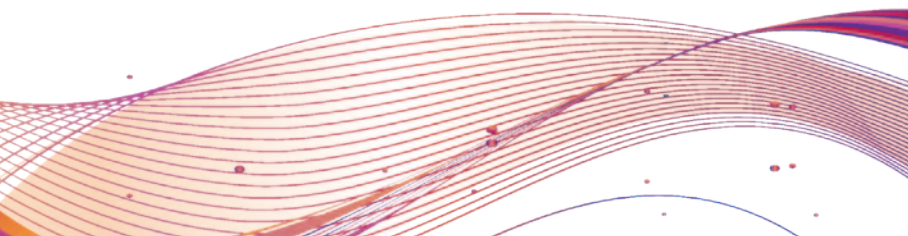
FSM – Swiss Research Foundation
for Electricity and Mobile Communication

Electromagnetic Fields, Science and Policy

Gregor Dürrenberger (Ed.)



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Content

Preface

This brochure informs interested readers about biological effects and health impacts of electromagnetic fields (EMF) produced by power and radio technologies. It collates the current scientific knowledge about the topic. Furthermore, it explains how the issue is perceived by the general public, and how policy can handle the fact that public perceptions partly conflict with expert assessments. The brochure doesn't focus on technical aspects of EMF technologies, i. e. infrastructures and appliances in the power frequency and the radio frequency domains.

The paper by **Guido Santner** is written for readers that are not yet familiar with EMF and, especially, with the topic of EMF and health. It gives a brief introduction into the field. The paper by **Mats-Olof Mattsson** represents the core of the booklet. It gives a systematic overview of the current scientific insights into biological and health effects caused by electromagnetic fields, and it comments the credibility and significance of key results. The paper by **Ortwin Renn** describes risk-perceptions by the general public, and focuses on the question of how policy may respond to the fact that public perceptions partly dissent from expert insights and scientific risk assessments.

Three **interviews with researchers** active in the field supplement the articles. They give insights into the interviewees' research activities and illustrate with personal viewpoints selected topics from the articles.

An executive science summary about "EMF and health" completes the booklet.

The brochure originated in the 10 years anniversary of the Swiss Research Foundation of Electricity and Mobile Communication (FSM) that took place at ETH Zurich in autumn 2012. The articles replenish the scientific lectures given at the event. The latter can be downloaded from the website of FSM, **www.emf.ethz.ch** under "events". Readers that like to have more detailed information about the issues discussed in this booklet may visit the "knowledge" section of the FSM-website.

Gregor Dürrenberger
Executive Officer FSM

Science Summary

Biological and Health Effects of EMF

Gregor Dürrenberger This summary section presents, based on the article by Mats-Olof Mattson, the state of the evidence about biological and health impacts of electromagnetic fields (EMF).[1] The main focus is on the general public. The text does not discuss risks due to workers' exposure to EMF. The scientific insights available today are structured into three sections that reflect the main frequency domains: radiofrequency (broadcasting, mobile communication – infrastructure installations as well as mobile devices – DECT-phones, WiFi, etc.), extremely low frequency (ELF, i. e. power lines, transformer stations, domestic wiring, electric appliances, etc.), and other frequencies (applications in other than above mentioned two frequency windows will be listed in the section text).

Effects of Radiofrequency EMF

Brain Physiology and Sleep[2]

The measurement of the electric brain activity and its visualization as electroencephalogram (EEG) is for diagnostic reasons a routinely applied technique. Research about effects of EMF on brain activity has revealed that pulsed radiofrequency signals (as used by GSM mobile phones) impact the EEG. The magnitude of the effect, however, lies within the normal physiological range and drinking a cup of coffee before sleep, for instance, has also a detectable impact on the EEG. Overall, the available studies clearly show that pulsed radiofrequency fields – in contrast to continuous waves – alter the EEG. The biological mechanisms underlying these observations are unknown, and no health impacts are reported. Also, subjective sleep quality and overall sleep architecture are unaffected by exposure.

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[1] See this brochure as well as: SCENIHR (Scientific committee on emerging and newly identified health risks) (2013): Preliminary opinion on potential health effects of exposure to EMF. European Commission, Brussels

[2] http://www.emf.ethz.ch/en/knowledge/topics/health/sleep-behaviour/

Cancer[3]

The question whether radiofrequency EMF (RF-EMF) is increasing cancer risks is given special attention by both research and policy. Of primary concern are brain tumour risks in association with mobile phone use. Mobile phones belong to the most relevant sources of human exposure, and the brain, and the head in general, is most exposed (if we refrain from the hand that holds the device). Overall, there is limited evidence for an increased risk. The limitations relate to long-term mobile phone use, i. e. more than 10 – 12 years of regular use. For such periods, the data is inconclusive. The possibility of a higher risk cannot be excluded. However, the available cancer statistics do not show an increase in incidence rates (the number of diagnosed cases per year) and some recent epidemiological studies tend to be reassuring. This is especially true for the most important malignant brain tumour, glioma. Nevertheless, overall evidence of all studies remains controversial. Regarding other forms of cancer and other RF-EMF exposures than mobile phones (for instance broadcasting or mobile phone base stations), no evidence for increased cancer risks is available. This is especially true when looking into large studies that are less prone to chance associations compared to studies that deal with a few cases only. Also with regard to children, no increased risks have been statistically detected. However, because only a few data about adolescents and children is currently available no firm conclusions can be made.

Electrohypersensitivity[4]

There are people who attribute health symptoms like insomnia, nausea, fatigue, memory disorders, or otherwise reduced wellbeing to radiofrequency EMF. In the last decade, a series of studies have been performed to examine whether these symptoms are causally linked to RF-EMF, probably only in a small subgroup of individuals particularly sensitive to this radiation. The results of the studies do not point towards a causal relationship between RF radiation and symptoms of reduced wellbeing. Evidence is strongest for short-term exposure and acute symptoms which can be investigated in laboratory settings, and it holds for all age groups, and for people stating to be electrohypersensitive. In the case of chronic exposures, typically investigated in "real world" settings, the evidence points in the same direction. However, the data is less robust. The main reason relates to exposure assessment that is much more difficult to perform in real settings compared to controlled laboratory condi-

[3] http://www.emf.ethz.ch/en/knowledge/topics/health/cancer/

[4] http://www.emf.ethz.ch/en/knowledge/topics/health/electrohypersensitivity-ehs/

tions. Without valid exposure information, no robust conclusions about an association between health symptoms and EMF can be drawn.

Other Effects [5]

The available scientific studies about RF-EMF and other biological effects than those listed above do not give convincing evidence about negative health impacts. This is true for male reproduction, which does not seem to be impaired by RF-EMF exposure, and for neurodegenerative diseases like ALS (sometimes also called MND – motor neurone disease), Alzheimer's or Parkinson's disease. Regarding cognition and cognitive performance, the evidence for biological effects is inconclusive, as with behavioural problems in children when their mothers were exposed to above-average levels of RF-EMF during pregnancy. It is important to state here, that many of the studies investigating such endpoints (effects) are not very informative in scientific terms due to methodological limitations, primarily regarding exposure assessment and control of confounders (i. e. other – known – factors that can cause the disease). These limitations may either mask a real effect or falsely identify EMF as the cause of the disease.

Effects of Power Frequency Magnetic Fields

Neurodegenerative Diseases [6]

Almost all published studies do not show an association between power frequency (also called ELF – extremely low frequency) magnetic fields from power lines and neurodegenerative diseases. Preliminary evidence from a Swiss study about an increased risk of Alzheimer's disease for people living within 50 m of a power line could not be confirmed in a larger and more robust study. No evidence about increased risks for people living close to a high-voltage transmission line exists for other neurodegenerative diseases like ALS, Parkinson's disease or dementia.

Cancer [7]

In 2001, WHO classified ELF magnetic fields (ELF-MF) as a possible carcinogen. The classification was strongly based on epidemiological findings about an association

[5] http://www.emf.ethz.ch/en/knowledge/topics/

[6] http://www.emf.ethz.ch/en/knowledge/topics/health/neurodegenerative-diseases/

[7] http://www.emf.ethz.ch/en/knowledge/topics/health/cancer/leukaemia/

between relatively high magnetic fields and increased risk of childhood leukaemia. This association was confirmed by most of the subsequent studies. No biological mechanism is known as to how ELF-MF may increase the leukaemia-risk in children. Also, animal studies are uninformative to date. Many hypotheses have been put forward to explain the association, from infectious diseases to differential participation based on parent's educational level. No scientifically convincing explanation has been established so far. Because childhood leukaemia is a rare disease and only a very limited number of children are exposed to relatively high ELF-MF, the overall number of cases, given the association was causal in nature, is rather small. In Switzerland 1–2 cases out of 50–60 newly diagnosed cases every year were attributable to power lines. Concerning other types of childhood cancer, other types of ELF-MF sources (for instance household appliances), or pre-natal exposures, no compelling evidence about increased risks exist. Regarding cancer in adults, no evidence for higher risks due to ELF-MF exposure has been consistently reported.

