Paper

Evaluation of Potential Dangers of Mobile Telecommunication Frequencies and Modulations

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Abstract—Mobile Telecommunication is one of the fastest growing technologies in the world. The effects of its high frequencies and complex modulations to the exposed population are considered in this paper. Experimental studies examining a variety of effects on all levels of the organism, ranging from effects on single cells to effects which manifest themselves as reactions of the entire body, there have been a number of epidemiological studies in order to establish the possible causal correlations between higher exposures to HF EMFs. Recommendations on the reduction of the effects of EMFs of Mobile Telecommunication on humans was presented.

Keywords—electromagnetic fields, frequency, health, mobile communication, modulation.

1. Introduction

No technology covering virtually entire countries with its emissions has ever been rolled out as quickly as mobile telecommunications. This technology which comprises of either Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA) or Code Division Multiple Access (CDMA) are electromagnetic fields (EMFs) based [1]. At the same time, there are only few direct studies of the potential health risks of typical mobile telecommunications frequencies and modulations for the exposed population. Also, many of the existing studies worked with high levels, which will only be found in rare cases in the real environment. High levels of high frequency electromagnetic fields can heat the absorbing tissue and trigger stress reactions in the body and thus with rising temperatures lead to thermal damage. Effects from high intensity high frequency EMFs, also known as thermal effects, on the central nervous system, the immune system, the cardiovascular system and the reproductive system including teratogenic effects, have been proven for mammals with a multitude of experiments [2]. The results of studies of the thermal effects of high frequency EMFs form the basis of the recommendations of the International Commission on Non-Ionizing Radiation Protection (ICNIRP), which, in the past, were the basis for the guidelines set by the government in many countries. The base guideline was an upper limit on the Specific Absorption Rate (SAR), i.e., the amount of energy absorbed by the body from the field within a given unit of time.

According to ICNIRP, thermal damage will not occur at SAR values of below 4 W/kg and exposure levels of 0.4 W/kg for professional exposures and 0.08 W/kg for the general population are considered safe. Parallel to the experiments examining thermal effects, there have been a growing number of studies examining the effects on the body of HF EMFs at sub-thermal intensities. We now have a plethora of experimental studies examining a variety of effects on all levels of the organism, ranging from effects on single cells to effects, which manifest themselves as reactions of the entire body. In addition to the experimental studies, there have been a number of epidemiological studies in order to establish the possible causal correlations between higher exposures to HF EMFs, for example was found near base stations, and health damage amongst the population groups with higher exposures. The mobile telecommunications situation reflects, once again, the dilemma already known from chemical toxicology [3]. The study of potential health effects cannot generally compete with the speed of technical development and the roll out of the product. The extremely fast roll out of the mobile telecommunications technology and the accompanying public fear of the potential danger of this technology have stimulated research insofar that now we have more studies examining the effects of frequencies and modulations as used in mobile telecommunications on biological systems. There are also a growing number of experiments using lower intensities, reflecting the real conditions of exposure in the vicinity of base stations and equipment, so that effects found in the studies can be extrapolated into real life conditions.

The number of studies which examine the physiological effects of real mobile exposures is still very low, compared to the degree of penetration achieved by the technology and the number of (potentially) exposed persons. The World Health Organization (WHO) amongst others, have only recently begun to develop targeted strategies to examine the potential health risk from mobile telecommunications and results can earliest be expected within several years [4]. In the meantime, it is only possible to assess the potential dangers of mobile telecommunications using the results generated by uncoordinated research, which is still mainly orientated towards topics and criteria of relevant to science only, rather than addressing the requirements of society as a whole. Faced with a state of incomplete scientific

research it is necessary to chose between two fundamentally different assessment theories when planning to assess the potential health risks of new technologies. Table 1 illustrates some typical artificial sources of electromagnetic fields with frequency and intensity. Natural sources like the magnetic field of the earth are not included. Note, however, that big variations occur.

