Environmental Medicine Evaluation of Electromagnetic Fields

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ÖÄK (Austrian Medical Association)
Environmental Medicine Diploma Course
Seminar 3 – Electromagnetic Fields
21 and 22 April 2007, Pörtschach a.W., Austria

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Introduction

Life on our planet has developed throughout evolution against the background and under the influence of the natural electromagnetic spectrum. Examples include photosynthesis and visual sense through visible light, tanning of the skin as a protection mechanism against UV radiation, navigation of migratory birds along the static geomagnetic field, weather sensitivity for certain sferics in the kHz-range, or the synchronization of brain waves through Schumann resonances (ca. 8 Hz and others).

Cells, tissues, organs, and entire organisms do not only function through chemical reactions, but at the same time these complex, non-linear processes are closely linked to internal and external electromagnetic events. Plants, animals, and humans are electromagnetic beings.

Never before in human history, stretching back for about seven million years, have we seen a comparable development as it has been unfolding with increasing speed and infiltration for the past 100 years – the exposure of more and more people to artificially generated electromagnetic fields and waves with most diverse frequencies and signal patterns.

In line with the experiences of our past, the author assumes that the human exposure to human-made electric, magnetic and electromagnetic fields will continue to rise with regard to intensity as well as frequency range. As a consequence, the associated health implications will become more obvious, resulting in change.

In physics, we generally distinguish between five clearly defined types of electromagnetic fields and waves:

- Static magnetic fields - magnetostatics
- Static electric fields - electrostatics
- AC electric fields – ELF /VLF
- AC magnetic fields - ELF /VLF
- Elelectromagnetic waves – radiofrequency (RF) and microwave (MW) radiation

Static Magnetic Fields (Magnetostatics)

Properties

Beside the geomagnetic field, static magnetic fields occur, for example, in current-carrying DC conductors, permanent magnets and magnetized metal parts. The unit of the magnetic field strength is A/m (ampere per meter), from which the magnetic induction or flux density T (tesla) is derived.

Sources

Magnetized steel parts in beds, furniture, innerspring mattresses, steel joists in floors, extensive steel reinforcement, steel tank in the basement, car in the garage below the bedroom, direct current from electric trams and buses.

Effects

Life on our planet has evolved against the background of the geomagnetic field. We have data on how migratory birds and other animals use the geomagnetic field for navigating (Binhi 2002). In vitro investigations of nerve cells (Blackman 1985) and mathematical models (Thompson et al. 2000) show that the orientation as well as the strength of the geomagnetic field are important factors for responses of the calcium ion channels, which are crucial for signal transmission. Animal experiments show that static magnetic fields can impact the production of melatonin, a hormone of the pineal gland (Reiter 1993).

Taking the exposure to visible light into consideration, a study showed that there is a significant inverse relationship for the geomagnetic activity of the past 36 hours measured in nT, whereby this factor is correlated with many other variables, and the amount of the melatonin derivative 6-hydroxymelatoninsulfate (6-OHMS) in morning urine (Burch JB, 1999). With regard to direct impacts on sleep behavior and well-being caused by, for example, geomagnetic disturbances in buildings, we have individual cases documented in the building biology literature (Maes 2005). The data on potential health impacts caused by building-related static magnetic fields, however, is very unsatisfying. The root cause for the lack of data has to do with the fact that up until now there are no epidemiological studies, which would have selected static magnetic fields as an exposure factor.

Besides using a compass for the measurement of the horizontal deviation from the geomagnetic field, there are also single- and triple-axis probes available that measure the intensity of static magnetic fields based on the fluxgate principle.

Target Aspects

At present, when aiming for the least possible disturbance of the naturally occurring geomagnetic field, it is reasonable to recommend that materials that do disturb the geomagnetic field are avoided in close proximity to the human body including magnetized iron components such as steel trusses, door jambs, heating panels, steel tanks, innersprings in mattresses and loudspeaker boxes.

Static Electric Fields (Electrostatics)

Properties

Electric fields form between positive and negative charges, between which this field is built up as lines of force. The unit is V/m (volt per meter).

Sources

The natural static electricity of the earth is determined by the potential difference between the earth's surface and the electrically charged particles of the atmosphere, measuring about 100 V/m in fair weather. During a thunderstorm, atmospheric electricity can reach more than 10 kV/m. Due to discharges (lightening), the field is reduced again. In buildings, too, high electrostatic fields can build up in dry air. Causes may include the separation of charges due to movement across poor electrically conductive materials such as synthetics. Movements (friction) resulting in separation of charges can be caused by walking with rubber soles on synthetic flooring, rolling plastic office chair castors across synthetic flooring, rubbing with wool pants against a synthetic armchair cover or by warm, dry air rising from a heater and flowing across synthetic drapes. Other sources can be TV displays and old CRT computer monitors.

Effects

When a person becomes charged due to charge separation, he or she will experience a spontaneous discharge as soon as an opportunity conducive to discharge presents itself such as shaking hands with another person or touching a door knob. In some instances such an event may even generate sparks and a painful electric sensation. These electrostatic discharges pose a great risk for electronic devices because they may destroy electronic components. Electrostatic sparks can also cause explosions in air-solvent mixtures. In buildings, high static electricity causes an imbalance in the indoor climate by the decrease of small air ions. In individual cases (Maes 2005), correlations were seen with asthma attacks, concentration problems, stress and headaches. Likewise, epidemiological studies are urgently needed in this field.

Target Aspects

Considering that the natural atmospheric electricity during fair weather is around 100 V/m, surface treatments and materials that tend to have a great potential for charge separation, e.g. poor electrically conductive synthetic materials, should be avoided in indoor environments. In addition, indoor relative humidity should possibly not fall below 35% during winter.

AC Electric Fields – ELF/VLF

Properties of AC Electric Fields

Electric fields form between positive and negative charges, between which this field is built up as lines of force. This field does solely exist because of an electric potential difference, that is, even when no electric current flows. The unit is V/m (volt per meter). The strength of the AC electric field or the density and distribution of the field lines, respectively, are determined by the potential difference and the distance between the high potential terminal (field source) and the low potential terminal as well as their surface. The frequencies below 30 kHz can be divided in the ELF-range (Extremely Low Frequencies) between close to zero Hz and 3 kHz, followed by the VLF-range (Very Low Frequencies) between 3 kHz and 30 kHz.