Other Effects [8]

The available studies about reduced well-being and other subjective health symptoms (see above) attributed to power frequency fields show discordant results. Most experimental evidence points to the absence of causal effects and there is also no convincing data that people, including hypersensitive individuals, can reliably detect/perceive ELF magnetic fields. The findings from observational studies are contradicting. An important reason thereof is the fact that these studies generally suffer from limitations in sampling and exposure assessment or do not properly control confounders. These limitations make results prone to chance effects or biases. All in all, the available data does not provide credible evidence of an effect of residential ELF exposure on symptoms of impaired wellbeing. Another area of investigation relates to potential effects of maternal power frequency magnetic field exposure on foetal development. Recent results do not show an effect of ELF-MF on the reproductive function in humans. Preterm and stillbirth rates do not differ between more or less exposed women, and no differences were found with regard to weight and size of the new-borns as well as with regard to congenital anomalies. However, in two recent studies increased risks were identified for asthma and childhood obesity. These preliminary findings need to be reproduced in order to evaluate their significance for risk assessment.

[8] http://www.emf.ethz.ch/en/knowledge/topics/

Effects of Other EMF Exposure

Terahertz-EMF (THz)

It is likely that in the near future new applications in the Terahertz domain (several hundred to several thousand Gigahertz; 1 THz = 1000 GHz) will be developed and put on the market. An example for a THz-technology is the whole body imaging technology (body scanner) which can be found on several airports in the last few years.[9] Due to the very small wavelength, THz-EMF does not strongly penetrate into the body. Most of the power is absorbed by the skin, including cornea. Current regulation sets exposure limits that prevent detrimental thermal effects, also for pulsed fields as used in body scanners. Only a limited number of studies, mostly laboratory studies with rats or mammalian cell-lines, about biological effects of weak THz radiation are available to date. For firm conclusions, more systematic research is needed. At present, no risk assessment about potential non-thermal effects can be made.

Kilohertz-EMF (kHz)

These frequencies – also called intermediate frequencies, IF – are located between ELF and RF and cover the spectrum from roughly a thousand Hertz (Kilohertz, kHz) to a Million Hertz (Megahertz, MHz). Examples of technical applications are: induction stoves, energy saving lamps (compact fluorescent lamps), electronic article surveillance systems, RFID, cathode ray tubes (now mainly replaced by flat screens), wireless power transfer systems, or AM broadcasting. In this frequency window the biological interaction mechanisms known from both ELF and RF fields are at work, and regulation takes both into account. According to WHO, no strong evidence about potential health detriments from weak fields below the exposure limits exists.[10] Electrosensitive persons, however, often attribute symptoms of impaired wellbeing to kHz-EMF. Comparable to the THz domain, there are only a few studies available about cellular mechanisms and long-term exposure. At present, no risk assessment about potential health effects below the current guidelines can be made.

Static Magnetic Fields

The main research interest is in acute exposure to very strong fields as those produced by MRI (magnetic resonance imaging) technology in hospitals. In daily life, exposure to static magnetic fields is many orders of magnitude below the levels of this technology, and no health implications from everyday exposure are known.

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[9] http://www.icnirp.de/documents/mmwavesICNIRPstatement2012.pdf

[10] http://www.who.int/peh-emf/publications/facts/intmedfrequencies/en/

10 Years of EMF Research

Guido Santner In the past 10 to 15 years, the question whether mobile phone exposure has a detrimental impact on human health was extensively investigated. At present, it seems that the health risks, if any, are small. However, research has demonstrated that radiation from mobile phones can affect physiological responses.

Background

Switzerland has 8 million inhabitants and 10 million mobile-phone subscriptions. Mobile phones have become ubiquitous and modern life can no longer be thought of without this technology. However, many people are concerned about their health when they make a phone call with a device that radiates electromagnetic energy right at the head.

In the 1950's it was realized in the context of radar technology that it can be dangerous to stay in front of an antenna. By that time, scientists began to investigate the interaction between electromagnetic fields (EMF), biology and health. With regard to radiofrequency radiation, the experts soon suggested **exposure limits** to prevent overheating of the body. Today, such limits are still in force. Mobile phones, for instance, are restricted to a maximum power of 2 W. Depending on the design, antennas may radiate power isotropically or in a concentrated way, similar to a spotlight that concentrates the energy in a lobe-like beam. When devices are used close to the body, even when the overall power is low the device may cause high local exposure if the antenna concentrates the energy towards the body. Local exposure limits can prevent overheating by such devices. The existing limits restrict the maximum power (in Watts) absorbed by the exposed tissue (in kilogram). WHO and other expert institutions advocate for local exposure of the head a limit of 2 W/kg, measured over 10 g of the most exposed tissue.

Guido Santner

Science Writer, Sprachwerk GmbH

Rollout of Antenna Networks

In 1995, most people did not yet have a mobile phone. By 2000, penetration of cellular phones was already considerable. The Swiss Federal Office for the Environment (FOEN) drafted an Ordinance Relating to the Protection from Non-Ionising Radiation (ONIR) that was put into force by the Federal Government by February 1, 2000. Among others, the Ordinance sets limits to the emissions of installations that expose locations regularly occupied by persons for prolonged periods as, for instance, houses, offices or schools. The exposure from such installations is limited to roughly 5 V/m (exact value depends on the frequency band). It was also in this period that the rollout of the mobile communication infrastructure peaked, what made many people aware of radiation. Local citizen organisations started to oppose installations and filed protests against building permits.

The limit value of 2 W/kg for mobile phones cannot be compared in a straight-forward way with the limit value of 5 V/m for electromagnetic fields from base-stations. In the case of mobile phones, antenna and head are in close proximity, exposure is inhomogeneous and antenna and body influence each other. In the case of base-stations, the human body is far away from the antenna, the exposure is relatively homogeneous and no interaction between body and antenna exists. The measured field strength of a mobile phone at the head is much higher (up to 200 V/m) than the field strength of a base station measured at locations where persons generally stay (mostly well below 1 V/m). Peak exposure by mobile phones is allowed to be much higher than peak exposure by installations.

FOEN introduced the (roughly) 5 V/m limit as a precautionary limit. WHO, for instance, does not advocate precaution and recommends for mobile communication as exposure limit (roughly) 50 V/m. Swiss limits are much lower because they take current scientific ignorance into account, for instance ignorance with regard to potential non-thermal health effects. Of special attention here is a possibly increased cancer-risk.

In Fear of Cancer

The biological mechanisms how mobile-phone radiation may impact cancer development are still unknown. Since 2000, the sciences thoughtfully investigate this issue. The Swiss Research Foundation for Electricity and Mobile Communication (FSM) as well as the Swiss National Research Programme 57 about Non-Ionising Radiation and Health, terminated after 4 years of research in 2010, significantly contributed to this field.

At the 10 Year anniversary of the FSM, Primo Schär, Professor for molecular genetics at the University of Basel, summarised the laboratory evidence gained with **cell experiments** as follows: under specific EMF exposure conditions one can observe

an increase in DNA strand breaks.[1] However, Primo Schär puts forward: "Every day 100 000 strand break occur in the cells of the human body mainly due to reactive oxygen species that are formed as a natural by-product of the normal metabolism". Such strand breaks are automatically repaired by the cells. The number of (additional) strand breaks triggered by EMF exposure is at the limits of measurability. And Schär adds: "The genotoxic effects of alcohol consumption or smoking are clearly demonstrated and by orders of magnitude more accentuated".

The research team of Primo Schär is primarily interested in identifying mechanisms of interaction between EMF and DNA. What is known: the energy of mobile-phone radiation cannot directly induce strand breaks, as for instance UV or radioactive radiation. That's why EMF belongs to the so-called non-ionising part of the electromagnetic spectrum.

EMF Effects Cell Reactions

Schär exposes cells to 50 Hz magnetic fields. 50 Hz is the power-frequency in Europe. However, the field strength in the exposed samples is much higher (up to 1 Millitesla) compared to everyday levels. The precautionary limit in ONIR is set at 1 Microtesla, which is a factor of 1000 below Schär's laboratory condition. In one study, Schär replicated experiments first performed in Vienna in 2003. He could confirm the increase in strand breaks observed by the Vienna team. However, the mechanism remains unknown. Schär hypothesises that the radiation may impact the cell-cycle, for instance apoptosis. "It might also be the case that the radiation interacts with DNA synthesis. Cells duplicate their DNA when they go into mitosis. The radiation may have impacts on this duplication process and the number of strand breaks during synthesis phase may increase".

Concerning the potential of EMF to increase cancer risks, Schär says that the effects documented in literature are very small in terms of magnitude. They can hardly be detected against background noise, i. e. naturally occurring strand breaks. Nevertheless, Schär wants to understand the underlying **biological and biochemical processes** because the working of a cell does not only depend on its DNA but also on roughly 100 000 proteins that steer cellular functions. During embryogenesis, the cells differentiate from unspecialised embryonic stem cells into cells specialised in all types of tissue. Such cellular differentiation does not involve a change in the DNA. Instead proteins modify gene expression. Schär: "Every single one of these proteins steering cell development and cell functions could be an antenna sensitive to a specific frequency as used, for instance, in mobile communication".

[1] See: www.emf.ethz.ch (events/conferences/10 Year anniversary of FSM – papers in German only)

Epidemiology

When large groups of people are exposed to a potential risk, epidemiologists are asked for evidence about the magnitude of the risk. If a potential risk is a real risk, the **disease** associated with this risk-factor should be detectable in the statistics after some latency period.[2] Environmental epidemiologist Martin Röösli from the Swiss Tropical and Public Health Institute in Basel: "In 1845, London suffered from the cholera epidemic. Nobody had an idea about the cause of the disease but epidemiologists identified a specific well as a fomite", Röösli explained.

In a similar way, the potential cancer **risk** associated with mobile phones can be investigated. If the radiation was carcinogenic, the number of diagnosed cancer cases will increase. "If we look into the cancer statistics, no such increase is documented", Röösli says. However, he adds that the number of expected new cases strongly depends on the latency time of cancer. In case of a 1-year-latency the statistics would certainly show a sharp increase. In case of a 10-years-latency the statistical signal would be rather moderate. "However", Röösli tells us, "if the risk associated with mobile phone radiation was large one would observe a rise of the incidence rate today".[3]

Technology Shifts

In case of mobile communication technology epidemiologists face a specific problem: Older generations of technology become replaced by new standards and equipment. 2G and 3G will become displaced by 4G, i. e. LTE. The signals of GSM, UMTS and LTE differ not only in terms of carrier frequency (e. g. 900 MHz, 1800 MHz, etc.) but also in terms of modulation. In case of GSM, 8 mobile phones share one carrier frequency but they use the carrier in a serial way, one phone after the other. As a consequence, the mobile phone signal is strongly pulsed, i. e. a short transmission is followed by a long silent period. During this transmission pause, the carrier can be used by the other handhelds. When all devices have used their allocated time-window, the sequence starts again. In case of UMTS, all mobile phones simultaneously use the same base-station carrier. However, every mobile phone has its own code. The coded signal can be filtered out with the help of this code. With LTE, the modulation scheme becomes even more complicated because this standard allocates in a dynamic way spectrum to mobile phones which allows to better exploit the available bandwidth. As a consequence of such technology shifts, no one is exposed to a specific signal for more than a few years.

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[2] See interview with Prof. Leeka Kheifets

[3] See: www.emf.ethz.ch (events/conferences/10 Year anniversary of FSM – papers in German only)

Effects on Brain Activity

Neither laboratory experiments with cell cultures nor epidemiological studies directly point towards a significant health risk of mobile phones. Nevertheless, the radiation may possibly impact our well-being, for instance by causing headaches. Peter Achermann, Professor at the Institute of Pharmacology and Toxicology at University of Zurich, investigates the impact of radiation from cellular technology on human brain physiology. Several studies revealed that RF-EMF affects brain activities. This can be best observed during sleep.

Achermann analyses the **sleep-EEGs** of volunteers participating in his experiments (EEG: Electroencephalogram). During sleep, brain activity is characterised by typical sleep-patterns. To record the electric activity of the neurons, electrodes are mounted on the head of the participants. "People often ask me whether RF-EMF is reducing well-being. With regard to sleep quality our experiments do not show peculiar effects. A cup of coffee, for instance, induces changes in the EEG, too", Achermann says.

Some experiments were repeated with other equipment, e. g. PET-scanners. In PET (positron emission tomography), the blood is radiolabelled. The scanner is measuring the signals from the radiotracer. Typically, the signals are stronger where the blood-flow is increased, i. e. where cells are active (and, hence, require more blood). "The PET-studies with mobile-phone radiation show that the effects on brain activity are much more local than what would be expected from the exposure pattern. This might be an indication that the observed effects are **non-thermal** in nature", Achermann explains. However, he also reminds us to be cautious. At the anniversary event of FSM he explicated: "In one study, the acoustic cortex of the volunteers got activated when the battery of the mobile phone was switched on and off, however, the subjects could not consciously perceive the sound". The physiological effects Achermann has observed are not generic in nature. Out of 34 volunteers, an effect may be observed in 24 subjects only and 10 may not show any change.

Pulse-Modulated Signals

In his review about 10 years of research about EMF and brain physiology, given at the 10-years anniversary event of FSM [4], Achermann concluded that RF-EMF has biological effects on the human brain, and that the radiation cannot be perceived by man. Furthermore, the observed effects are signal specific, i. e. only pulse modulated signals as used, for instance, by GSM mobile-phones, trigger reactions. No effects have been observed with exposure to continuous waves. The same is true for weak signals (SAR < 1 W/kg). In sum, research revealed biological effects in case of mobile

[4] See: www.emf.ethz.ch (events/conferences/10 Year anniversary of FSM – papers in German only)

phone exposure, but it did not do so in case of exposure to signals similar to those from mobile communication base stations.

The scientific speakers at the anniversary event concluded that **no detrimental health effects** from RF-EMF below the exposure limits could be substantiated to date. Yvonne Gilli, medical practitioner and member of the parliament, remains cautious: "Many people suffer from EMF and some even have to sell their exposed houses!" She refers to the group of sensitive persons that are adversely affected by EMF. This so-called hypersensitivity is a self-attribution and not an objective medical diagnosis.

Electrohypersensitivity

Because of the observed individual differences in EMF sensitivity, research specifically focused on the subgroup of hypersensitive persons. According to a review report published by the Swiss Federal Office for the Environment (FOEN) it was impossible to confirm in double-blinded laboratory settings the sensitivity hypothesis. In such experiments, there was no difference in well-being between exposed and unexposed conditions. However, there was a reduced base-line well-being which is attributable to the fact that hypersensitive persons tend to be stressed by partaking in exposure experiments. With that, the FOEN-report addresses a delicate topic: the so-called **nocebo-effect.** When an electro-hypersensitive person is convinced to be exposed, his or her well-being is likely to be reduced.

Such nocebo-effects show people really suffering from health problems as soon as an exposure is known, disclosed, declared or imagined. At the FSM anniversary event, Gilli said that such persons should be seriously recognized: "when these persons are in my surgery, there symptoms can be plausibly attributed to EMF"

Information and Communication

In the past 10 years, the FSM served as a platform to bring together the policy, business and science stakeholders of the EMF and specifically the mobile technology community. Also controversial topics like electro-hypersensitivity received funding from FSM and the community at large, and the insights from these projects clarified a series of important questions.

During the anniversary event, the discussion developed from the established topics like cancer and hypersensitivity towards the more recent issues under public attention like security, media competence and youth protection. Today, it seems that the topics associated with **mobile media consumption** generate more emotions and concerns in society than electromagnetic radiation from mobile technology.

What is Known and What is Not

Mats-Olof Mattsson The non-ionizing part of the electromagnetic spectrum covers a frequency range from static magnetic and electric fields (at zero or close to zero in frequency) up to the longest wavelengths of the ultraviolet region. In our everyday life, we are constantly using devices and processes that emit non-ionizing radiation from man-made objects from well below the low frequencies used for modern radio communication up to microwaves and terahertz radiation. This is often referred to as emissions of **electromagnetic fields (EMF)**, which sometimes more correctly is emissions of electric or magnetic fields (EF and MF), respectively.

The introduction of novel technologies in the (post-) industrial society is naturally a positive development. Nevertheless, concerns related to possible negative effects on human health and the environment have been raised.

Background

During the last three decades, three major areas of EMF-exposure have received considerable interest from a health perspective. The first area relates to distribution of electricity, which typically employs AC current distribution in the extremely low frequency (ELF) area of 50 or 60 Hz (geographical differences). This concern is due to an initial observation of a correlation between electrical wiring configuration and childhood leukemia.[1] This observation led to a suspicion that **extremely low frequency magnetic fields (ELF-MF)** can be involved in carcinogenesis. Up to this day, this area receives a certain research and health policy attention, since ELF MF appear in the vicinity of high-voltage overhead power lines and also around electrical appliances.

[1] Wertheimer N., Leeper E. (1979): Electrical wiring configurations and childhood cancer. American Journal of Epidemiology 1979, 3, 273–84.

Prof. Dr. Mats-Olof Mattsson

AIT Austrian Institute of Technology, Health & Environment Department

The second area of concern in modern times is related to the introduction of computers to the office environment. This on-going revolution of an occupational setting got started in the mid 1980´s. Of particular concern were the emissions of various types of both electric and magnetic fields from video-display terminals ("monitors") that were used in those days. The concerns dealt primarily with potential effects on reproductive outcome, and with various self-reported symptoms (skin rashes, burning sensations, headaches, etc.). The subsequent scientific studies could not substantiate any effects on these outcomes due to EMF exposures from these types of equipment. As of today, the technology has brought new types of monitors to the office environments, where few "old-fashioned" CRT-run monitors remain.

The third major area of a new technology associated with public concern includes the rapid development and implementation of communication technologies based on **radio frequency electromagnetic fields (RF-EMF).** The most obvious example is the mobile phone, which today has a penetration of practically 100 % in the industrialized parts of the world. In addition, an ever increasing number of wireless devices that use the RF part of the EMF spectrum are inhabiting our society. Here, the concern is whether the mobile phones, mobile phone base stations, and/or other wireless devices have (negative) health effects. A substantial amount of research, on the international level, has been performed to try to answer this question.

Another aspect of EMF use and effects concern the medical area, where instruments employing various types of EMF are used for diagnostic purposes and treatments. Prime examples of diagnostic tools include the magnetic resonance imaging (MRI) instruments that are being used more and more for investigations of both hard and soft tissues and also for observation of physiological processes. These instruments employ very **complex EMF signals,** including strong static fields, pulsed fields, and radiofrequency fields. A more novel type of instrument is the magneto-encephalogram (MEG) which continues to be an appropriate tool for e. g. epilepsy diagnosis, and functional imaging and mapping of the brain. For therapeutic purposes, devices based on radiofrequencies and pulsed lower frequencies are employed in many settings, including electrosurgery, cosmetic surgery, diathermy, wound and bone fracture healing, and transcranial magnetic stimulation for treatment of depression and pain. These methods are not always approved by national authorities and their efficacies are poorly validated.

For both diagnostic and therapeutic applications, the benefit to the patient is considered to outweigh any negative health consequence of EMF exposure. For occupational settings, the exposures are considered to be harmless as long as recommended exposure levels in guidelines are not exceeded. Occupational exposures to EMF is

otherwise often very complex, and can in many cases exceed the exposure to the general public with orders of magnitude in intensity.

Assessments of Health Risks

A natural question is of course if we (as general public and/or as part of the occupational force) are appropriately protected against EMF-overexposures. Competent authorities in e. g. European countries exert their protective duties by adhering to exposure guidelines, that are issued by expert organizations like ICNIRP (International Commission on Non Ionizing Radiation Protection) or IEEE/ICES (exposure limits in the ICNIRP guidelines are described in more detail below).

These guidelines in turn are based on health risks assessments, where the available and adequate scientific literature is evaluated on a regular basis. In Europe, exposures for both the general public and for workers are most often limited to the values given by ICNIRP[2]. Furthermore, the EU Directive 2004/40/EC[3] (undergoing revisions) is used to regulate the occupational exposures. In addition to these guideline-issuing expert bodies, there are other assessments performed by expert groups both on an international (e. g. WHO and it's daughter organizations IARC)[4], European (e. g. the EC's independent scientific committee SCENIHR[5], the EU EFHRAN Project[6]) and on a national level (e. g. recent assessments performed by HPA/AGNIR in the UK[7],

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[2] ICNIRP (International Commission on Non-Ionizing Radiation Protection) (2010): Guidelines for limiting exposure to time-varying electric, magnetic fields (1 Hz – 100 kHz). Health Physics 2010, 6, 818 – 836.
ICNIRP (International Commission on Non-Ionizing Radiation Protection) (1998): Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz), Health Physics 1998, 4, 494 – 522.

[3] EU (European Union): Directive 2004/40/EC of the European Parliament and of the Council of 29 April 2004 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields). Official Journal of the European Communities, L184/1.

[4] IARC (International Agency for Research on Cancer) (2013): Non-ionizing radiation, part 2: radiofrequency electromagnetic fields. IARC Monograph 102, Lyon, 2013.
IARC (International Agency for Research on Cancer) (2002): Non-ionizing radiation, part 1: static and extremely low-frequency (ELF) electric and magnetic fields. IARC Monograph 80, Lyon, 2002.

[5] SCENHIR (Scientific Committee on Emerging and Newly Identified Health Risks) (2013): Preliminary opinion on potential health Eeffects of exposure to EMF, European Commission, Brussels.

[6] EFHRAN (European Health Risk Assessment Network on Electromagnetic Fields Exposure) (2012): Risk analysis of human exposure to electromagnetic fields. EFHRAN, Report D2.

[7] AGNIR (Advisory Group on Non-Ionising Radiation)(2012): Health effects from radiofrequency electromagnetic fields. UK Health Protection Agency (HPA), Chilton.

Norwegian Institute of Health [8], Swedish Radiation Safety Authority [9] and others, including Swiss Federal Office for the Environment [10]).

Such evaluations are based primarily on published scientific studies. To some extent, documents from other evaluating bodies, competent authorities, and/or data from the industry or other interest organizations can occasionally be used for the evaluations. The data that are used emanate from different types of studies ("lines of evidence").

The most important data come from studies where humans are the subject. Where appropriate, **interventional clinical studies** that are randomized and double-blind (neither the subject nor the experimenter knows if the subject is exposed to a specific treatment) provide the most valuable information. Such studies can provide conditions where the exposure is correctly characterized and where the direct effects of a treatment are studied. In the case of EMF, these studies are limited to direct and short-term effects.

Another type of widespread analysis is the **epidemiological inquiry,** where populations are studied over time. This research can also be highly relevant but does not address causality, only statistical correlation. Its value is particularly the information about long-term effects, in large groups of subjects. For EMF research, epidemiological studies have provided important knowledge about the correlation between EMF exposures and chronic diseases.

Studies that are performed on animals **(in vivo studies)** are very useful for investigations of specific conditions (controlled exposures, many end-points are possible to investigate) where the results can be extrapolated to humans. However, the relevance of the animal study for the human situation can be questionable. This has to do with possible species differences where certain disease conditions are difficult to investigate in animals, or where biological differences are such that processes are not identical, but also related to exposure details. The advent of transgenic technologies in the last decades has improved considerably on the appropriateness of many

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[8] Norwegian Institute of Health (2012): Low-level radiofrequency electromagnetic fields – an assessment of health risks and evaluation of regulatory practice. Norwegian Institute of Health, Report 2012:3.

[9] Swedish Radiation Safety Authority (2013): Eighth report from SSM:s Scientific Council on Electromagnetic Fields. Swedish Radiation Safety Authority, Report 2013, 19.

[10] Hug K., Röösli M. (2013): Strahlung von Sendeanlagen und Gesundheit. Umwelt-Wissen Nr. 1323. Bundesamt für Umwelt, Bern.
Hug K., Rapp R., Taschner N. (2009): Niederfrequente Magnetfelder und Krebs. Umwelt-Wissen Nr. 0934. Bundesamt für Umwelt, Bern.

animal models of disease. Nevertheless, there are still medical conditions where there are no suitable animal models.

By using cells in culture as the experimental material **(in vitro studies),** scientists can learn more about mechanisms by which different agents influence biological processes. In vitro studies are also very important for screening of possible hazardous properties of chemicals or physical agents. This knowledge is then very useful for setting up in vivo studies that more accurately reflect the "real life" situation.

In recent years, knowledge based on in vitro findings and also on basic knowledge in chemistry and physics has led to the development of new tools based on computer modeling of possible interactions between biological systems/processes and chemical or physical agents. This is called **in silico studies.** For both in vitro and in silico studies, it is important to realize that the data from these studies are important for mechanistic understanding and for identification of possible hazards, but that the data are not sufficient for a proper risk assessment. Nevertheless, there is a growing interest in further developing these approaches so that more specific and relevant studies can be performed where animals or humans are involved, and to reduce the number of animals that are used for experimental purposes.

A final risk assessment is then using the data from all these types of studies and trying to make an over-all analysis. It is recognized that the quality of the individual studies has to be taken into account. That means that not all studies are of equal importance. The overall picture that emerges when taking many studies into account is often the result of a weighing process, where the level of evidence for a specific statement is a function of what types of data, their amount, and their quality are considered.

Exposure Limits

ICNIRP is an organization of independent scientists (chartered 1992) that voluntarily use their knowledge to translate scientific findings into exposure guidelines for the exposure to non-ionizing radiation. The organization is also a formally recognized non-governmental organization in non-ionizing radiation for the World Health Organization and the International Labour Office. A major output of ICNIRPs activities is their exposure guidelines, which are available for e. g. various frequency bands of EMF. In many countries, the national authorities recognize these guidelines and have adopted them as the principal documents in their protection of the citizens against overexposures to EMF. The guidelines are set to protect against acute exposures that can cause excitation of nerve or muscle tissue (an effect of low frequency electric and magnetic fields) or tissue heating (an effect of radiofrequency EMF). Exposures to EMF levels that cause such effects are thus considered to have biological effects,

which also can translate into detrimental health effects. Furthermore, safety factors are included in the guidelines so that recommended upper exposure levels are several times lower than the levels where effects are known to occur.

