion of power line frequency can be obtained from a NIEHS publication[1] (NIEHS 2002.)

For the purpose of comparison, PLC and analog meters were included in the field investigation. Different levels of RF power density were detected from residences with PLC and analog meters during the field investigation. The measured RF levels from residences with analog and PLC meters were comparable to each other (see Table 3), and their respective background levels. For example, the three 5-minute average for one house were 0.0000178, 0.0000159, and 0.0000154 W/m^2. The background level was 0.0000142 W/m^2. The results suggest that only a very little amount of RF may be emitted from PLC meters.

Conclusions

Review of Radio Frequency Regulation and Literature:

ADHS reviewed: (1) regulatory standards developed by the US and other countries such as Australia, Canada, Russia, and New Zealand, (2) exposure recommendations provided by the International Committee on Non-Ionizing Radiation Protection (ICNIRP) and the Institute of Electrical and Electronics Engineers (IEEE), (3) smart meter radio frequency studies conducted by other states such as California, Texas, Maine, and Vermont, (4) peer-reviewed scientific publications, and (5) smart meter and RF

[1] EMF: Electric and Magnetic Field Associated with the Use of Electric Power

exposure related documents submitted to the Arizona Corporation Commission's eDocket. Based on the available information, ADHS found that:

- The majority of the countries determined their standards based on the recommendation of the ICNIP and IEEE. The values of specific absorption rate (SAR) and power density were established to prevent thermal effects from radio frequency radiation. No value was recommended for non-thermal effects because the ICNIP and IEEE, based on the available information, feel that the evidence from epidemiological and laboratory studies are not sufficient to identify there is a health hazard nor to be used as a basis to develop exposure guidelines.
- Russia set a much lower standard which was determined to prevent any possible biological consequences among the exposed population. The study was conducted by Russian scientists and the paper was written in Russian. ADHS was not able to review the report. The source indicated that the value was determined based on chronic immunology studies from a number of animal studies.
- States conducting radio frequency studies have similar findings, based on scientific literature review or field measurements. Their results agreed that the thermal effects of radio frequency are well understood, and the current FCC standard is sufficient to provide an adequate protection to prevent thermal effects. In addition, no sufficient evidence to support a need for additional standards to protect the public from electronic meters.
- ADHS concurs with the findings from the other states. ADHS reviewed articles on the potential health risks from RF radiation, mainly from wireless communication. The review examined the potential biological and health effects from exposure to RF fields from studies that have been published. The authors reviewed relevant research investigations in different areas: epidemiology studies, empirical studies in cell cultures and animals, and clinical human studies. An overall assessment was then conducted based on the aggregated evidence across reviewed areas. ADHS found that most experts agree that exposure to RF at high enough strengths for long enough time can result in adverse health outcomes from thermal effects. However, when discussing non-thermal adverse health outcomes, the literature is not clear.
- ADHS also reviewed articles published in the last five years that discussed the health concerns most noted by Arizona citizens. These health effects are: headaches, insomnia, cancer, ear pain/tinnitus, and fatigue. Most of the studies concluded that there was no association between RF exposure at low levels and adverse health outcomes. A couple of articles found weak associations. Some studies called for additional research.

Field Investigation:

ARRA conducted a field investigation to identify the levels of RF radiation emitted from different types of meters (i.e. analog, PLC, AMI, and AMR meters.) The measurements were taken from single family homes, and apartment complexes at rural and urban areas. After receiving data from ARRA, ADHS conducted an assessment to evaluate the potential health risks associated with exposure to radio frequency radiation emitted from electronic meters (i.e. AMI and AMR meters.) Based on the available information, ADHS reached the following conclusions:

- The measured RF radiation emissions (in power density) from electronic meters are below the FCC standard of 6 watts per square meter (W/m^2).
- In general, the measured RF radiation emissions are higher from AMI and AMR meters. The measured RF radiation emission from analog and PLC meters are similar to the background levels.
- In general, for electronic meters, the measured RF radiation emissions are higher for apartment complexes when they are compared to single family homes.
- In general, for electronic meters, the measured RF radiation emission is higher from urban area when they are compared to those from rural area.
- *Exposure to electric meters (AMI and AMR) is not likely to harm the health of the public.* This conclusion was reached because (1) none of the detected power densities exceeded the FCC standard of 6 W/m^2. This standard was determined based on thermal effects, and was set to prevent whole-body heat stress and excessive localized tissue heating; (2) available government assessments and scientific literature indicated that there is no consistent or convincing evidences to support a cause-and-effect relationship related to the exposures to the RF frequency (900 – 930 MHz) used by the smart meters ; (3) none of the detected power density exceeded the lowest available guideline of 0.1 W/m^2 (determined by Russia.) This value was determined to ensure that no exposure would cause any possible biological consequences among the exposed population.

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Appendices

Appendix A: Health Concerns Mentioned in Submissions to the ACC eDocket

Health Concerns Mentioned in Submissions to the ACC eDocket		Number of times mentioned
Top Five Concerns	Headaches	28
	Insomnia	27
	Cancer	15
	Fatigue	14
	Ear pain/hearing	14
Other Health Concerns Mentioned	Difficulty concentrating/brain damage	12
	Heart problems/palpitations	12
	Agitation/Anxiety	11
	Depression	8
	Dizziness	8
	Nausea	7
	Muscle pains	6
	Hay fever/allergies	5
	Chest pain	5
	Seizures	5
	Shortness of breath	4
	High blood pressure	4
	Skin rashes	4
	Sperm production	3
	Autoimmune diseases	3
	Memory loss	3
	Confusion	3
	Shaky hands	2
	Nervous system issues	2
	Autism	2
	Fibromyalgia	1
	Hair loss	1
	Sore throats	1
	Miscarriage	1
	Birth defects	1
	Eye problems	1

	Diarrhea	1
	High blood sugar	1
	Nose bleed	1
	Mutation	1
	Jaw pain	1
	Digestion problems	1
	Stroke	1
	Back pain	1
	Total Number of Health Concerns	**164**

Appendix B: Review of Submitted Articles

ADHS reviewed the articles submitted by concerned citizens related to potential health effects from the RF radiation produced by smart meters. The main points from the most cited articles are listed below, and ADHS's response is provided:

1. Article: "Electromagnetic and Radiofrequency Fields Effect on Human Health." The American Academy of Environmental Medicine (AAEM). 2008.