Sources of AC Electric Fields

Appliance connection cables, extension cords, lamp cords, electric installations, electric devices, especially unshielded devices with flat plugs that are used in close proximity to the body such as heating blankets, desk lamps, electric typewriters and electric calculators as well as walls and floors that spread AC electric fields due to the home wiring installed in them; overhead power lines. Energy saving lamps, electronic controls and dimmer switches can generate AC electric fields in the kHz range. For the power frequency 50 Hz in Europe, typical indoor exposures range from 1 to 20 V/m, in individual cases up to 100 V/m.

Effects of AC Electric Fields

Based on epidemiological studies, in vitro studies and animal experiments, draft recommendations (NCRP 1995) for the US National Council of Radiation Protection were prepared under the leadership of Ross Adey in 1995. Among other things, the draft suggests various policy options how to deal with AC magnetic and electric fields in the frequency range between close to 0 Hz up to 3 kHz. From a total of 4 options, option 2 recommended 0.2 µT (2 mG) as an exposure guideline for the magnetic flux density and 10 V/m for the AC electric field. The report stated with regard to AC electric fields: „Although largely neglected in the emphasis on magnetic field bioeffects, there is also a body of laboratory evidence relating biologically significant effects, particularly in cerebral tissue calcium binding, to ELF electric field exposures in the range 10-100 V/m. Neurobehavioral effects, including a regulatory role in biological rhythms of man and animals, have been attributed to ELF environmental electric fields at intensities in the range 10-100 V/m.“

In contrast to epidemiological research on AC magnetic fields, AC electric field research is so far still in its infancy. Below epidemiological studies for living environments and work spaces are discussed.

Studies on AC Electric Fields and Cancer / Childhood Leukemia

The case-control study (n=140/109) on AC electric fields and childhood leukemia (age 0-10), published by London et al. (1991), found no association for the AC electric fields as measured in the center of the children's bedrooms. Since the AC-electric-field exposure is dominated by local field sources such as wiring in the wall next to the bed, lamp cords and appliance connection cables, measurements taken in the center of a room are of no relevance due to their high potential for exposure misclassifications. For this reason alone, there are no associations to be expected. Thus the study results cannot be utilized.

In a case-control study on childhood leukemia < 15 years (n=56/56) (Coghill et al. 1996), the exposure to AC magnetic and electric fields was measured at the actual sleeping area of the children. The arithmetic mean of AC magnetic fields over 24 hours resulted in 0.07 µT (0.7 mG) for cases in contrast to 0.057 µT (0.57 mG) for controls. The arithmetic mean of the vertical component of the AC electric fields over 12 hours (8:00 pm to 8:00 am) measured 13.9 V/m for cases in contrast to 7.3 V/m for controls. For the statistical risk calculations, the publication cites the relative risk (RR). This method of calculation, however, is reserved for cohort studies. The odds ratio (OR) would be the appropriate method for case-control studies. The publication also missed to include any information on the significance level for the four-stage evaluation. Therefore, the author of this paper (Oberfeld) calculated the respective OR and the significance level of the exposure-effect relationship from the raw data of the publication.

Exposure 8:00 pm - 8:00 am (V/m)	Cases (n)	Controls (n)	OR	95%CI
<5	17	30	1	
5-9	12	13	1.63	0.61-4.36
10-19	14	8	3.09	1.07-8.85
>19	13	5	4.59	1.39-15.09

The analysis shows that with increasing electric field strength the risk also increases and that with $p=0.038$ a significant exposure-effect relationship exists. Exposure values above 10 V/m showed a significantly increased leukemia risk with OR 3.09.

In the McBride et al. (1999) case-control study on childhood leukemia (n=274/331) with ages 0-14 and AC electric fields, a personal exposure meter was used and the 48-hour mean value was used as exposure variable. The publication provides no information on the measurement procedure regarding the physiologically relevant night phase. Since the exposure to AC electric fields is dominated by local field sources such as wiring in the wall next to the head area, appliance connection cables etc., the measurement of AC electric fields is only meaningful if taken directly in the bed. Even if the exposure meter was placed on the bedside table, this would lead to considerable exposure misclassifications and no relationships could be expected. The result is therefore useless.

Like the McBride et al. (1999) study, the Green et al. (1999a) case-control study (n=88/133) on childhood leukemia (ages 0-14) and AC electric fields also used personal

exposure meters. For the exposure variable, the 2-day mean value of the AC electric field without the night phase was chosen. As a result, the most essential information, that is nighttime exposure, is missing and therefore respective risk analyses for the endpoint childhood leukemia are not usable.

Within the framework of the United Kingdom Childhood Cancer Study, Skinner et al. (2002), a case-control study on childhood leukemia (age at diagnosis 0 to 14), Coghill et al. (1996) took measurements of the vertical component of the AC electric field in the bed of the children (pillow and center of bed) as part of a pilot study with limited case numbers. As an OR for acute lymphocytic leukemia, cancer of the central nervous system, all forms of leukemia, other types of cancer and all types of cancer with different case/control numbers, n=273/276 and n=426/419, two sets of results were presented that differ from each other with regard to the quality assurance of the measurement results. The exposure ranges were divided into 0-<10V/m, 10-<20 V/m and ≥20V/m.

In the evaluation group, for which the validity of testing results was checked twice, nine out of the ten calculated OR values were greater than one, indicating a trend towards an increased risk. For the testing results with a lower quality assurance, the ratio was five to five. The factor that might be able to explain this discrepancy is not mentioned in the publication. The time between diagnosis and testing took on average about three years for cases as well as controls. There are no statements or analyses that would show a correspondence between the exposure level detected on the day of testing and the etiologic relevant time period. Moving, changing bedrooms or changing the use of electric devices in close proximity to the bed have a direct impact on exposure levels in the sleeping area, which is why misclassifications of exposure levels may occur, thereby reducing the effect or risk evaluation towards zero. In addition, the OR calculation was based on unevenly distributed exposure tertiles. As a result, not only the exposure gradient is lowered but the statistical power as well. When considering all of these aspects, it is more likely than not that the study results point towards an association.

Studies on AC Electric Fields and Leukemias / Non-Hodgkin's Lymphoma in Adults – Occupational Exposure

In a nested case-control study (matching 1:4) on non-Hodgkin's lymphoma (n=51/203), Villeneuve et al. (2000b) found a significantly increased risk for the job-exposure matrix in relation to AC electric fields (60Hz) in a cohort of male utility workers (Ontario Hydro). For the evaluation, the percentage of time spent above selected threshold field intensities was determined in tertiles. For the exposure index „exposure career" (threshold value 10 V/m), the comparison between the reference tertile (0-<11.19% of the time) and the mean tertile (11.19-15.27%) showed an OR 1.63 (0.56-4.723), and for the third tertile (>15,27%) an OR 3.05 (1.07-8.8). The assessment showed exposure-effect relationships.

In another nested case-control study (matching 1:4) on leukemia (n=50/200) by the same author Villeneuve et al. (2000a), a significantly increased risk for electric-field exposure

(60 Hz) based on a job-exposure matrix could be shown for the same cohort (see above). As in the study above, the evaluation determined the percentage of time spent above selected threshold field intensities in tertiles and took also the exposure duration into consideration. For employees with exposure periods of more than 20 years (threshold value 10 V/m), the comparison with the reference tertile (0-<11.19% time) showed an OR 10.48 (1.20-90.98) for the first 10 years of employment for the mean tertile (11.19-<15.27%) as well as an OR 14.79 (1.76-124.10) for the highest tertile (> 15.27%). The assessment showed exposure-effect relationships.

Target Aspects

When evaluating the effects of alternating electric fields, this is not only about chronic disease such as cancer, but also about sometimes considerable impairments of well-being such as sleep disturbances, reduced performance and vitality, etc. Even though we have no epidemiological studies on the latter, this does not mean that these effects could not or do not occur. Therefore a documentation of individual cases is considered instead. A Swedish commission gathered written statements about personal experiences and health problems associated with electric, magnetic and electromagnetic fields from people who are adversely affected by the exposure to such fields. These documents were published in a report called „Black on White" (Granlund-Lind et al. 2004).

The IARC (2002) has dealt with the issue of human carcinogenity in association with alternating electric fields. It states that there was no data from animal experiments available that would be relevant to carcinogenity with regards to alternating electric fields. For humans there was insufficient evidence concerning carcinogenity and alternating electric fields.
This assessment does not mean that there was no evidence, but rather that at the time of the assessment the available data was insufficient to classify it, for example, as a possible, probable or definite carcinogen.

The ICNIRP Guidelines (1998) are based on reference values for short-term, acute health implications such as irritation of the peripheral nerves and muscles, shocks and burns, which can be caused by the contact with a conductive object as well as increased tissue temperatures, which result from the absorption of energy during EMF exposure. The recommended threshold limit for the exposure of the general public is set at 250/f, covering the frequency range from 25 Hz to 3 kHz. At a frequency of 50 Hz, the formula 250/0.050 kHz results in 5000 V/m. At 60 Hz, 250/0.060 kHz results in 4,166 V/m. At higher frequencies the threshold value decreases.

Based on the information available, it is possible to draft a first preliminary assessment of alternating electric fields. Though not officially issued, the NCRP drafted recommendations for a target value of 10 V/m as one of four policy options based on a thorough investigation of the then most current literature, not least due to Dr. Ross Adey's highly qualified chairmanship of this commission. This recommendation coincides with the exposure guidelines of the Swedish TCO certificate for office equipment such as computer monitors and printers in the frequency range between 5 Hz

and 2 kHz. The TCO exposure limits evolved within the framework of risk reduction based on technical feasibility, and in the meantime they have gained acceptance as a standard worldwide. Two epidemiological studies in employees and one study in children showed significant associations with leukemia or non-Hodgkin's lymphomas at values above 10 V/m. In sleeping areas, isotropic and potential-free measurements of AC electric fields usually show values between 1 and 20 V/m, sometimes even up to 100 V/m. In keeping with the available data on 8-hour daytime or nighttime exposures, the author (Oberfeld) suggests 10 V/m as a preliminary assessment value for areas with continual exposure. In both Canadian studies (Villeneuve et al. 2000a, Villeneuve et al. 2000b), it was observed that time-dependent exposures are associated with adverse effects. As a precaution, therefore, target values for sleeping areas should be set lower, around 1 V/m.

AC Magnetic Fields – ELF/VLF

Properties

AC magnetic fields are generated, among other things, around current-carrying conductors, forming closed circles around it. An actual current flow is necessary for any magnetic field to be formed, whose magnitude depends on the strength of the current but not the voltage. The unit of the magnetic field strength is A/m (ampere per meter), from which the magnetic induction (induction of electric currents and voltages through changing magnetic fields) T (tesla) is derived.

The magnetic field strength decreases with increasing distance whereby the degree of decrease depends on compensation effects, among other things. In single conductor systems, such as net and fault currents, the decrease can be given with $1/r$, in two-conductor systems with ca. $1/r^2$, in transformer coils with ca. $1/r^3$. Magnetic fields permeate almost all materials unimpeded. Field deflections are possible with such materials like highly conductive nickel-iron alloys (mu-metal), transformer sheet metal or combinations thereof (sandwich sheets).

The magnetic field strength or flux density, respectively, is increased or decreased by for example:
- Level of load (current)
- Phase angle
- Spatial configuration (distance) of current-carrying and return current-carrying conductors (compensation effects)
- Net currents along electrically conductive pipes, grounding conductors, across soil, etc.
- Quality of compensation and shielding strategies
- Distance from magnetic field sources

Sources of AC Magnetic Fields

First of all, we need to distinguish between short-range magnetic fields, which only reach a few feet, and far-range magnetic fields, which reach much further. In the following listing the various field sources are roughly sorted according to their field range:

- Small loudspeakers in headsets and phone receivers in close proximity to the human body
- Transformers from e.g. 110 or 230 V clock radio, CD player, radio, typewriters, calculators // electric blankets, heated waterbeds, magnetic field pads // electromotors in tools, kitchen appliances, clocks, aquarium pumps, overhead projectors // electric stove

- Feeder and riser cables in multi-family homes and multi-storey apartment buildings (without fault currents)
- Low-voltage (12V) halogen rope lighting, depending on distance between conductors
- Underground cable
- Overhead feeder cable mounted on the roof, especially when individual conductors are spatially separated
- Individual conductors running through electrical tubing instead of a single electric cable
- Net currents across electrically conductive structures such as water piping, heat piping, district heating piping, gas piping, grounding conductors, computer network cables with shielding that is grounded on both ends, etc. as well as fault currents in circuits with or without ground loops
- Electric railways with and without net currents
- High voltage power lines

This classification according to the field range, that is, the distance where the usual background level is reached, is of great relevance when considering exposures.

Note: In rural areas typical background levels range between about 0.01 and 0.02 µT (0.1 and 0.2 mG) caused by the electrical home wiring system.

The relevance of the magnetic field range results from the probability for long-term exposures. In the case of exposures from far-range sources, this is more relevant because avoidance is often impossible. Apart from obvious sources such as low, medium and high voltage power lines, far-range magnetic fields cannot be recognized by a simple visual inspection even if performed by an expert because ground currents on a gas pipe can only be detected with specific current probes or magnetic field testing equipment. An exception would be an electric railway (16 2/3Hz), which can cause screen interference on CRT display units at levels around several 0.1 µT (1 mG), thereby drawing the user's attention to it. Short-range field sources can lead to extended exposure periods, especially in sleeping areas and at workplaces.

Statistical Distribution of AC Magnetic Fields

Information on the level of magnetic field exposures in residences is urgently needed in order to better evaluate the existing exposure from, for example, the 220-kV Salzburg transmission line and the proposed exposure from the 380-kV Salzburg transmission line.

For Austria, there is no exposure data available as far as the distribution of AC magnetic fields is concerned. In Germany, Schüz et al. (2000) conducted 24-hour measurements of AC magnetic fields as part of the Germany-wide case-control study on the causes of childhood leukemia. The table below shows the distribution of AC magnetic fields (50 Hz) as median of the 24-hour measurements in the children's rooms of n=1314 controls.

Field Distribution	Median	
µT	n	%
< 0.05	1006	76.6
0.05-≤0.1	217	16.5
0.1-<0.15	49	3.7
0.15-<0.2	24	1.8
0.2-<0.3	13	1.0
0.3-<0.4	2	0.2
0.4-<0.5	0	0.0
≥0.5	3	0.2

Table: Statistical distribution of AC magnetic fields (50 Hz) in Germany from various sources as 24-hour median in the children's rooms of n=1314 controls.

When combining the data in the 0-<0.1 µT (0-<1 mG) category, it accounts for 93.1% (n=1223).
When combining the data in the 0-<0.2 µT (0-<2 mG) category, it accounts for 98.6% (n=1296).

Statistical Measurements	µT (mG)
Arithmetic mean	0.040 (0.40)
25th percentile	0.016 (0.16)
Median (50th percentile)	0.027 (0.27)
75th percentile	0.048 (0.48)
95th percentile	0.117 (1.17)
Maximum	0.682 (6.82)

Table: Statistical distribution of AC magnetic fields (50 Hz) in Germany from various sources in the children's rooms of n=1314 controls.

It is really important to keep this distribution in mind, when interpreting epidemiological studies since researchers often work with so-called cut-off values of 0.1 µT (1 mG), 0.2 µT (2 mG), etc. For the given distribution, this calculation approach, among other things, may cause a dilution effect since it mixes lower and higher exposures, resulting in a reduced measure of association towards zero. Furthermore, high cut-off points also result in a reduced statistical power with the consequence that results can be statistically instable. As far as risk assessment is concerned, an alternative approach is the quantile classification into, for instance, quartiles whereby the first quartile would be the reference category, which then would allow us to determine the risk of, for example, a disease in relation to the reference category. From the above values, the resulting reference category (1st quartile) would cover exposures from 0 to 0.016 µT (0.16 mG).

The exposure distribution with regards to AC magnetic fields depends on many factors. Schüz et al. (2000), for example, found that in rural areas of Lower Saxony about 0.9% of the 24-hour medians of the studied control population were above 0.2 µT(2 mG). In West Berlin it was at 3.5% and in East Berlin 10.3%, whereby less than 20% of those values above 0.2 µT (2 mG) could be associated with the proximity to high tension power lines.

AC Magnetic Field Effects

The public discussion on health impacts from electromagnetic fields has one of its roots in the epidemiological studies by Wertheimer and Leeper, investigating the association between the proximity to power lines and the increased incidence of childhood leukemia (Wertheimer and Leeper 1979) or adult cancer (Wertheimer and Leeper 1982) in Colorado, USA. The authors found exposure-effect relationships, which were independent of age, urbanization or socioeconomic status.

The suspicion that leukemia mortality might be associated with occupational exposures to AC electric and magnetic fields was voiced for the first time in the literature in 1982 when Milham (1982) studied male electrical workers, stating that „*The findings suggest that electrical and magnetic fields may cause leukemia.*" These first studies triggered intense research activities in the area of power-frequency magnetic fields, especially for the frequencies 50 Hz and 60 Hz.

Data on Childhood Leukemia and AC Magnetic Fields

The environmental medicine evaluation of all relevant endpoints, which have been studied in the relation of exposures to AC magnetic fields, would go far beyond the scope of this report. Therefore the data on childhood leukemia will be used as an example to show that the current evidence for adverse health impacts, especially from long-term exposures to AC magnetic fields at field strengths as they occur, e.g. in the vicinity of high tension power lines, is sufficiently documented. The association between AC magnetic fields and childhood leukemia in particular was and is the subject of epidemiological research. The following information is taken from Schüz (2002) and applies to Germany, which in contrast to Austria has a childhood cancer registry that meets international standards:

Leukemia is the most frequent cancer in childhood with about 35% from all malignant disorders. In Germany, about 620 children out of 13.2 million below the age of 15 become ill with leukemia every year. This corresponds with an incidence of 4.8 leukemia cases per 100,000 children per year. Today the prognosis of healing is above 80%. For children with an acute lymphocytic leukemia (ALL), which accounts for about 85% of all childhood leukemias, the prognosis is considerably better than for children with acute myelocytic leukemia (AML) for whom the five-year survival rate is still below 60%. AML accounts for the remaining 15% of all childhood leukemias. Only very few children become ill with a chronic or a lymphocytic-myelocytic mixed leukemia.

In a review paper on what roll environmental factors play in the development of leukemias at childhood age, the author (Schüz 2002) summarizes the results from the data of several papers published in various journals as shown in the table below. It becomes obvious that the highest odds ratio with an OR 3.6 (1.5-8.8) is associated with the mother's exposure to pesticides during pregnancy followed by exposures to magnetic fields at night ≥ 0.2 µT(2 mG) with an OR 2.8 (1.4-5.5).

Environmental Factors	OR (95%-CI)[a]	Other Factors	OR (95%-CI)[a]
Use of insecticides at home[b]		Age of mother at birth[f]	
more than 1x per year	1.2 (0.9-1.6)	≥ 35 years	1.1 (0.8-1.5)
Use of pesticides[b]		Smoking of mother (pregnancy)[f]	
in gardening	1.0 (0.8-1.2)	1-10 cigarettes per day	0.8 (0.6-1.1)
in agriculture	1.5 (1.0-2.2)	11-20 cigarettes per day	0.5 (0.3-0.9)
Occupational pesticide exposure[b]		>20 cigarettes per day	1.3 (0.4-4.7)
mother (pregnancy)	3.6 (1.5-8.8)	Smoking of father (prior to pregnancy)[f]	
father (prior to pregnancy)	1.5 (1.1-2.2)	1-10 cigarettes per day	1.1 (0.8-1.5)
Magnetic fields at night[c]		11-20 cigarettes per day	1.0 (0.8-1.2)
≥ 0.2 microtesla	2.8 (1.4-5.5)	>20 cigarettes per day	0.9 (0.7-1.2)
Occupational radiation exposure (ionizing)[d]		Birth weight[f]	
father (prior to pregnancy)	1.2 (0.8-1.7)	<2.5 kg	1.7 (1.1-2.8)
		>4 kg	1.4 (1.0-1.8)
X-rays of mother (pregnancy)[d]		Previous miscarriages[f]	
≥ 1 time	0.9 (0.7-1.4)	≥1 time	1.1 (0.9-1.3)
Occupational Exposures (pregnancy)[e]		Breastfeeding (more than half a year)[g]	
mother with solvents	1.2 (0.9-1.7)	2-6 months	1.2 (0.9-1.5)
mother with paints, varnishes	1.6 (1.1-2.4)	not at all or 1 month	1.2 (0.9-1.6)
mother, metal industry	1.0 (0.6-1.7)		

[a] Odds Ratio and 95% confidence interval; [b] from Meinert et al. (2000); [c] from Schüz et al. (2001a); [d] from Meinert et al. (1999); [e] from Schüz et al. (2000b); [f] from Schüz et al. (1999a); [g] from Schüz et al. (1999b)

Table: Selected results from a national case-control study (1992-2000) on the causes of childhood leukemia (Source: Schüz 2002).

The incidence peak for acute lymphocytic childhood leukemia is found between the age of two and four years. This is referred to as „Childhood Leukemia Peak," which has developed only over the last century. In 1961, Court Brown and Richard Doll (quoted in Milham and Ossiander 2001) relate it as follows: "„ ... *a new leukemogenic agent ...", had been introduced first into Britain in about 1920, and later into the United States and other countries."* This statement is based on the important observation that leukemia mortality in ten-year-olds has increased over the past 50 years since 1911 by 4.5% on average per year. An analysis of the association between leukemia mortality in the age group of 2- to 4-year olds showed a significant association with the degree of electrification of the studied population in the US (Milham und Ossiander 2001). In this publication the authors come to the conclusion that the „childhood leukemia peak" is related to the electrification and that 75% of acute lymphocytic leukemia cases could be avoided.
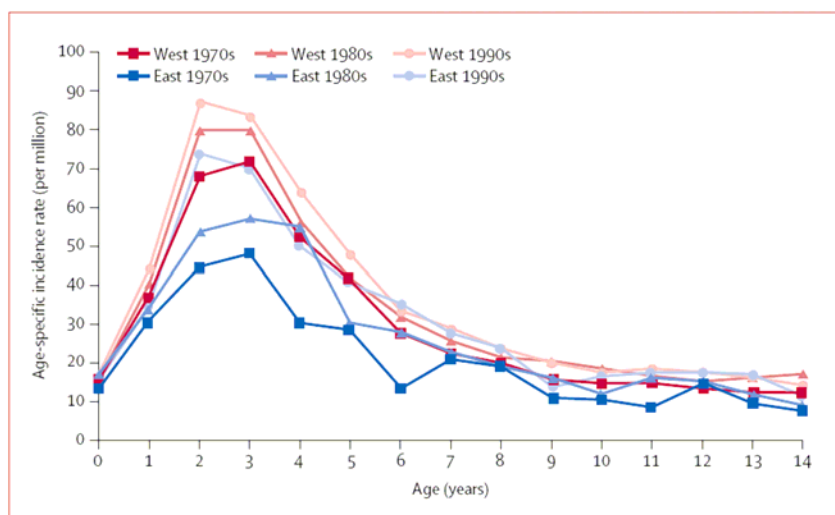
Steliarova-Foucher et al. (2004) published data on cancer incidence trends in children and adolescents across Europe. Data was only taken from cancer registries that met certain data quality standards. The map below shows the percentage of usable data from the participating countries.

Graph: Population coverage of cancer registries in the study for children and adolescents in percent. Source: Steliarova-Foucher et al. (2004).

The graphic below shows the incidence rate for lymphocytic leukemia in the age group 0-14, distinguishing between eastern and western Europe in decades. Two observations can be noted here, on the one hand, we have an increase during the last three decades and, on the other hand, the incidence rate between Eastern (blue line) and Western Europe (red line) is different, with Western Europe having the higher incidence.
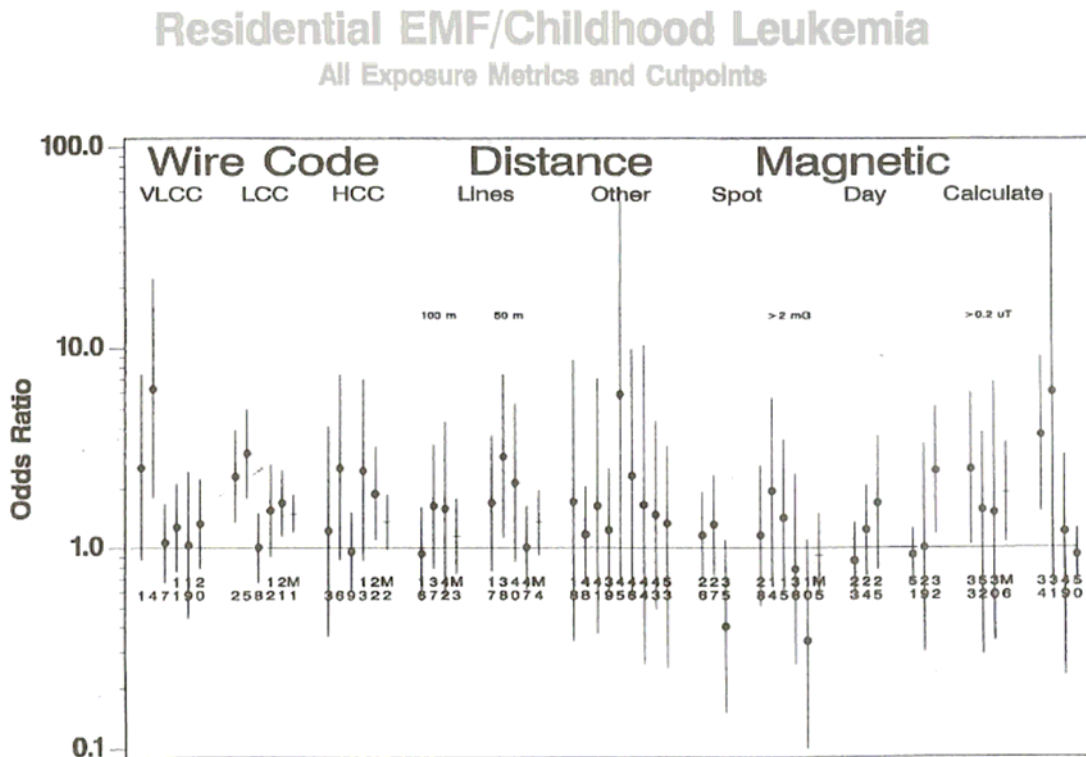

Graphic: Age-specific incidence rates for lymphocytic leukemia in children and adolescents up to 14 years. Source: Steliarova-Foucher et al. (2004).

Regarding the potential association between magnetic field exposure and cancer incidence including leukemia, Milham and Ossiander (2002) quote that since the early 1980s about 100 epidemiological studies were published on employees and about 40 on the general population (NIEHS 1999). Furthermore, they point out that from the about 500 individual risk factors, we have six increased risk factors for each decreased risk factor.

To date, we have one meta-analysis (Wartenberg 1998) and two pooled analyses (Ahlbom et al. 2000, Greenland et al. 2000) for the issue of childhood leukemia and AC magnetic field exposures.

After having reviewed 16 studies on childhood leukemia, Wartenberg comes to the conclusion: „... *the data provide relatively strong and consistent support for a somewhat weak elevated risk of leukemia for children living in proximity to power lines.*"

The graphic below shows the distribution of risk ratios given as odds ratio (OR). An OR value above 1.0 means an increased risk, an OR value <1.0 a reduced risk. An OR value of 1.6, for example, translates into an increased risk by the factor 1.6 or 60%. From the graphic below it becomes clear that the majority of the OR values is above 1.0. The analysis also shows the wide confidence intervals for many, though not all, of the studies, which include the value 1.

Graphic: Results of the analysis of the individual studies on the association between electric as well as magnetic fields and cancer in children and the selected meta-analysis. Source: Wartenberg (1998).

The pooled analysis by Ahlbom et al. (2000) evaluated nine case-control studies (n=3203/10338) on childhood leukemia and AC magnetic fields. Adjusting for age and gender, a significantly increased OR value 2.00 (1.27-3.13) was found for the exposure class >0.4 µT (4 mG) with the reference category <0.1 µT (1 mG) (see table, last line „All studies"). The analysis of acute lymphocytic leukemia adjusted for age, gender and traffic exhausts showed an increased OR value 3.24 (1.22-8.63) for the exposure class >0.4 µT (4 mG).

Type of study	0.1–< 0.2 µT	0.2–<0.4 µT	≥ 0.4 µT	O	E	Continuous analysis
Measurement studies						
Canada	1.29 (0.84–1.99)	1.39 (0.78–2.48)	1.55 (0.65–3.68)	13	10.3	1.21 (0.96–1.52)
Germany	1.24 (0.58–2.64)	1.67 (0.48–5.83)	2.00 (0.26–15.17)	2	0.9	1.31 (0.76–2.26)
New Zealand	0.67 (0.20–2.20)	4 cases/0 ctrls	0 cases/0 ctrls	0	0	1.36 (0.40–4.61)
UK	0.84 (0.57–1.24)	0.98 (0.50–1.93)	1.00 (0.30–3.37)	4	4.4	0.93 (0.69–1.25)
USA	1.11 (0.81–1.53)	1.01 (0.65–1.57)	3.44 (1.24–9.54)	17	4.7	1.30 (1.01–1.67)
Calculated fields studies						
Denmark	2.68 (0.24–30.45)	0 cases/8 ctrls	2 cases/0 ctrls	2	0	1.50 (0.85–2.65)
Finland	0 cases/19 ctrls	4.11 (0.48–35.1)	6.21 (0.68–56.9)	1	0.2	1.15 (0.79–1.66)
Norway	1.75 (0.65–4.72)	1.06 (0.21–5.22)	0 cases/10 ctrls	0	2.7	0.78 (0.50–1.23)
Sweden	1.75 (0.48–6.37)	0.57 (0.07–4.65)	3.74 (1.23–11.37)	5	1.5	1.31 (0.98–1.73)
Summary						
Measurement studies	1.05 (0.86–1.28)	1.15 (0.85–1.54)	1.87 (1.10–3.18)	36	20.1	1.17 (1.02–1.34)
Calculated fields studies	1.58 (0.77–3.25)	0.79 (0.27–2.28)	2.13 (0.93–4.88)	8	4.4	1.11 (0.94–1.30)
All studies	1.08 (0.89–1.31)	1.11 (0.84–1.47)	2.00 (1.27–3.13)	44	24.2	1.15 (1.04–1.27)

Table: Analysis for individual studies and the pooled analysis, all leukemias.
Source: Ahlbom et al. (2000).

In a pooled analysis, Greenland et al. (2000) evaluated among others eleven case-control studies (n=2078/5516) with data on childhood leukemia and AC magnetic fields. Adjusted for age, gender, social and economic variables, the OR 2.06 (1.4-3.01) was calculated to be significantly higher for the exposure group >0.3 µT(3 mG) based on a reference category of <0.1 µT(1 mG). Thus the results of the two analyses, based on partly overlapping studies, are in agreement.

In addition, the case-control study by Draper et al. (2005) is the single largest study published to date with the endpoints leukemia (n=9700/9700), central nervous system/brain tumor (n=6605/6605) and other cancer diagnoses (n=12776/12776) in children (age: 0-14 years) regarding their association with the distance to 275-kV and 400-kV power lines as well as a small portion of 132-kV power lines in England and Wales (total length of power lines ca. 7,000 km). The group of children with the distance >600 m was classified as reference group and compared to the exposure levels at distances of 0-49 m, 50-69 m, 70-99 m, 100-199 m, and 200-599 m. For all groups of distances, the risk ratio was above 1.0 with a significant exposure-effect association of p for the trend <0.01. The adjusting for the socio-economic status did not change the risk ratios.

Distance, d (metres)	$1/d$	RR (95% CI)
0-49	0.040	1.67 (0.40 to 6.97)
50-69	0.017	1.51 (0.48 to 4.79)
70-99	0.012	2.02 (0.76 to 5.39)
100-199	0.007	1.64 (1.00 to 2.71)
0-199	0.010	1.69 (1.13 to 2.53)
200-599	0.003	1.23 (1.02 to 1.49)
≥600 (reference group)	0.000	1.00

Table: RR unadjusted for various distances from the high tension power lines,
(Draper et al. 2005).

A case-control study (n=251/495) from Japan (Kabuto et al. 2006) showed a significantly increased risk OR=4.67 (1.15-19.0) for acute lymphocytic leukemia in children ages 0-15 and exposure to AC magnetic fields, measured as weekly mean values in the children's bedrooms with magnetic field levels above 0.4 µT (4 mG) compared to the reference category of 0.1 µT (1 mG). The result proved to be rather stable even when adjusted for covariables or maximized for selection bias.

In a prospect cohort study, Foliart et al. (2006) examined the survival rate (5.07 years median follow-up) in 361 children with acute lymphocytic (B-cell) leukemia, ages 0-15, in the US. During this period, 28 children died, most of them through a relapse. Within the first months after the initial diagnosis, personal 24-h magnetic field measurements were obtained. Though only this first series of measurements could be consulted for evaluation purposes (The participation rate for follow-up measurements one and two years later was too low.), children with exposure levels above 0.3 µT (3 mG), who died, showed an HR (hazard ratio) of 4.53 (1.49-13.76) compared with the reference category 0.1 µT (1 mG). Even if this study can be viewed only as hypothesis generating and further studies are needed, it does fit in with the existing picture.

Especially in the area of epidemiological investigations, the qualification and quantification of (historical) exposures poses one of the greatest challenges. At the beginning of studying magnetic field exposures from high tension power lines, for example, investigators tried to determine the exposure levels by calculating the field strengths from wire codes. This method, however, has the disadvantage that other field sources, which can also contribute to elevated magnetic fields, are not captured, causing exposure misclassifications (in this case so-called non-differential exposure misclassification). This can result in a dilution effect, which can even go so far that no effect will be discovered. Later investigators tried to determine magnetic field levels by taking so-called spot measurements, for example, in the living room, bedroom or in front of the entrance door. The disadvantage of this method is that those measurements can also result in exposure misclassifications due to the usual, sometimes rather strong fluctuations of the magnetic field strengths associated with high tension power lines, underground cables, net currents, transformers and distribution cables (e.g. night storage heating).

Thus it is more suitable to study a smaller, well-defined sample than a large group with poor exposure analysis. But even person-related, 24-hour data logging of exposures has its drawbacks because in general current measurements do not necessarily have to coincide with past exposure levels, which is why in the latter case region-specific wire codes, as long as all relevant power lines are accounted for, can have advantages. In this context, it is crucial for the quality of epidemiological studies that exposures in the etiologically relevant period are documented as accurately as possible and that cases/controls with incomplete exposure analysis are either removed from risk calculations or at least adjusted for. Since not all studies have been adjusted this way, the interpretation of results needs to take this into consideration.

The distinction between daytime and nighttime exposures as well as their separate analysis is also very important. At a threshold value of 0.2 µT (2 mG), Michaelis et al. (1997b) could show a significant risk increase for childhood leukemia from OR 2.3 (0.8-6.7) to OR 3.8 (1.2-11.9) when assessing the measurements of the nighttime period. By limiting the assessment to the age group 0 to 4 years, the risk increased to OR 7.4 (1.4-38.4). When interpreting study results, these aspects need to be taken into consideration because they can often cause the risk ratio to be moved towards zero and existing associations will not become visible. In general, the actual risks are almost always and often significantly higher than can be captured through epidemiological studies.