The complete guidelines are too many and too complicated to be covered in detail in this short overview. Instead, two examples will serve as illustrations of the guidelines. The first is the limits of exposure to time-varying electric (E) and magnetic (B) fields in the frequency range of 1 Hz to 100 kHz **(the low frequency range).** The basis for the guidelines is that E-fields can cause biological effects (ranging from perception to annoyance) through surface electric-charge effect and that B-fields can stimulate central and peripheral nerve tissues and induce retina phosphenes. Acute effects on the nervous system are well established at sufficiently high exposure levels (threshold levels). To avoid that, the exposures guidelines set limits for the general public that are 5 kV/m for the E-field and 0.2 mT for the B-field at 25–50 Hz (at other frequencies, these effects occur at other exposure levels). For the occupationally exposed, the same magnetic field exposure limit is 1 mT. The general population is thus five times "more protected" by the ICNIRP limits than the workers.

Exposure to EMF at **frequencies above 100 kHz** can lead to significant absorption of energy and temperature increase. There are established biological and health effects from 10 MHz to a few GHz that are consistent with that exposures cause a body temperature increase > 1 °C (this is called a thermal effect by the EMF). A whole body SAR (specific absorption rate; the measure of absorbed RF energy) of 4 W/kg for ca. 30 min will accomplish this temperature increase. There are many established biological and health effects from tissue heating by high frequency EMF. Thus, the ICNIRP guidelines for time-varying E- and B-fields in the frequency range up to 300 GHz state that the general public should not be exposed to more than 0.08 W/kg (averaged over 6 min), or to more than 2 W/kg if the exposure is restricted to head and trunk, for the frequency range 10 MHz – 10 GHz. The latter exposure level is also the maximal output level allowed for RF from mobile phones. As in the case for ELF, here the occupational level is higher (five times), so that the head and trunk exposure is limited to 10 W/kg.

EMF Exposures and Health Concerns

The obvious question is of course if these exposure guidelines can protect against all biological or health effects at lower exposure levels. Specifically, can **ELF magnetic fields** have effects at levels below 1 mT, and are there RF-related effects at non-thermal exposure levels? To some extent, here is a controversy spanning many years. As mentioned in the introduction, epidemiological studies from the late 1970´s and early 1980s suggested that domestic exposure to magnetic fields, clearly below the acute

exposure level of 0.2 mT could be related to childhood leukemia. In an overview, the WHO organization IARC (International Agency for Research on Cancer) actually classified exposures to ELF magnetic fields as a carcinogen class 2B (a possible carcinogen) in 2002 [11]. This classification was based on epidemiological studies that showed increased cancer (childhood leukemia) risk. Subsequent epidemiological research is in line with this association, and also suggested that annual average domestic exposure levels above 0.3–0.4 μT is correlated to the condition. There is however no mechanism that can explain how very low-level magnetic fields can have any biological effects, or even be causing diseases. This is an intriguing fact and a matter for on-going research.

A large number of research projects during the last 10–15 years have investigated possible health effects of **exposure to RF,** more specifically exposure to mobile phone emissions in the RF range. Naturally, there is also then an interest in possible effects due to emissions from mobile phone base stations and other novel devices for wireless communication.

The most prominent source of EMF in the RF range is the mobile phone. However, since the first generation of mobile telephony, there is a trend in the technology of mobile terminals for lower time-averaged emitted power, and thus lower exposure to the user. The exposure from environmental sources is dominated by mobile communications base stations, although this is much lower than the exposure from the mobile phone itself. It has been shown that such systems have increased significantly the EMF levels in the urban environment compared to the levels measured during the 1980's, when only analogue radio and television broadcasting were present. However, historical data from spot measurement campaigns and continuous radiation monitoring systems indicate that the introduction of new technologies after the 2G systems, even the emerging 4G systems, do not increase significantly the measured fields in the environment. Indoors, the installation of access points and short range base stations, e. g., 3G femtocells, WiFi hotspots and DECT devices, have given rise to exposure at distances within 1 m from them, whereas farther away the EMF generated cannot be distinguished from the background levels. The intensity of these devices, even combined, give still a very low exposure compared with limits set by international guidelines.

Research on possible health effects due to exposures from these communication devices has been extensive during the last 10–15 years. A substantial amount of publications are available, from all of the approaches mentioned previously. The areas

[11] IARC (International Agency for Research on Cancer) (2002): Non-ionizing radiation, part 1: static and extremely low-frequency (ELF) electric and magnetic fields. IARC Monograph 80, Lyon, 2002.

of study include neoplastic diseases and other chronic illnesses, effects on behavior and learning as well as other nervous system associated conditions, endocrinological and reproductive outcomes, the immune system and inflammation, self-reported (subjective) symptoms, and other areas. Many studies are well performed and are informative, but it is also clear that a substantial numbers of studies lack in quality and cannot be used for any assessment of possible health risks from exposure to RF EMF. This is not the place to cover all studies and all outcomes, but instead a short overview of three areas will be given; i) neoplastic diseases and use of mobile phones, ii) experimental studies of human nervous functions using EEG, and iii) idiopathic environmental intolerance attributed to EMF (IEI-EMF).

Although there are many studies in vivo and in vitro that address possible **neoplastic effects** of RF exposure, most interest has focused on the epidemiological effects of mobile phone use. Overall, there is little evidence that moderate mobile phone use is associated with any cancer in the head and neck region. This is supported by large-scale epidemiological studies of three different designs. Only one case-control study shows risk increases at moderate usage levels, but the results are incompatible with observed time trends in incidence rates in reality checks and can therefore not be used for hazard assessment. [12]

Evidence is more controversial for heavy use of mobile phones; "heavy use" is difficult to quantify, but an indication would be self-reported use of mobile phones on a daily basis of 30 minutes or more over a time period of 10 years. For this segment among users, particularly the largest case-control study (the Interphone study [13]) observed about 40 % increased risks for glioma and for acoustic neuroma. It cannot be concluded from the available studies whether this reflects a causal association, or if selection bias and reporting bias can explain all, or part of, the observed association.

Recently, a working group at the International Agency for Research on Cancer (IARC), within the Monograph program on the evaluation of carcinogenic risks to humans, classified the epidemiological evidence for glioma and acoustic neuroma as limited and, therefore, total RF exposure as a possible human carcinogen. [14] Based on the studies published since this assessment, it appears the evidence for glioma

[12] See: IARC (International Agency for Research on Cancer) (2013): Non-ionizing radiation, part 2: radiofrequency electromagnetic fields. IARC Monograph 102, Lyon, 2013.

[13] INTERPHONE Study Group (2010): Brain tumour risk in relation to mobile telephone use: results of the INTERPHONE international case-control study. International Journal of Epidemiology 2010, 3, 675 – 94.

[14] IARC (International Agency for Research on Cancer) (2013): Non-ionizing radiation, part 2: radiofrequency electromagnetic fields. IARC Monograph 102, Lyon, 2013.

became weaker while the possibility of an association with acoustic neuroma remains open.

Regarding **nervous system effects,** most of the recent studies have reported an effect of RF exposure on the spectral power of sleep and the waking resting state EEG. The effects on sleep EEG, however, are not restricted to the spindle frequency range. Furthermore, half of the experimental studies looking at the macrostructure of sleep (especially those with a longer duration of exposure) also found effects, which, however, are not consistent with the affected sleep parameters. [15]

The majority of well performed studies looking at RF EMF effects on cognitive performance found an effect in at least one parameter. Given the great variety of cognitive tasks and tests, this has to be interpreted with caution. The biological significance of the small physiological changes remains unclear. So far there is no indication of any associated health effect.

One of the more common health concerns associated with RF exposure is the onset of short-term symptoms such as headaches, fatigue and dizziness. Identifying whether RF exposure can cause these **symptoms** has attracted a substantial amount of research. As well as assessing these effects in the general population, the existence of a group of people who report being particularly sensitive to various forms of electromagnetic fields has also been of special interest. Their condition is commonly referred to as "electromagnetic hypersensitivity" or "electrosensitivity", although a technically more accurate term is "idiopathic environmental intolerance attributed to electromagnetic fields" (IEI-EMF) [16]. People with IEI-EMF usually describe seeing a clear relationship between exposure to RF and the development of symptoms.

The provocation studies that have been published in recent years were generally of good quality, involving double-blind methods, lengthy exposures and, in the case of handset studies, relatively high SAR levels. While their use of self-reported outcome measures could be considered a weakness by some, as it might allow the psychological stress associated with laboratory testing to obscure any effects of the exposure, in practice it has been demonstrated that these studies are able to detect a difference in symptom outcomes when exposures are conducted non-blind. The fact that these effects disappear once blinding is put in place suggests first, that no effect of RF exposure exists and second, that believing RF to be present is sufficient to cause

[15] See e. g.: Loughran S.P., McKenzie R.J., Jackson M.L., Howard M.E., Croft R.J. (2012): Individual differences in the effects of mobile phone exposure on human sleep: Rethinking the problem. Bioelectromagnetics 2012, 1, 86–93.

[16] Baliatsas C., Van Kamp I., Lebret E., Rubin G.J. (2012): Idiopathic environmental intolerance attributed to electromagnetic fields (IEI-EMF): a systematic review of identifying criteria. British Medical Journal Public Health. 2012, 12, 643.

symptoms via a nocebo effect. Actually, also the most recent studies add weight to the conclusion that RF exposure is not the cause of these symptoms.[17] This appears to be true for the general public, children and adolescents and people with IEI-EMF. For symptoms triggered by short-term exposure to RF fields (measured in minutes to hours), the consistent evidence from multiple double-blind experiments strongly suggest that such effects do not occur.

For symptoms associated with longer-term exposures (measured in days to months) observational studies do not support any effects of exposure. However, many studies lack an objective monitoring of exposure. It is therefore difficult at present to make a firm statement regarding the effects of longer term exposures.

Remaining Questions

Despite the considerable efforts made by scientists to elucidate the effects of various types of EMF exposure on human health, certain knowledge gaps remain. Until these gaps are filled, it is likely that the research area will continue to be controversial. Stronger conclusions will need improvements in exposure assessment, based on more personalized assessments and taking into account technological advancements that frequently take place. It is fundamentally important to answer the basic mechanistic type questions that are behind the concerns, namely if low exposure levels (below the thresholds that are causing effects underlying exposure guidelines) really can cause biological effects in the first place, and then if that has any health relevance.

Another area where only a modest amount of research has been performed concerns co-exposures of EMF with other environmental factors. Although there may be a possibility for EMF to act additively or synergistically with other agents, the basic questions of any interaction of weak EMF with biological systems has to be answered first.

[17] Hug K., Röösli M. (2012): Elektromagnetische Hypersensibilität. Bewertung von wissenschaftlichen Studien. Umwelt-Wissen Nr. 1218. Bundesamt für Umwelt, Bern.

From Risk Perception to Responsible Risk Policy [1]

No Risk – No Fun?

Ortwin Renn Perceptions are a reality of their own: Just as cartoon film figures only begin to fall into the chasm after stopping in mid-air as they suddenly realise the danger, so human beings construct their own reality and classify risks according to their subjective perception. This form of intuitive risk perception is based on the provision of information about sources of danger, the emotional and cognitive processing mechanism of uncertainty and earlier experiences with danger. The result of this mental process is the perceived risk, namely a collection of images that human beings associate with risk sources based on the information available to them and common sense about sources of danger. [2] Here, attention is concentrated on the level of the constructed reality, i. e. the world of conceivability and connotations with the aid of which human beings understand their environment and upon which they base their actions.

The starting point for this article is the question: how do we perceive the risks that threaten our life, health and environment? In the process we will review a number of important findings from psychological, social-psychological and sociological research about our decision-making and perceptual behaviour and relate them to the question of political risk governance.

Examples of Risk Perception

In the area of life, environment and health risks, risk perception is characterised by a series of special features. Firstly, are the accompanying circumstances of the risk

[1] This extract is, in part, taken from the book: Renn O. (2014): Das Risikoparadox. Fischer: München.

[2] Renn O., Schweizer P.-J., Dreyer M., Klinke A. (2007): Risiko. Über den gesellschaftlichen Umgang mit Unsicherheit. Oekom: München, 80ff.

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assumption of importance[3] for the risk assessment? Can I control the level of risk myself? Have I chosen to take the risk myself or has it been forced on me by others? Does the risk lead to particularly terrible consequences? Are we already used to these sources of risks and do we believe that we can handle them appropriately? Is the source of risk artificial or natural? These are just a few characteristics that play an important role in risk evaluation. Secondly, the question of the equitable distribution of risks and benefits within different groups of persons is an important indication for many people as to the level of risks and in particular in the evaluation of their acceptability.[4] In the course of cultural evolution **semantic examples** of or patterns for the perception and evaluation of risks have evolved.[5] This can be partially explained by the inherited reactions to risks, i. e. feigning death, escape and fighting. In the meantime these behaviors have further developed into complex patterns of response, which make it easier for us all, when confronted by information about new sources of risk, to make a quick correlation and evaluation.

Within these sematics the example of **insidious danger** is particularly noticeable, as it relates to many of the current health and life-threatening risks including the evaluation of risks from mobile telecommunications.[6] Risks that fall under this semantic example characterise themselves in that we cannot perceive them sensually, that there is often a long passage of time between trigger and effect, that complex structures of the cause-effect chain exist and that we are dependent on information from third parties in evaluating these risks. Examples for this use of this risk category can be found in the cognitive handling of low doses of electromagnetic radiation, food additives, chemical pesticides or gene manipulation of plants and animals. The perception of these risks is closely connected with the need to identify the causes of apparently inexplicable effects, e. g. cancer in children, the mass occurrence of allergies in specific regions, the death of forests, etc.

If we consider the data about these insidious dangers from a specific source of information credible we can then, on the basis of this information, make a personally coherent evaluation of the benefits and risks. If we consider that none of the information media is credible, then we seek zero risk. We either distance ourselves

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[3] Slovic P. (1992): Perception of risk: reflections on the psychometric paradigm. In: Krimsky S., Golding D. (eds.): Social theories of risk. Praeger, Westport and London, 153 – 178.

[4] Rayner S., Cantor R. (1987): How fair is safe enough? The cultural approach to societal technology choice. Risk Analysis 1987, 1, 3 – 13.

[5] Summary in: Renn O. (2002): Die subjektive Wahrnehmung technischer Risiken. In: Hölscher R., Elfgen R. (Hrsg.): Herausforderung Risikomanagement. Identifikation, Bewertung und Steuerung industrieller Risiken. Gabler, Wiesbaden, 73 – 90.

[6] Renn O. (2004): Perception of risks. In: The geneva papers on risk and insurance 2004, 1, 102 – 114.

completely from the source of risk or we fight to ensure that it is no longer tolerated by society. In a third case we endeavour to assign credibility to one of the competing sources of information, but we cannot easily judge from the content or rather its message, the judgement that has earned this credibility.

In this third case so-called peripheral characteristics gain particular importance. The two social psychologists Richard Petty and John Cacioppo identified in their studies of attitudes and attitude changes, that most people make judgements about risks according to either a central or a peripheral approach.[7] When the topic is particularly important they follow the central route and when it is less important the peripheral one. Features of the central route are the analysis of the content of the available information and an as rational as possible evaluation of the respective arguments for or against a particular view of things. The peripheral route on the other hand uses external features of the credibility attribution to reach a speedy choice between the contradictory arguments.

The special feature of insidious dangers is that even those who consider the respective topic of major importance have no or few possibilities to verify each individual argument and make an assessment based on evidence.[8] Whether or not one wishes to follow the central or peripheral route in a controversial question, one is always reliant on peripheral characteristics in order to grade the credibility of the arguments. As these peripheral features correlate only by coincidence with the truth of the relevant claims, it is then logical that chance dictates which chain of argument is most convincing for the recipient.

This dependence on information from experts, the validity and truthfulness of which we are unable to verify ourselves, leads to a series of psychological heuristics **seeking orientation.** Psychologists have researched this extensively. Four are particularly enlightening in respect of our topic: the rules of thumb of availability, anchoring effects, the representativeness and the affective bias.[9] These rules of thumb mislead us into believing information that relates directly to stored memories from the past and which is analogue to information that we always believed. If claims that suggest widely-accepted conclusions are hypothesised there, we are even more likely to also draw these conclusions and consider them true. This is all the more true if redundant information is available and if timely or regional concurrences of supposed causes

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[7] Petty R.E., Cacioppo J.T. (1986): The elaboration likelihood model of persuasion. In: Berkowitz L. (ed.): Advances in Experimental Social Psychology, vol. 19. Academic Press, San Diego, 123–205.

[8] Renn O. (2008): Risk governance. Coping with uncertainty in a complex world. Earthscan, London, 233ff.

[9] Jungermann H., Pfister H.-R., Fischer K. (2010): Die Psychologie der Entscheidung. Eine Einführung. 3. Auflage. Spektrum, Berlin und Heidelberg, 169ff.

and their results are cognitively present. Rules of thumb help us to quickly deal with complex and contradictory information without any major internal conflicts. However they confuse often enough because they incorrectly simplify complex facts and lead us to have confidence in our own judgement, something that is unjustified in the views of the experts.

Political Consequences of Risk Perception

Which benefits can science and politics draw from the research of risk perception in this situation? What can be normatively deduced from the studies into intuitive risk perception for risk and technology political decision making? [10]

Scientific risk analyses are helpful and necessary parts of a forwards-looking technology and risk policy. Only with their help can relative risks be compared with each other and options expected to result in the lowest level of damage selected. However, they cannot and may not be used as the sole guideline for government action. Their universality is bought namely by taking them out of context and by hiding the remaining rational meaningful perceptual features. Without the inclusion of context and situation-specific accompanying circumstances, decisions cannot satisfy the need to reach a rational and value-optimising package in a given situation.

Context and accompanying circumstances are crucial features of risk perception. These patterns of perception are not just any individually aligned ideas but are concepts that have developed through cultural evolution and proven in everyday life, and which in many cases control one's behaviour as a universal human reaction to the perception of danger

From a rational point of view it seems absolutely desirable to systematically record the various concerns of intuitive risk understanding and to measure each empirically given characteristic in these concerns. How much different technical options, such as different types of mobile communication, distribute risk differently on sections of the population, to what extent institutional control possibilities exist, and in how so far risks can be dealt with by voluntary agreement, can in principle be measured by the appropriate tools of research. That these factors ought to be considered in the political decision can be learned from the study of risk perception. Based on the view that the concerns of intuitive risk perception must be legitimate parts of a **rational**

[10] Renn O. (2011): Wissen und Moral-Stadien der Risikowahrnehmung. Aus Politik und Zeitgeschichte 2011, 46–47, 3–6.

policy, the assessment of the various risk sources in every dimension but according to rational scientific procedures must follow. [11]

Risk perception offers no replacement for rational policies. No more than technical risk analysis can be made the sole basis for decisions, should one make the factual evaluation of risks into a political scale of their acceptability. When one knows that certain risks, such as the dangers to health from high levels of exposure to electromagnetic fields, are based on expert know-how, then a political risk reduction is acceptable even when there is a lack of appreciation of the problem in the population. Many risks are suppressed simply because people do not wish to face them. This is particularly the case for risks that have a high positive symbolic value. To let oneself be guided by suppressed or manifestly false ideas can hardly be a justification for the definition of a **forwards-looking** risk and technology policy. The knowledge from this pattern of perception can, however, be used beneficially for the design and implementation of an information and education programme. The inability of many people to understand probabilistic statements or to recognise the degree of risk in familiar risk sources of long standing is certainly a problem area on which targeted education and information programmes can be tied. [12] Thereby mutually complementary technical risk analysis and intuitive risk perception is required.

In my view it is a central task of politicians, to merge scientific know-how about possible effects and remaining uncertainties with the evaluation and design ideas of the population affected by these risks, and integrate them into a single knowledge and value orientated policy. Risk politics may not be reduced to purely an orientation of knowledge or to a value orientation.

[11] Renn O. (2002): Die subjektive Wahrnehmung technischer Risiken. In: Hölscher R., Elfgen R. (Hrsg.): Herausforderung Risikomanagement. Identifikation, Bewertung und Steuerung industrieller Risiken. Gabler, Wiesbaden, 73–90.

[12] Renn O., Klinke A., van Asselt M. (2011): Coping with complexity, uncertainty and ambiguity in risk governance: a synthesis. AMBIO, 2011, 2, 231–246. Renn O. (2008): Risk governance. Coping with uncertainty in a complex world. Earthscan, London, 64–66.

The So-Called Typical Study Does Not Really Exist

▸ *Peter Achermann, in your laboratory in the Institute of Pharmacology and Toxicology of the University of Zurich you expose people to electromagnetic fields in order to study potential biological effects. What are the common interests between research in pharmacology and electromagnetic research?*

Peter Achermann Pharmacology has no direct links to electromagnetic research. It is simply due to historical reasons, that the sleep laboratory, designed to conduct basic research, is located at the Institute of Pharmacology and Toxicology. Most of our EMF research projects focus on sleep and brain activities during sleep and are therefore conducted at our Institute. Because the sleep laboratory is located underground and constructed as a "building within a building", our rooms are perfectly shielded against ambient radiation.

▸ *How many people typically participate in a study? What kind of volunteers do you look for and how do you find the participants?*

Size and composition of the groups depend on the study interests. Recruitment efforts also vary according to group characteristics. In most studies we use a group size of 20 to 30 subjects. Generally, we work with young men, mostly students that have been recruited with notices posted in the campuses of the University and ETH Zurich. In a larger study about UMTS radiation and human well-being (see box on the next page) we recruited the volunteers with newspaper advertisements. In another study that investigated whether the brain of a child responds more sensitive to electromagnetic fields than the brain of an adult, we approached children and parents on

Prof. Dr. Peter Achermann

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different channels like paediatric practices, visits at schools, parent organisations, the "Science page" of 20 Minutes or the Swiss television's science magazine "Einstein".

▶ *How does a typical study design look like?*
The so-called typical study does not really exist. However, many of our studies roughly meet the following design characteristics: the study participants have to accept predefined sleeping periods throughout the study and they have to abstain from naps. Three days prior to the study they are not allowed to consume alcohol or caffeine. The first night serves as an adaptation night. The first experimental condi-

Project

"Effects of UMTS Radio-Frequency Fields on Well-Being and Cognitive Functions"

A Swiss study consortium replicated a Dutch study that showed an impairment of well being due to UMTS radio frequency radiation. The Swiss study has been coordinated by the Swiss Research Foundation on Electricity and Mobile Communication (FSM) and was carried out under the lead of Prof. Dr. Peter Achermann. The emphasis was put on the verification of the Dutch results with improved methodology.

The Swiss study investigated the effects of electromagnetic fields similar to those emitted by a UMTS base station on well being and cognitive function (attention and working memory). Thirty-three subjects with and 84 persons without subjective complaints aged between 20–60 years were investigated. To investigate a potential dose-response relationship, electric field strengths of 1 V/m and 10 V/m were applied, as well as a control condition without an electromagnetic field. Subjects were exposed for 45 minutes at a time, but neither they nor the investigators knew when the two field strengths or the control condition were applied.

The researchers found no effect of this short-term UMTS radiation on well being and observed no consistent effect on cognitive functioning, neither at the 1 V/m nor at the 10 V/m condition. In addition, the subjects were not able to perceive the actual exposure conditions.

Link: www.emf.ethz.ch (see: projects)

Publication: Regel S..J., Negovetic S., Röösli M., Berdiñas V., Schuderer J., Huss A., Lott U., Kuster N., Achermann P. (2006): UMTS base station-like exposure, well-being and cognitive performance, in: EHP 2006, 114, 1270–1275.

tion is applied in the second night. The condition can be an active field (out of one or several predefined levels) or a so-called sham condition (no field at all). Every week, such sessions with an adaptation and an experimental night are applied until all experimental conditions have been tested. The sequence of conditions varies by chance following a cross-over design.

▶ *Are the participants informed about the study goals, the nature and level of radiation they are exposed to, the kind of tests they will have to perform, how long the experiments last, and similar aspects?*
The participants get full information about the study, about what study relevant conditions they have to adhere to, and about potential risks. All participants sign an informed consent form. This is a declaration about having been informed about the study and agreeing with the experimental procedures. All experiments are performed in a double-blind manner, i. e. neither the participants nor the scientists in charge of the study know the applied condition.

▶ *Have you also conducted studies with extremely low frequency fields, typically emitted by power lines or electric appliances?*
So far, we did not work with this kind of exposure. It would be very challenging to conduct such studies in a laboratory setting.

▶ *What are the main achievements and insights of your work?*
We found consistent effects of pulsed radiofrequency electromagnetic fields like those radiated by mobile phones on brain activity during sleep. Pulse modulation was the key to induce effects. However, we did not find impacts on the quality or the architecture of sleep. Furthermore, we do not think that the fields have an impact on cognitive performance.

▶ *What can you tell us about radiofrequency exposure and well-being?*
In our study on UMTS radiation and human well-being we could not find an association between real exposure and well-being, however, we observed an association between perceived exposure and well-being. In general, our study subjects could not detect exposure.

▶ *How robust are your findings in light of the relatively low number of study participants in your experiments?*
I think our results are quite robust because we got similar findings in several studies, and the outcomes of other research teams point in the same direction. However,

we have to be cautious in interpreting the data: we cannot generalize. For instance, we do not know how elderly people or persons with sleep disturbances react to the fields. Furthermore, we do not know the impact of long-term exposure at very low levels because we only studied acute effects of a single exposure of the head to a relatively strong field, comparable to the one of a mobile phone.

▶ *Back to your findings: Do you know where exactly electromagnetic fields interact with the brain and how the interaction mechanisms look like?*
The biological interaction mechanisms are not known. We have discovered that pulsed electromagnetic fields as those of mobile phones influence brain waves, i. e. impact brain activity. Pulse modulation seems to be the key characteristic to induce the effect. Our conclusion is that such an effect cannot be explained by thermal load. Another biological response need to be at work.

▶ *When do you hope to get a final answer?*
What kind of answer? In science, you never get final answers. I suppose your question points at potential health impacts of EMF. As long as we do not understand the biological mechanisms at work, it is difficult to give firm answers.

▶ *Peter Achermann, many thanks for this interview!*

Everyone Would Prefer a Clear Yes or No

▶ *Leeka Kheifets, you work at UCLA, one of the most prestigious universities worldwide. Does your work benefit from being located at UCLA? In which way?*
Leeka Kheifets UCLA is a great place, it allows for collaboration with the best scientists and students. I particularly enjoy working with methodologists – our collaboration contributes both to the subject knowledge and advances the science of epidemiology and risk assessment.

▶ *You're an epidemiologist. Can you explain what epidemiologists do and what kind of research you are particularly interested in?*
Epidemiology is the study of the distribution of disease, health, and their determinants in the human population. Although the body of evidence is always considered as a whole, based on the weight of evidence approach and incorporating different lines of scientific enquiry, epidemiologic evidence, as most relevant, is given the greatest weight. My work focuses on potential health effects of non-ionizing radiation. I am particularly interested in methodological issues, including use of epidemiology for evidence-based health policy.

▶ *In the early years of 2000 many researchers did not believe that epidemiological studies on, for instance, mobile communication exposure could be scientifically informative. What progress has epidemiology made in this area since then?*
Indeed studying such a rapidly growing and changing exposure is very difficult. Nevertheless, epidemiological evidence concerning cell phones and the risk of brain tumours in adults is, so far, reassuring. There are suggestions of effects in some

Prof. Dr. Leeka Kheifets

UCLA, School of Public Health, Department of Epidemiology

analyses that might be due to biases and this needs to be further understood. There are also some suggestions, coming from our own data, of an influence of mobile phone use during pregnancy and early childhood development. This needs to be looked at prospectively and verified by others. Cell phone use is nearly ubiquitous now, and it will become increasingly difficult, if not impossible, to identify unexposed individuals in the coming years. It is, therefore, important to do more work now.

▶ *Many citizens feel confused about the contradictory statements by experts. Some tell that there is no or a close-to-zero risk associated with EMF exposure, others are ringing the warning bells. Which camp should I believe?*
Neither one, although everyone would prefer a clear yes or no answer. It is important not to overstate and also not to understate scientific evidence. I believe that attempted reassurance, even well intentioned, can be counterproductive. While there are no reasons, in my opinion, to ring the warning bells, stating that we know that there is no problem is also wrong, when only few diseases have been adequately (if at all) studied and there is still little data on children.

▶ *In your opinion, how solid is the association between ELF exposure and childhood leukaemia?*
Residential exposure to magnetic fields as a possible risk factor has been examined in over 30 studies with most finding increased risks, based, however, on case-control studies with a small number of highly exposed cases. The consistent association found between childhood leukaemia and average magnetic-field exposure above 0.3–0.4 μT could be due to selection bias, misclassification, other factors which confound the association, or true causal relationship. Unfortunately, the possible explanations so far identified all seem unlikely, with good arguments for and against each possibility. Thus the epidemiologic evidence on magnetic fields and childhood leukaemia presents a substantial but unresolved body of data.

▶ *In terms of overall weight of scientific evidence, how do you evaluate the fact that there is still no biological mechanism known whether ELF can cause leukaemia?*
Causation has not been established and appears unlikely due to lack of plausible mechanisms that can operate at low levels and lack of support from animal studies. The absence of plausible biophysical mechanisms at low levels do not prove that health effects are impossible, but they do require an epidemiologic evidence to be stronger than otherwise; and currently epidemiologic evidence, even for childhood leukaemia, remains insufficient to overcome scientific challenges from other lines of evidence, but sufficient to require research to resolve this issue.

► *What is the appropriate way for public health policy to deal with risks that are not scientifically established?*
Good public health policy for risks that are not scientifically established should involve precaution and research, both approached with rigour and good judgement.

► *Looking at the history of risk governance for mobile phones and power lines: what have been the strong points / deficits, and what are the crucial lessons learned?*
The principal risk-governance issue for power lines is how to respond to weak and uncertain scientific evidence that nonetheless causes public concern. For mobile phones, the issue is how to respond to large potential consequences and large public concern where only limited scientific evidence exists. The main lessons to be learned from power lines are that an open and proactive approach to research is crucial to the governance of a potentially volatile issue that could have tremendous societal costs. While there are still disputes, particularly at the local level, continued research, public involvement and adoption of low and no-cost exposure reduction measures allow for a manageable process of building and upgrading power-lines. I think deficits in risk governance for mobile phones are larger. RF is a more recent issue and where the pressures, commercial and other, are stronger. Here opinions are pushed to the extreme, with even simple and cheap measures, such as display of information on SAR for phones in the stores and use of hands free devices are challenged and ridiculed. Also, attempts to control research, through funding and other mechanisms, is more prevalent.

► *In Europe, and particularly in Switzerland, precautionary approaches and public participation are important elements of political culture, also for the EMF issue. From an international governance perspective, what role and status do you attribute to stakeholder and citizen involvement and precaution?*
When I was at WHO, I was fortunate to participate in one such event in Switzerland. I was impressed and inspired by the level and quality of public participation. I believe we need to acknowledge the importance of public involvement, from defining a problem to managing it. What is difficult is to obtain a right balance. At times, all sides overstate the possible consequences of alternatives which they disfavour, with exaggeration of the adverse consequences of taking protective measures or exaggeration of the scientific evidence. The same applies to precaution, it should be part of any policy, but in a way that does not restrict benefits. For mobile phones, many precautionary measures would not in fact limit benefit from these technologies.

► *Leeka Kheifets, many thanks for this interview!*

Emotions are Pivotal

▸ *Michael Siegrist, one of your chief scientific interests is how people perceive risks. How does the Swiss population perceive risks associated with electromagnetic fields compared with the perception of other risks?*

Michael Siegrist Mobile phones and base stations are perceived as unknown risks generating limited concerns. For most people, EMF is not an urgent matter. However, this attitude may change when a new base station is planned in close vicinity. Then, even a moderate risk can be perceived as unacceptable.

▸ *Do people discriminate between the diverse sources as for instance radiation from broadcasting, mobile communication infrastructure, mobile phones, power lines or electric appliances?*

Power lines are clearly perceived as most risky. Next are base station antennas for mobile communication. The other sources are located on lower levels of risk perception.

▸ *What is the role of knowledge for risk perception? Do we perceive risks differently when we are well informed?*

The crucial question here is to what the notion of knowledge refers to. A general or basic scientific knowledge doesn't impact perceptions very much. Specific knowledge, however, can influence risk attitudes. To know that my mobile phone has an antenna and that the antenna will radiate with more power when I sit in a car may affect my risk perception.

▸ *What role do emotions play, and do they affect moral and political beliefs?*

Emotions are pivotal. Images associated with a technology are much more important in risk perception than data and statistics. In contrast to that political opinions, in gen-

Prof. Dr. Michael Siegrist

ETH Zurich, Institute for Environmental Decisions (IED), Consumer Behavior

eral, do not play a key role. However, policy views are important for the question of technology acceptance. This is not contradictory because perceived utility is generally more important for technology acceptance than perceived risk.

► *Why do people like discussing questions about what is a risk or not – an instance thereof is EMF – instead of delegating this task to the experts and addressing more urgent problems of everyday life?*
It is partly true that people are often concerned about minor risks. However, the experts contribute to this with conflicting assessments. Whatever topic you choose, you will find experts identifying risks associated with this topic. There is an inherent interest of many experts to identify and communicate risks. Without perceived risks there is no funding for risk research.

► *Sometimes, risk research is blamed to serve as a means towards increasing technology acceptance. Where is the limit between independent research and research tuned to sponsor interests?*
In our studies, sponsors have no veto right and we publish the results we think are worthwhile to be issued. And don't forget: nowadays it is not easy to get results published that are in line with sponsor interests. Our research rules guarantee that sponsors cannot intervene, neither with the design of a study nor with the analysis and publication of results.

► *This brings me to the Swiss Research Foundation for Electricity and Mobile Communication of which you are a member of the Board. How does FSM safeguard her research funding against sponsor interests?*
We have a Scientific Committee that takes the funding decisions. The Committee consists of scientists only, without any representatives from the sponsors. This firewall shields the Committee from industry preferences whatsoever.

► *Let me come back to EMF research. What kind of studies do you conduct and can you illustrate your research findings with one or another example?*
We study, for instance, the mental models of laypersons. This research revealed that base station antennas are perceived as more risky to humans because most consumers think that mobile phones do not have a radiating antenna. This is a major reason why people are more concerned about base stations than about mobile phones. Our research indicated what knowledge is relevant to consumers and needs to be communicated. Furthermore, we learned that when this knowledge is appropriated, the willingness to accept base stations in the neighbourhood increases.

► *In which direction do you intend to develop your EMF research agenda in the upcoming years?*

The reconstruction of the electricity network will become a major issue in the near future. This topic will generate a series of important social science research questions.

► *Michael Siegrist, many thanks for this interview!*

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