   Main Points Stated by the Article:

   - In the last 20 years, physicians began seeing patients who reported that electric power lines, televisions, and other electrical devices caused a wide variety of symptoms.
   - Multiple studies correlate RF exposure with diseases such as cancer, neurological disease, reproductive disorders, immune dysfunction, and electromagnetic hypersensitivity.
   - Exposure limits determined by the FCC and other regulatory agencies do not account for effects from non-thermal radiation.

   ADHS's Response: AAEM are not recognized by the American Board of Medical Specialties.

2. Article: Loren Vanderlin. "Update and Review of Research on Radiofrequencies: Implications for a Prudent Avoidance Policy in Toronto." Toronto Public Health. November 2007.

   Main Points Stated by the Article:

   - Despite limitations in the body of research to date, the possibility of harmful health effects from RF exposures cannot be ruled out.
   - Studies of the impacts on children from cell phone RFs, while limited in number, do not rule out the possibility that children require greater protection from RF exposure.
   - Research in populations near cell phone base stations in Europe indicates that some people living within about 300 meters of a base station are more likely to experience symptoms, such as headache, memory changes, dizziness, tremors, depression, and sleep disturbance.
   - In the face of uncertain risks, prudent avoidance is still the best approach to minimize public exposure from the new and increasing number of RF sources.
   - In response to this article, Toronto Public Health (TPH) reviewed the predicted RF values provided by companies applying to install new cell phone base stations in Toronto and requested that providers keep RF emission levels 100 times below Safety Code 6, Health Canada's public exposure guideline. From its review of recent health evidence, TPH notes that the majority scientific opinion indicates that the health risk to the public from cell towers and other telecommunications sources of RFs is low.

   ADHS Response: Although this article infers the biological feasibility of RF exposure and non-thermal effects, this article does not directly relate to the goals of this review. ADHS focused on

RF exposures in the home. RF exposure at or near cell towers tend to be at much higher power densities than that which are measured near electronic meters, and is therefore not within the scope of this report.

3. Article: Andrew Goldsworthy. "The Biological Effects of Weak Electromagnetic Fields – Problems and Solutions." March 2012.

   Main Points Stated by the Article:

   - Weak electromagnetic fields from cell phones, cordless phones, and WiFi can have serious effects on human and animal health. These include damage to glands resulting in obesity and related disorders, chronic fatigue, autism, increases in allergies and multiple chemical sensitivities, early dementia, DNA damage, loss of fertility, and cancer.
   - The frequencies that give damaging biological effects lie between 6Hz and 600Hz. Virtually all digital mobile telecommunications systems use pulses within this range.
   - Until the mobile telecommunications industry makes its products more biologically friendly, we have little alternative but to reduce our personal exposure as far as possible by using cell phones only in emergencies, avoiding cordless phones, and substituting WiFi with Ethernet.
   - This article is only one of many included in the FCC's electronic comment filing system. To arrive at its guideline, the FCC considers a large number of comments submitted by industry, government agencies, and the public. The radiation emitted from smart meters is well below the FCC standard.

   ADHS Response: This article references RF between 6 Hz and 600 Hz. However, the range of RF is actually 3KHz to 3GHz. EMF in the range of 6 Hz and 600 Hz is actually Extremely Low Frequency (1-300Hz) and Intermediate Frequency (IF) Fields (300 Hz – 10 MHz). This review focused on RF and did not research the potential health effects of ELF or IF.

Appendix C: Field Sampling Form

Meter Sampling Checklist

Name of technician:_____ RF Sampling Device:_____/ Calibration Date:_____

Please circle one for each option:

Single Family Home or Apartment Complex		Urban Area or Rural Area		Single meter or Multiple meters (# of meters:_____)

Background reading in the shade:_____ Background reading in the sun:_____

Address:_____ Location of meter on home: garage or living space

Meter Model:_____

Time period:		Sample Time 1		Sample Time 2		Sample Time 3	
Weather Condition (circle one):		Sunny | Partly Cloudy | Mostly Cloudy		Sunny | Partly Cloudy | Mostly Cloudy		Sunny | Partly Cloudy | Mostly Cloudy	
Reading Taken in Shade (Yes/No)		Yes | No		Yes | No		Yes | No	
Date and Time:							
Readings		Average	Max	Average	Max	Average	Max
Distance 1 foot	*Measurement 1: (at 5 min)*						
	Measurement 2: (at 10 min)						
	Measurement 3: (at 15 min)						

Comments:

Address:_____ Location of meter on home: garage or living space

Meter Model:_____

Time period:		Sample Time 1		Sample Time 2		Sample Time 3	
Weather Condition (circle one):		Sunny | Partly Cloudy | Mostly Cloudy		Sunny | Partly Cloudy | Mostly Cloudy		Sunny | Partly Cloudy | Mostly Cloudy	
Reading Taken in Shade (Yes/No)		Yes | No		Yes | No		Yes | No	
Date and Time:							
Readings		Average	Max	Average	Max	Average	Max
Distance 1 foot	*Measurement 1: (at 5 min)*						
	Measurement 2: (at 10 min)						
	Measurement 3: (at 15 min)						

Comments: