Report prepared for

WSSC Water

On potential impacts on human health of advanced metering infrastructure

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EXECUTIVE SUMMARY

This comprehensive review of potential radiofrequency impacts on human health from exposure to radiofrequency (RF), particularly from exposure to water advanced metering infrastructure (AMI), is based on peer-reviewed literature, as well as studies that provide levels of exposure from smart meters used in advanced metering infrastructure.

Smart meters measure attributes of electricity, natural gas, or water as delivered to consumers and transmit that information using RF to utility companies. The RF transmitters in wireless-equipped Smart Meters operate at similar power levels and in similar frequency ranges as many other digital communications devices in common use.

Since RF radiation induces heating in body tissues and imposes a heat load on the whole body, prevention of excessive heating serves as a basis for most international guidelines for human exposure. Many different non-thermal mechanisms for RF have been proposed. Generally, it is thought that non-thermal interactions are unlikely to be biologically significant at the RF levels below guidance values, but much of the on-going research is directed towards non-thermal mechanisms.

The International Agency for Research on Cancer (IARC) classified RF as possibly carcinogenic to humans based on limited evidence in humans (from studies of glioma and acoustic neuroma in relation to mobile phones) and limited evidence in animals (based on co-carcinogenicity studies).

Because Smart meters are not used in close proximity to human body (unlike cell phones, tablets, computers and even WIFI) and because they transmit relatively infrequently their exposure levels are very low and far below U.S. and international exposure limits.

Policy Relevant Highlights

- As society takes advantage of the many new technologies that use RF, to improve lifestyle and work efficiency, RF exposure has been increasing rapidly. Balancing benefits of technologies to the society overall with potential risks to individuals remains a challenge.

- Radiofrequency fields have been classified as a 'possible human carcinogen', or a Group 2B, by the International Agency for Research on Cancer (IARC). However, the weight of evidence has not risen to a level that would change the basis for RF exposure limits, a which are currently based on preventing heating of the tissue.

- Because Smart meters are not used in close proximity to human body (unlike cell phones, tablets, computers and even WIFI) and because they transmit relatively infrequently their exposure levels are very low.

- Some of the reasons leading to concern about smart meters, include whole body exposure, that their use is not under the control of the public, their presence is not perceived to be of direct individual benefit and misinformation about smart meters.

- The exposures to RF from smart meter are neither long enough nor strong enough to approach the safety standards set by the Federal Communications Commission (FCC) and other bodies.

Introduction

At the request of WSSC Water I have conducted a comprehensive review of potential radiofrequency impacts on human health from exposure to radiofrequency (RF), particularly from exposure to water advanced metering infrastructure (AMI). As part of this review I conducted a review of peer-reviewed literature to identify most relevant studies which examine potential health effects of RF, as well as studies that provide levels of exposure from smart meters used in advanced metering infrastructure.

The electromagnetic spectrum encompasses frequencies that range from above approximately 10^{20} hertz (Hz) for ionizing radiation at the high end of the spectrum, to static fields at the low end. In order of decreasing frequency, the spectrum comprises gamma-rays, X-rays, ultraviolet radiation, visible light, infrared radiation, radiofrequency (RF) and extremely low frequency electric and magnetic fields. Over the past two decades a lot of the research has focused on radiofrequency fields (RF), in particular, on mobile phone use and tumors of the head and neck, with less attention to other sources and outcomes.

Technological developments involving exposure to electromagnetic fields bring social and economic benefits to large sections of society, but the health consequences can be difficult to predict and manage. As countries take advantage of the many new technologies that use RF, to improve lifestyle and work efficiency, RF exposure has been increasing rapidly.

Traditional water meters are read quarterly by a meter reader, and a water bill is generated from this manual reading of the meter. Advanced meters (or "Smart" meters) can be read remotely and more frequently, providing instant access to water consumption information for both customers and water utilities (Ref.: 1). Smart meters have many benefits for customers and water agencies. For customers, the systems allow them to make informed conservation decisions and enable leak detection (Ref.: 2). For agencies, the meters reduce costs associated with manual meter reading. In general, Environmental Defense Fund has been supportive of use of wireless smart meters (Ref.: 3). However, concerns have been raised about

the safety of smart meters, mainly because they use radiofrequency (RF) waves.

In this report, I summarize potential health effects of radiofrequency exposure using both original publications and comprehensive evaluations by international review bodies (focusing on publications over past two decades), describe applicable federal and state standards and guidelines for RF radiation, evaluate what is known about RF exposure from advanced metering infrastructure on residences, including single family homes and apartment complexes and compare these exposures to standards and guidelines.

Summary of Potential RF Health Effects

(adopted from Ref.:4)

Sources and environmental levels

With rapid advances in electromagnetic field technologies and communications, people are increasingly exposed to frequencies in the radiofrequency (RF) range. RF fields are produced by radio and TV broadcasts, mobile phone base stations, and other communication infrastructure. The most relevant exposure is to mobile phones. This technology typically uses frequencies from 450 to 2,500 megahertz or million hertz (MHz), although new technology has broadened this band to Gigahertz or billion hertz range (GHz).

In a cellular radio network, the base station is used for the transmission and reception of the radio signals between the mobile phones and the network. The transmission from a base station to a mobile phone is called downlink. The transmission path from a mobile phone to a base station is called uplink.

Other sources of exposure to the general population are radio and television transmitters which operate at between 200 kilo hertz or thousand hertz (kHz) and 900 MHz. Radio and TV signals are broadcast to a large area from comparatively few sites (Ref.:5). Compared to radio and TV transmitters, mobile phone base stations cover a smaller area, and produce much lower emissions, but are vastly more common in many countries. Residential exposures also come from wireless monitors used in children's cribs, cordless phones, and Wi-Fi (wireless Internet connections) commonly used at home and in schools. Occupational exposures include RF PVC welding machines, plasma etchers, and military and civil radar systems. All operate at different frequencies.

Handheld mobile phones available since the late 1980s became widely used by the general population only in the late 1990s. Most used mobile phone technology worldwide Most used mobile phone standard for calling, data transmission and short message service (SMS) is Global

System for Mobile Communications (GSM), which transmits at frequencies are 900 MHz, 1800 MHz and 1900 MHz.

Currently there are more than 5 billion mobile phone users worldwide, with a penetration in some countries reaching 120 percent (i.e. many people have more than one). Use of mobile phones has changed markedly over recent years, concomitant with the development of new technologies (e.g. 2G to 3G, power control, handover management, and novel uses of smartphones). Phones operating under 2G and 3G can have significantly different output power; 3G is thought to be around 1% of the power emitted by a phone operating under 2G. 5G technologies and networks use the largely untapped bandwidth of the millimeter wavelength, between 30 and 300 GHz on the radio spectrum, which uses smaller base stations than current wireless technology. As a result, wireless antennae may be placed densely throughout neighborhoods on infrastructure such as lamp posts, utility poles, and buildings. The Internet of Things (IoT) refers to the ever-growing network of physical objects that feature an IP address for internet connectivity, and the communication that occurs between these objects and other Internet-enabled devices and systems. Machine-to-machine, or M2M, is a broad label that is used to describe any technology that enables networked devices to exchange information and perform actions without the manual assistance of humans. Both IoT and M2M devices are becoming a reality, which will likely lead to changes in RF exposure.

In addition, modes of mobile phone use are constantly changing as texting, web-surfing, playing games, and listening to music and video streaming on mobile phones are now common. Exposure from mobile phones is concentrated closest to the handset and the antenna. Absorption of RF from mobiles is localized and depends on the position of the phone during use. This represents a very important determinant of exposure: only calls made with the mobile phone close to the head result in absorption of RF energy inside the head.

For whole body exposure, mobile phone base stations, can be the largest individual source of RF, but other sources such as radio or TV transmitters can result in comparable exposures depending on where the measurements are taken (most people do not live close to radio or TV transmitters). For RF sources other than mobile phones, typical power

densities outdoors would be 0.01–1 milliWatt per square meter (mW/m2), but could be orders of magnitude higher (i.e. 100 mW/m2 and above). Indoor levels are often lower than outdoor exposures by orders of magnitude; for example, in Europe, a median indoor power density of 0.005 mW/m2 has been reported. Recent study of European children reports median total personal RF-EMF exposure of 75.5 microWatts per square meter (μW/m2) (6). Downlink was the largest contributor to total exposure (median: 27.2 μW/m2) followed by broadcast (9.9 μW/m2). Exposure from uplink (4.7 μW/m2) was lower. Wi-Fi and cordless phones contributed very little to exposure levels in children. While exposures from mobile phone base stations are several orders of magnitude lower than from phones, it differs from that of mobile phones in other ways: base stations expose the whole body, and the exposure duration is considerably longer. Perhaps more importantly, base station exposure has been a subject of much concern to the public because it is not under the control of the public and its presence is not perceived to be of direct individual benefit.

Population exposures to RF fields are less completely characterized than exposures to extremely low frequency (ELF) fields. This is due to: (1) technical challenges; (2) the rapid evolution of RF-related technology (frequency, coding schemes); and (3) changing patterns of use (duration of calls, text messaging, web surfing, etc.).

Health effects

Since RF radiation induces heating in body tissues and imposes a heat load on the whole body, prevention of excessive heating serves as a basis for most international guidelines for human exposure. Studies of the interaction of RF with tissue in the range used for mobile phones have led to the proposal of many different non-thermal mechanisms for RF interaction. Generally, it is thought that non-thermal interactions are unlikely to be biologically significant at the RF levels below guidance values, but much of the on-going research is directed towards non-thermal mechanisms.

Cancer

Epidemiological studies of health effects related to RF exposure from mobile phones are numerous and have

primarily focused on cancer, especially brain tumors, although studies with long-term exposure with sufficient latency are still limited. Currently it is only possible to evaluate short- to medium-term effects of mobile phone exposure; while some studies report effects for heavy or long-term users (Ref.: 7), the majority of studies have found no effects on either brain or parotid gland tumor risk (Ref.: 8). Exposure assessment remains problematic: substantial random error has been shown for even short-term recall of mobile phone use; and information bias appears to affect at least the reporting of the side of the head where the phone is commonly used. Also, some studies may be compromised by a non-representative control group, caused by an increased participation of mobile phone users. Results for acoustic neuroma are more suggestive albeit inconsistent (Ref.: 8). Recently, a few studies have examined other cancers, such as leukemia, non-Hodgkin's lymphoma, and uveal and testicular cancers. Results are unremarkable, but subject to the same limitations as brain tumor studies. So far only one study has examined the possible association between brain tumors and use of mobile phones in children (Ref.: 9). Small and imprecise risks were reported in the high exposure categories, which became more pronounced in a subgroup of about 1/3 of the subjects for whom objective operator data were available. However, due to methodologic limitations, some internal inconsistencies, and most importantly, lack of increases in the brain tumor rates for children in the registry, the authors considered their data to argue against causality. Clearly, more studies of children are needed.

A few studies have assessed cancer risk in relation to radio and TV transmitters (Ref.: 10). Often driven by a previously identified cancer cluster, these analyses are based simply on distance from the source and often include an extremely small number of cases. It is therefore not surprising that such studies have been uninformative. Four recent case-control studies of cancer risk related to mobile phone base stations (Refs.: 11-14) have employed improved methods both in terms of design and exposure assessment. While reporting some positive associations for disease and exposure subgroups, overall these studies provide no consistent evidence of association between exposure from base stations and other transmitters and risk of childhood cancer. However, numerous methodologic limitations

remain, including the inability to detect small increases in risk.

Although occupational studies have been performed over a longer time period (since 1988), we are only beginning to measure and learn about RF exposures in various occupations, and the exposure may not always be relevant for an assessment of effects of mobile phone frequencies. Although some increased risks have been found in certain studies, there is no consistent evidence of risk increases for any cancer sites (i.e. many studies are imprecise, some showing an increase and others a decrease of risk). The studies have several methodological weaknesses: (1) studies are not based on measurements of the actual RF exposure for the subjects included; (2) exposure classification has often been based on job title alone; and (3) control of other factors, if any, has been limited (Ref.: 10).

All of the studies have reported null results for carcinogenicity in normal animals at exposure levels compatible with mobile phones, however, co-carcinogenicity studies (studies in which animals are exposed to both RF and another exposure, e.g. chemical) have been suggestive (Ref.: 15). Of note is the most comprehensive animal study conducted by National Toxicology program (NTP) of the National Institute of Environmental Health Sciences (NIEHS) investigating whether mobile phone radiation increases cancer risk in rats and mice. Rats were exposed at 0, 1.5, 3, or 6 W/kg for 7 days per week, throughout gestation and lactation and after birth. Exposure was up to 18 hours and 20 minutes per day with continuous cycling of 10 minutes on and 10 minutes off during the exposure periods. The NTP studies found that exposure to RF (900 MHz) was associated with clear evidence of tumors in the hearts of male rats (malignant schwannomas), some evidence of tumors in the brains of male rats (malignant gliomas), some evidence of tumors in the adrenal glands of male rats (benign, malignant, or complex combined pheochromocytoma). It was unclear if tumors observed in the studies were associated with exposure to RF in female rats (900 MHz) and male and female mice (1900 MHz) (Ref.: 16). Most recent publication from the same study suggest that exposure to RFR is associated with an increase in DNA damage in mice and rats (Ref.: 17).

Other outcomes

It is well established in animal studies that hyperthermia during pregnancy can cause embryonic death, abortion, growth retardation, and developmental defects; development of the central nervous system is especially susceptible. Numerous studies have evaluated developmental effects of RF fields on mammals, birds, and other non-mammalian species (Refs.: 18,19). These studies have shown that RF fields can cause birth defects at exposure levels that are high enough to cause significant increases in temperature. There is no consistent evidence of effects at non-thermal exposure levels, although a few studies have evaluated possible effects on postnatal development using sensitive endpoints, such as behavioral effects. Serious health effects of hyperthermia in humans however, are associated only with greatly elevated body temperatures (>40°C), and such temperature rises are well above those generated by the maximum allowable level for public RF exposure.

Several studies of occupational RF exposure, primarily of physiotherapists (note some devices used by physiotherapists, such as diathermy devices, can produce high fields), have reported an increased risk of congenital malformations, but no specific type of malformation has been consistently reported, and there is a potential for recall bias in these studies (Ref.: 20). Exposure to RF during sensitive periods of development in early life may lead to lasting effects on health (Ref.: 21). No association was found between mobile phone use during pregnancy and early neurodevelopment in very young children in two studies (Refs.: 22,23). A Danish study has raised the hypothesis that pregnancy and childhood exposure to mobile phones may result in common childhood behavioral problems (Ref.: 24). Prospective evaluations of this association was confirmed in the same cohort (25). Behavioral problems related to mobile phone use in children stands out as the only association independently confirmed in several studies (Refs.: 26,27,28): pooling of five international cohorts found that maternal mobile phone use during pregnancy may be associated with an increased risk for behavioral problems, particularly hyperactivity/inattention problems, in the offspring (Ref.: 29). The interpretation of these results is unclear as other factors may influence both maternal cell phone use and child behavioral problems.

Possible health effects based in part on anecdotal reports of numerous symptoms such as headaches and sleep

disturbance from continuous whole-body RF exposure from base stations is an area of major public concern. Because of numerous methodologic shortcomings, data regarding effects of such RF exposure on symptoms are inadequate for assessment at present.

Reviews

The International Agency for Research on Cancer (IARC) classified RF as possibly carcinogenic to humans (Ref.: 15) based on limited evidence in humans (from studies of glioma and acoustic neuroma in relation to mobile phones) and limited evidence in animals (based on co-carcinogenicity studies).

The Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) of the European Commission concluded (Ref.: 30):
"Overall, the epidemiological studies on mobile phone RF EMF exposure do not show an increased risk of brain tumours. Some studies raised questions regarding an increased risk of glioma and acoustic neuroma in heavy users of mobile phones. The results of cohort and incidence time trend studies do not support an increased risk for glioma while the possibility of an association with acoustic neuroma remains open. Epidemiological studies do not indicate increased risk for other malignant diseases, including childhood cancer. … mobile phone RF EMF exposure may affect brain activities as reflected by EEG) studies during wake and sleep…. However, the relevance of the small physiological changes remains unclear and mechanistic explanation is still lacking. …Overall, there is a lack of evidence that mobile phone RF EMF affects cognitive functions in humans. …. Symptoms that are attributed by some people to various RF EMF exposure can sometimes cause serious impairments to a person's quality of life. However, … RF EMF exposure is not causally linked to these symptoms. This applies to the general public, children and adolescents, and to people with idiopathic environmental intolerance attributed to electromagnetic fields (IEI-EMF). …no adverse effects on reproduction and development from RF fields at non-thermal exposure levels. Human studies on child development and behavioural problems have conflicting results and methodological

limitations. Therefore, the evidence of an effect is weak. Studies on male fertility are of poor quality and provide little evidence. “

There are many national government agencies that have published reviews and released statements regarding potential health effects from RF. Additionally, there are self-appointed groups who have reviewed the RF science. For review of opinions from more than 30 government agencies and international organizations see ref 31.

Guidelines and Limits

Although safety limits on exposures to high power RF sources (which can cause serious injury) have always been necessary, and there were reports of health effects at lower levels in the 1960s and 1970s (Ref.: 32), serious scientific inquiry about possible health effects to the public is relatively recent.

Among the most influential guidelines are those set by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) (Refs.: 32,33) and the Institute of Electrical and Electronics Engineers (IEEE) (Refs.: 34-36). As there are no compulsory international safety standards for the exposure to nonionizing radiation various international limit guidelines are adopted in each country into its national recommendations or legally binding regulations. World Health Organization (WHO) compiled a database describing worldwide Standards (Ref.: 37). In the US, the main agency responsible for RF health and safety standards is Federal Communications Commission (FCC) (Ref.: 38).

Since the Commission is not a health and safety agency, they defer to other organizations and agencies with respect to interpreting the biological research necessary to determine what levels are safe. FCC adopted present exposure limits in 1996, based on guidance from federal safety, health, and environmental agencies and the recommendations of other organizations. In 2013 FCC has opened an Inquiry, to determine whether current exposure limits remain appropriate. The Inquiry is intended to open discussion on both the currency of our RF exposure

limits and possible policy approaches regarding RF exposure, and is still ongoing.

Guidelines often allow for higher exposure for the occupationally exposed population (ie. those trained to be aware of potential risk and to take appropriate precautions, such as, for example, turning transmitter off prior to servicing it). Additionally, occupationally exposed population consists of adults who are generally exposed under known conditions. By contrast, the general public comprises individuals of all ages and of varying health status and may include particularly susceptible groups or individuals, thus for them, a further reduction of 5 times is introduced.

Limits are based on effects associated with heating of tissue, as these are considered to be established effects (Ref.: 39). Although the International Agency for Research on Cancer has classified RF as a 'possible human carcinogen' (Group 2B) based on 'limited evidence' from both human and animal studies (Ref.: 15) the weight of evidence has not risen to a level that would change the basis for RF exposure limits. Most of the ongoing research is focused on possible non-thermal effects.

FCC sets limits as Specific Absorption Rate (SAR) expressed in W/kg and maximum permissible exposure (MPE) expressed in W/m2. These limits are frequency dependent. FCC limits on exposure for mobile phones the general public is intended to restrict local tissue temperature rises to acceptable levels and currently is set to 0.08 Wkg–1, for the whole body, and 1.6 Wkg–1, for the head. As the increase in temperature of the body's tissues as a result of RF exposure is gradual, FCC allows a 6-min averaging time for occupational exposures and a 30-min average for the public. MPE is often used for exposure to stationary devices measured where human exposure is likely to occur at a distance of more than 20 cm. For example, for 902–928 MHz, the frequency band in which many smart meters transmit, the FCC's maximum permissible exposure (MPE) for the general public is 6.1 W/m2 (0.61 mW/cm2) averaged over a 30-min period (for 400 MHz limits will be lower around 2 W/m2).

Smart Meters

Description

Smart meters measure attributes of electricity, natural gas, or water as delivered to consumers and transmit that information (e.g., usage) digitally to utility companies. The RF transmission originates from the Meter Interface Unit (MIU) that is hard-wired to the register of the smart meter. Some Smart meters are also designed to transmit real-time information to the consumer. These smart meters replace traditional, analog meters and meter readers with an automated process that is expected to reduce operating costs for utilities, and potentially, costs for customers (Ref.: 40).

There are many kinds of smart meters manufactured by a variety of companies. They provide for the automatic meter infrastructure (AMI) through different set-ups such as point to point or mesh network. In point to point set-up the meter sends data (using RF fields) to an access point, where it is collected along with data from many other customers and transmitted to a utility company. In Mesh set-up a meter is part of a broader network ("mesh") and may act as a relay among other smart meters and an access point. The Table below provides some information on frequencies used, and type of transmission of some of the water meters (provided by WSSC Water)

Vendor	Technologies	Licensed	Frequency	Open Standards	Technology Age	Collector Style	Integrations
Sensus	Point to Multipoint RF	Yes	901 and 941	No	>5 Years	Base Station	MultiSpeak, CMEP
Aclara	Point to Multipoint RF	Yes	450 and 470	No	>5 Years	Pole Mount, Tower Mount (lattice or water tower), roof top	MultiSpeak, Flat File Transfer (CMEP or custom)
Neptune	Point to Multipoint RF	No	902 – 928 ISM	Yes (L900 System is LoRaWAN)	>5 Years (R900) <5 Years (L900)	Pole Mount (R900 System); Network as a Service (L900 System)	Published Web-services API
Mueller	Point to Multipoint RF	No	902 – 928 ISM	Yes (LoRaWAN System)	>5 Years LoRa <5 Years LoRaWAN	Pole Mount (LoRa System); Base Station (LoRaWAN System)	Flat File Transfer
Itron	Mesh (Single Hop)	No	902-928 ISM	Yes (WI-SUN)	<5 Years	Pole Mount	XML
Master Meter	Point to Multipoint RF	Yes	450 and 470	No	<5 Years	Base Station	Flat File Transfer
Badger	Cellular	Yes	GSM and CDMA	Yes (Narrowband IoT)	>5 Years	N/A	Flat File Transfer

The main determinants of exposure to the general public from smart meters are distance, power of the transmittal and rate of transmission (or duty cycle). Some manufacturers make both electric and other meters (e.g. ITRON), including water, and state that the technology is same or similar (Ref.: 41).

About 60% of WSSC water meters are located inside the basement of homes. Whereas, 40% are located outside the home at the property line. As of today, WSSC does not have a bank of meters in apartment buildings. Generally, in the water industry, these types of dwelling units have one master meter outside in a vault at the property line. The distance from the front door to the property line can vary with minimum distances of about 5-10 feet (personal communication WSSC). Therefore, in general, meters are located away from area where people spend time.

Most systems transmit at 1W (with a range from 0.25 to 2W). with a low duty cycle. Transmission is typically below 1% (4-6 times a day and typically less than 1s each), with higher transmission for mesh networks, where meters communicate with each other. Duty cycle is likely to be lower for water meters.

Measurements around smart meters

No exposure assessment studies focused on water smart meters have been identified, however several studies have looked at electric smart meters. Given that exposure from electric meters is likely to be higher than that of water meters they are reviewed below as representative of an upper bound.

The study of the Itron meters arranged as a mesh network, with end point meters operating at 902–928MHz rated at 250mW, and some meters acting as access point (AP) rated at 1.5W (836.6MHz GSM) and 0.75W (1880MHz GSM) (Ref.: 42). The study made measurements around meters both in laboratory and real life environments. The highest instantaneous power density at 0.3m was from 6.8% to 14.5% of the FCC's MPE. Duty cycles whose value is crucial to assessing time-averaged exposure levels were typically <1 %.

The second was a study of the GE/LG end point meters, rated at 1W, operate within a mesh network in the 902–928MHz band (Ref.: 43). Unlike the Itron system, this network reports to an AP mounted on a pole top away from the residences, transmitting the data at a power of 1W. the spatial average power density was 21% of the peak value (for the GE) and 18% for LG. For duty cycle the 90th-, 99th-, and 99.9th-percentile values were 0.13%, 0.40%, and 1.13%, respectively, with a maximum of 13.9%.

A study in Japan assessed human exposure to radiofrequency fields in the vicinity of a smart meter using the finite-difference time-domain method to calculate spatially averaged specific absorption rate (SAR) values over 10g of tissues (Ref.: 44). The operating frequencies were 920 MHz and 2.45 GHz, which are used for wireless communication between smart meters and AP. The position of the antenna in front of a human eye gives a higher SAR than other position at both 920 MHz and 2.45 GHz. In the case of a distance of 10 mm between a vertically oriented antenna and the right eye of a human, the maximum of SAR values were 0.11 W/kg and 0.37 W/kg at 920 MHz and 2.45 GHz with an input power of 20 mW.

A small study reported on measurements from one manufacturer (Trilliant) (Ref.: 45). Simple calculations based on a free space propagation model indicate that peak RF field intensities are in the range of 10 mW m or less at a distance of more than 1-2 m from the meters. The duty cycle of transmission from the meters is very low (< 1%).

The distribution of the electric fields from a sample of 39 smart meter devices was measured in a controlled laboratory environment, in a UK study (46). The maximum equivalent power density measured during transmission around smart meter devices at 0.5 m and beyond was 15 mW/m2, with an estimation of maximum duty factor of only 1%. One outlier electricity meter had a maximum power density of 91 mW/m2.

In a numerical assessment, by the same group, the smart meter antenna with 1 W power which is an overestimation of what real devices typically emit (15 mW). The highest observed whole body specific energy absorption rate value was 1.87 mW/kg within the child model at a distance of 15 cm from a 2,450 MHz device (Ref.: 47).

Environmental Measurements

Generally, emissions directly behind a smart meter, which would be those that cross a wall into a residence, are considerably lower than those directed outward to communicate with the network (in front of the meter). Following studies have attempted to measure exposures from smart meters and to compare them to other devices that contribute to overall RF exposure.

A total of 77 measurements were made in six residences, in the ITRON study described before (Ref.: 43). The peak fields for 90th, 95th, 97.5th, and 99th percentile were, respectively, 0.048%, 0.13%, 0.30%, and 0.80% of the FCC MPE for the general public. With the duty cycle factored in, these values are conservatively 100 times or more lower.

Limited measurements conducted in two houses with the meters, from a study previously described (Ref.: 45) were unable to clearly distinguish emissions from the meters from

the considerable electromagnetic clutter in the same frequency range from other sources, including Wi-Fi routers and, when it was activated, a microwave oven.

A final paper of the UK project provides quantitative information on exposure levels in real scenarios within a convenience sample of 20 homes which includes in home area network using Zigbee (Ref.: 48). They report that background exposure from the 2 GHz band (which includes Wireless Local Area Network (WLAN) and Zigbee (is a special type of WLAN) is similar or lower to common sources (e.g., mobile phone communications). In addition, smart meter devices generally have smaller duty factors compared with WLAN devices.

Radio frequency emissions from 55 residential devices were measured in 10 residences (Belgium and France) and compared to environmental levels and mobile phones (Ref.: 49). Wireless access points (due to frequent use) and especially mobile phones and other personal communication devices (due to their use close to the body) continue to represent the bulk of the radiofrequency electromagnetic field exposure in the smart home. However, some residential devices can significantly increase the exposure if their duty cycles are high enough (>10%), especially when held or used close to the body. Individual smart meters, on the other hand, will generally contribute little exposure, despite emissions of up to 20 V m at 50 cm, due to their low duty cycles (maximum 1%) and locations.

An indirect confirmation of very low exposures from smart meters comes from an extensive study of personal environmental exposure to radiofrequency electromagnetic fields in children of five European countries (Ref.: 50). Highest contributor to exposure was exposure from mobile phones during downlink. WiFi and cordless phones contributed very little to exposure levels. While exposure from smart meters was not included as it was judged to be very low.

Health effects

People claim that smart meters can cause cancer, anxiety, insomnia, and other complications. Additionally, there are

protests against adoption of smart meters, and protesters cite health as their main concern. However, I have been able to identify only one study that looked at potential health effects of smart meters (Ref.: 51). Unfortunately, this study was not designed to evaluate hypothesis, but was just a report of case series based on self-reporting with no information on actual exposure. The most frequently reported symptoms from exposure to smart meters were (1) insomnia, (2) headaches, (3) tinnitus, (4) fatigue, (5) cognitive disturbances, (6) dysesthesias (abnormal sensation), and (7) dizziness. Aside from a problem of numerous biases introduced by self-reporting, there is no information as to whether this group experienced higher or lower risk for any of these symptoms compared to general population or any unexposed group.