Table 1
Typical sources of electromagnetic fields

Frequency range		Some examples of exposure sources
Static	0 Hz	VDU (video displays), MRI, diagnostic/scientific instrumentation, industrial electrolysis, welding devices
ELF	0 – 300 Hz	Powerlines, domestic distribution lines, home appliances, cars, train and tramway electric engines, welding devices
IF	300 Hz – 100 kHz	VDU, shops anti-theft systems, hands free access and control systems, card readers and metal detectors, MRI, welding devices
RF	100 kHz – 300 GHz	Mobile telephony, broadcasting and TV, microwave ovens, radar, portable and stationary radio transceivers, personal mobile radio, MRI

Section 2 examines the health risks to humans resulting from exposure to EMF of mobile telecommunications. Section 3 discusses about infertility and teratogenic effects and evaluation of results from experiments. Sections 4 and 5 conclude and recommend the precautionary measure needed in relation to exposures to EMFs of mobile telecommunications respectively.

2. Health Risks Resulting from Exposure to the EMFs of Mobile Telecommunications

The triggering of an illness caused by an (environmental) pollutant and the development of this illness are a multiphased process, which begins with a biological, biochemical or biophysical primary interaction of the pollutant with the biological system and ends with the manifestation of the illness. During the different phases of the process, the body's own repair mechanisms can intervene and impede the further development of the illness. An assessment of the potential health risks of electromagnetic fields as they are used for mobile telecommunications should therefore be mainly based on studies conducted directly on humans. Extrapolations from animal studies or even in vitro studies on cell cultures only have limited validity for effects in humans, due to the difference in susceptibilities and the lack of organic interactions in cell cultures [5]. However, due to the ethical limits to the research on humans, it is unavoidable to use results from experiments with animals, single organs or cells in order to discover the biological and physiological mechanisms.

2.1. Cancer

Given the results of the present epidemiological studies, it can be concluded that electromagnetic fields with frequencies in the mobile telecommunications range do play a role in the development of cancer. This is particularly notable for tumours of the central nervous system, for which there is only one epidemiological study so far, examining the actual use of mobile phones. The most striking result of this study was an obvious correlation between the side at which the phone was used and the side at which the tumour occurred. The brain tumour incidence however was only slightly increased. A hypothetical explanation of such a finding could for example be that mobile fields have a promoting effect on previously initiated (multiple) tumours, triggering a defence mechanism in the body which is capable of suppressing unpromoted tumours [6].

2.2. Higher Risks for Several Forms of Leukaemia

Although the studies in relation to testicular cancer were examining particular exposure conditions (emitting equipment worn partly on the body at hip level), given the high risk factor found, a possible risk cannot be excluded, especially not for mobile users wearing the devices in standby mode on their belts. The epidemiological findings for testicular cancer also need to be interpreted in conjunction with the results of the studies of fertility problems occurring in relation to high frequency electromagnetic fields. The risk factors for cancers other than testicular cancer are only moderately increased, but not negligible, considering this technology will potentially reach full coverage of the entire population [3].

Reliable conclusions about a possible dose-response-relationship cannot be made on the basis of the present results of epidemiological studies, but an increase of cancer risk cannot be excluded even at power flux densities as low as 0.1 W/m^2. In long-term animal experiments, the carcinogenic effect of pulse modulated high frequency fields was demonstrated for power flux densities of circa 3 W/m^2 (mouse, exposure duration 18 months, 30 minutes per day, SAR about 0.01 W/kg) [7]. On the cellular level, a multitude of studies found the type of damage from high frequency electromagnetic fields which is important for cancer initiation and cancer promotion.

Chromosome aberrations and micronuclei occurred at power flux densities from 5 W/m^2. Neoplastic cell transformation and an enhanced cell proliferation were demonstrated for SAR of below 0.5 W/kg, and individual studies demonstrated that the obvious disturbance of the com-

Table 2
Overview over the results of epidemiological studies with regards to the health risks of high frequency electromagnetic exposures

Illness	Number of studies (results)	Studies (results) with RR > 1	Statistically significant results
All illnesses	2	0	0
Cancer, unspecified	6 (7)	5 (6)	3
Brain tumours unspecified and tumours of the nervous system unspecified	14 (21)	10 (15)	6 (7)
Cancer (eyes)	1	1	1
Cancer of the respiratory organs, lung cancer	5	2	1
Chest cancer, men	2	2	0
Breast cancer, women cancer of the lymphatic and blood forming	3	3	2
System unspecified	4	4	1
Leukaemia unspecified	12 (16)	9 (13)	5 (7)
Acute leukaemia unspecified	4	4	0
Lymphatic leukaemia unspecified	4 (7)	2 (5)	1 (4)
Acute lymphatic leukaemia	2	2	0
Chronic lymphatic leukaemia	4	4	1
Leukaemia, non lymph. non-myelo	1 (4)	1 (4)	1 (2)
Lymphoma, Hodgkin-Syndrome	5 (7)	3 (4)	1
Testicular cancer	3 (5)	3 (5)	3 (4)
Uterine cancer	1	1	1
Skin cancer	4	3	1
Cardio-vascular diseases	4 (5)	3 (4)	1
Infertility, reduced fertility, men	4 (5)	3 (4)	1
Infertility, reduced fertility, women	1	1	0
Miscarriages, stillbirths, malformations and other birth defects	2 (3)	2 (3)	2
Cancer, offspring (parental exposure)	2	2	1
Neurodegenerative diseases, Alzheimer's	1	1	0
Disruptions of motor and psychological functions and well-being	2 (9)	2 (9)	1 (7)

munication between cells, which is a prerequisite for the uninhibited proliferation of cells that is characteristic for cancer development, occurs at just a few W/m^2 [3].

3. Infertility and Teratogenic Effects

Teratogenic effects of a pollutant can – as with the carcinogenic effect – either be caused by the triggering of a genetic defect or a harmful impact on the foetal development. The formation of a genetic malformation during its initiation phase is analogous to carcinogenesis, i.e., teratogenic effects are also caused by direct or indirect impact on the DNA and disruptions of the endogenous repair mechanisms [2]. Later damages of the foetus can either be caused by direct effects of the pollutant on the foetus or by reactions to the pollutant within the mother's organism, which would then be passed on to the foetus.

3.1. Evaluation of Results and Analysis from Experiments

However there are a much larger number of studies available, in which the health effects of high frequency electromagnetic fields in humans were examined (Table 2). Just under a quarter of all results relative to exposures with low frequency pulse or amplitude modulated high frequency fields, such as they are used for mobile telecommunications, even if the carrier and modulation frequencies are in most cases not identical with those of mobile telecommunications.

A statistical evaluation of the results is presented in Table 2. Here, we list for every illness how many studies or separate results are available, how many of these show a relative risk RR > 1 and how many are statistically significant. Almost all the studies, in which the total cancer risk without any differentiation according to tumour form

were examined, showed a risk factor of RR $>$ 1. Half of the studies resulted in statistically significant risk factors with a maximum value of 2.1, which corresponds to a doubling of the statistical risk to develop cancer from exposure to high frequency electromagnetic fields. A similar picture was found in relation to tumours of the nervous system, especially brain tumours. Here, the maximum value for relative risk found was 3.4.

Eleven of the total of 15 studies yielded a positive result, more than half of which were statistically significant. The incidence of breast cancer in relation to high frequency fields must be examined separately for men and women. All three studies relating to the breast cancer incidence in women yielded risk factors greater than 1, the statistically significant values were 1.15 and 1.5. For men, risk factors of up to 2.9 were found, however, not all were statistically significant. Of the total of 16 results for leukaemia without further differentiation of the illness, 13 were positive (RR $>$ 1), more than half of these results were statistically significant.

The highest statistically significant value for the relative risk was 2.85. Amongst the results of the differentiated studies, the following are notable: lymphatic leukaemia (7 results, 5 positive, 4 statistically significant, RR maximum value 2.74) and acute myeloic leukaemia (4 different studies, 3 positive results, 2 statistically significant, maximum RR value 2.89).

With regards to the correlation of high frequency electromagnetic fields from radar and other sources and testicular cancer, three studies have been conducted. All lead to statistically significant risk factors with a maximum value of 6.9. The studies regarding cardio-vascular diseases did not result in a clear picture, not least because of the multitude of the symptoms examined. All four studies of fertility problems in relation to the exposure of men to microwaves indicate increased risk. In two studies statistically significant risk factors of up to 2.7 were found. With regards to irregular courses of pregnancies and malformations in children of mothers which had been exposed to high frequency fields, there are a large number of studies with positive results, of which only two fit into the frequency range relevant to our report. Both of these studies found statistically significant positive results with risk factors of up to 2.36. Of the studies of cancer risk of children whose fathers had been exposed to electromagnetic fields, only two correspond to the quality criteria required for inclusion into this report. Both indicate an increased risk, but only one result is statistically significant at a value of RR = 2.3, with regards to the cancer risk of children in correlation to the exposure of their parents [5].

Regarding the disruption of motor functions as well as psychological functions and wellbeing, there is only one valid study for the frequency bands relevant to this report, which yielded a slightly increased risk factor. However since other studies of transmitters with frequencies below 100 MHz resulted in serious indications of increased risk, indicating that this problem should be given more attention in the future, we also included the study of [8], although it didn't meet our quality standards with regards to the statistical evaluation. Unfortunately, the majority of the studies do not state the actual strength of the exposures. Measurements are only available for the radio and television transmitter used for the studies of [9] and [10]. The mean power flux densities for all 16 municipalities affected by this transmitter were 3.3 W/m^2 within the range from $2.6 \cdot 10^{-4}$ to $1.46 \cdot 10^{-2}$ W/m^2 [9].

4. Conclusion

An assessment of the potential health risks of electromagnetic fields as they are used for mobile telecommunications should therefore be mainly based on studies conducted directly on humans. Extrapolations from animal studies or even in vitro studies on cell cultures only have limited validity for effects in humans, due to the difference in susceptibilities and the lack of organic interactions in cell cultures. The analysis of the results of the studies for all stages shows the effect of EMFs on humans, however this can be prevented or reduced.

5. Recommendations

5.1. Precautionary Health Protection in Relation to Exposures to Electromagnetic Fields of Mobile Telecommunications

With mobile telecommunications we have to differentiate two exposure situations:

- exposure of residents near base stations,
- exposure of mobile users when using the devices.

To limit exposure to an acceptable degree, if this is possible at all, there is need for different strategies for the two different exposure groups.

5.2. Exposures from Base Stations

In humans, harmful organic effects of high frequency electromagnetic fields as used by mobile telecommunications have been demonstrated for power flux densities from 0.2 W/m^2. Already at values of 0.1 W/m^2 such effects cannot be excluded. If a security factor of 10 is applied to this value, as it is applied by ICNIRP and appears appropriate given the current knowledge, the precautionary limit should be 0.01 W/m^2. This should be rigorously adhered to by all base stations near sensitive places such as residential areas, schools, nurseries, playgrounds, hospitals, churches, Mosques and all other places at which humans are present for longer than 4 hours. We recommend the precautionary limit of 0.01 W/m^2 independent of the carrier frequency. The rough dependency on frequency with higher limits outside of the resonance range, as it is applied in the concept of SAR, is not justifiable given the results of the scientific studies which conclusively prove non-thermal effects of high frequency fields.

5.3. Exposures of Mobile Phone Users

Given the state of technology now and in the near future, it is currently technically impossible to apply the recommended maximum value for mobile base stations also to the use of mobile phones. However, a lowering of the guidelines to a maximum of 0.5 W/m^2 should urgently be considered. A particular problem in this exposure group is posed by children and adolescents, not only because their organism is still developing and therefore particularly susceptible, but also because many adolescents have come to be the most regular users of mobile phones. Furthermore, particular efforts should be made to lower the exposures during calls. It would be recommendable to conduct (covert) advertising campaigns propagating the use of headsets. It would also be important to develop communications and advertising aiming at minimizing the exposures created by carrying mobile phones in standby mode on the body.

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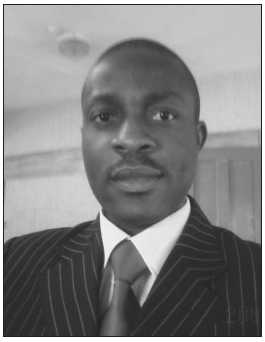

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