Comparison to Guidelines

In all studies of smart meters (Refs.: 42-49) both measurements and modeling of exposures were well below guidelines of both ICNIRP and FCC limits for the exposure to general public. Furthermore, in a detailed review of smart meter technology and subsequent RF exposures (Ref.: 52), authors calculate maximum exposure levels that under "no imaginable realistic circumstances could be exceeded in the opinion of the authors". With all factors considered a Geometric Mean of the time-weighted-average (TWA) whole-body-average (WBA) % of FCC MPE for general public is 0.31% with a 99th interval from 0.11% to 0.88%.

Opposition

Some argue that averaging emitted power over six(ICNIRP) or thirty minutes (FCC), during most of which time the meter is not emitting, is not appropriate, as it is based on tissue heating (Ref.: 53). As described above, only thermal effects are considered to be sufficient to serve as a basis for the guidelines and limits, while research on non-thermal effects continues. A group of scientists published an appeal in which they question adequacy of existing guidelines for RF from variety of devices, including smart meters (Ref.: 54).

As will be clear from the quotes below, most official organizations do not share this concern.

Statements on smart meters from Official Organizations

American Cancer Society (Ref.: 55):

> "Because, the amount of RF radiation you could be exposed to from a smart meter is much less than what you could be exposed to from a cell phone, it is very unlikely that living in a house with a smart meter increases risk of cancer. ""

IEEE Committee on Man and Radiation (Ref.: 56):

> "The low peak power of Smart Meters and the very low duty cycles lead to the fact that accessible RF fields near Smart Meters are far below both U.S. and international RF safety limits whether judged on the basis of instantaneous peak power densities or time-averaged exposures. This conclusion holds for Smart Meters alone or installed in large banks of meters."

The Environmental Protection Agency (Ref.: 57);

> "Advanced ("smart") meters transmit data using radio-frequency waves, which are a form of electromagnetic radiation. However, the radiation given off by a smart meter is similar in type and strength to the radiation from other common consumer devices."

Public Health England (Ref.: 58):

> "The evidence to date suggests exposures to the radio waves produced by smart meters do not pose a risk to health."

French Agency for Food, Environmental and Occupational Health & Safety (ANSES) (Ref.: 59):

> " .. the Agency concludes that it is unlikely that exposure to electromagnetic fields emitted by either radio-frequency smart meters (gas and water) or other meters (electricity), as they are currently being deployed, would generate health effects in either the short or the long term."

Australian Radiation protection and Nuclear Safety Agency (ARPANSA) (Ref.: 60):

> "The measured and calculated exposures are all well below the public exposure limits. The radiofrequency used is similar to the frequency used by GSM mobile phones and the peak transmission power is somewhat less. …The radiofrequency electromagnetic energy transmitted in a single pulse from the smart meter is similar to that measured from a car remote unlocking fob and much less than measured from a single GSM SMS transmission. The measurements do not provide any indication of why smart meter transmissions would provoke symptoms in people otherwise unaffected by other wireless technologies such as GSM mobile phone handsets."

Environmental Defense Fund (EDF) (Ref.: 3):

> "Even though we have very strong evidence that the use of smart meters and the smart grid can make a substantial contribution to protecting and enhancing human health, EDF would certainly change its position if strong enough evidence surfaced concluding that RFs emitted by smart meters — the wireless ones, at least were doing substantial health damage."

California Council on Science and Technology (Ref.: 61):

> "The current FCC standard provides an adequate factor of safety against known thermally induced health impacts of existing common household electronic devices and smart meters.
> 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 radiofrequency emissions to identify or recommend additional standards for such impacts".

Conclusions

The RF transmitters in wireless-equipped Smart Meters operate at similar power levels and in similar frequency ranges as many other digital communications devices in common use, and their exposure levels are very far below U.S. and international exposure limits.

In comparison to mobile phones, base stations expose the whole body, and the exposure duration is considerably longer. Perhaps more importantly, base station exposure has been a subject of much concern to the public because it is not under the control of the public and its presence is not perceived to be of direct individual benefit. These considerations apply to the smart meters as well, and perhaps, that is why there has been an opposition to their implementation, despite the fact that exposure from them so low.

In conclusion, the exposures to RF from smart meter are neither long enough nor strong enough to approach the safety standards set by the FCC and other bodies.

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