It is the goal of epidemiological studies to determine so-called exposure-effect associations. Usually this is accomplished by dividing the sample under study into different exposure categories, so-called quantiles such as tertile (three categories), quartile (four categories) or quintile (five categories), etc. The first quantile is the reference group (category with the lowest exposure). Furthermore, in comparison with the reference group, the so-called relative risk (RR) or odds ratio (OR) is calculated for the various exposure categories - either unadjusted or adjusted for various covariants (e.g. age, gender, suspected other risk factors, etc.).

In this calculation, the reference group is assigned the value 1 for RR or OR. If, for example, the 2nd quantile showed an RR/OR of 2.1, this would mean that the statistical mean for all n from the second quantile showed a 2.1 times (given as factor) higher risk/odds ratio for the disease under study (e.g. childhood leukemia) compared to the reference quantile.
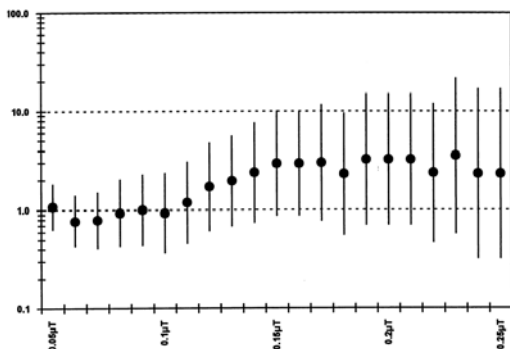
Instead of using quantiles, various investigations, studying the association between magnetic fields and the endpoint cancer, applied a so-called cut-off point or fixed classification (e.g. 0 – 0.1µT (1 mG)) as reference group versus 0.1-0.2 µT (2 mG) as well as 0.2–0.4 µT (4 mG), >0.4 µT (4 mG). With a cut-off point, the risk ratio/odds ratio of a group below a certain exposure threshold is compared to a group with exposures above this threshold (e.g. 0.2 µT (2 mG)). The meaningfulness of this assessment method is rather difficult to interpret when the distribution of the exposure levels in both groups is unknown.

The application of a fixed classification, especially when limited to this method, prevents any further gain of knowledge because it virtually prevents the analysis of the low-exposure category, to which the largest portion of the population is exposed. Since in most cases the exposure category 0 to 0.1 µT (1 mG) comprises about 95% of the samples, the statistical power is also greatly diminished. In summary, the combination of these classification and calculation methods may result in shifting the risk ratio towards zero. In the area of epidemiology and environmental epidemiology, the statistical assessment by means of quantiles is the methodically correct procedure. And for comparability purposes, the additional assessment of fixed classifications will be helpful, however, at a much lower and therefore reality-related level such as the following categories 0-0.02 µT (0.2 mG), 0.021-0.05 µT (0.21-0.5 mG), 0.051-0.1 µT (0.51-1 mG), >0.1 µT (1 mG)).

The following three examples are meant to demonstrate that ensuring a low-exposure group as reference group is one of the crucial points in a statistical assessment.

Example 1

The evaluation of the case-control study on childhood leukemia (Michaelis et al.1997a) (n=129/328) for children at the age of less than 14 years showed an OR 3.9 (0.9 – 16.9) with a cut-off point of 0.2 µT (2 mG) - determined as a median value of the AC magnetic field in the children's bedroom at night. In addition, the odds ratios were calculated in increments of 0.01 µT (0.1 mG) for the median of the 24-hour exposure value from 0.05 µT (0.5 mG) to 0.25 µT (2.5 mG) in the children's bedroom. The graphic below shows that a risk increase can be observed at values starting from 0.1 µT (1 mG). At the same time it is noted that this evaluation must not be compared with an exposure-effect curve, which for instance would result from contrasting quartiles. Data for the 25th percentile are not provided in the publication, however, the 24-hour median (50th percentile) is given as 0.025 µT (0.25 mG)! This kind of contrasting was not applied even though it would have been the statistical analysis method of choice. The cut-off point method divides the data into two categories, resulting in an underestimation and blurring of actual risk factors.

Graphic: Function of the odds ratio for the comparison of childhood leukemia cases and controls based on the 24-h median with cut-off points from 0.05 µT (50 nT/0.5 mG) to 0.25µT (250 nT/0.25 mG) in increments of 0.01 µT (10 nT/0.1 mG).
Source: Michaelis et al. (1997a).

Example 2

In a Canadian case-control study (Green et al. 1999a) (n=88/131) on childhood leukemia, magnetic field exposures were measured with personal exposure meters. In the group of those children under the age of six, a significant association in the form of an exposure-effect curve was found. With exposure levels as 24-h mean values, an increased risk was found at an OR 4.0 (1.1-14.4) for exposures from 0.07 µT (0.7 mG) to 0.14 µT (1.4 mG) as well as at an OR 4.5 (1.3-15.9) for exposures from 0.14 µT (1.4 mG). This is one of the few studies that did perform a quartile analysis, showing that significantly increased risks can already be observed below 0.1 µT (1 mG).

Exposure (24-h mean value) µT (mG)	Cases n	Controls n	OR	95%CI
<0.03 (0.3)	14	33	1	
0.03-0.07 (0.3-0.7)	18	32	2.0	0.6-6.8
0.07-0.14 (0.7-1.4)	27	33	4.0	1.1-14.4
>0.14 (1.4)	29	33	4.5	1.3-15.9

Table: Risk for childhood leukemia in relation to the 24-h mean value – quartile analysis

Example 3

With the EMF Study II from Germany, we have a case-control study (n=690/1717) on AC magnetic fields (50 Hz) and childhood leukemia, which was the most comprehensive single study until its publication in 2001 (Schüz et al. 2001). Unfortunately, as many as 625 out of 690 cases were accumulated into the reference category – with possibly serious consequences for the results. Yet, the analysis for the nighttime period (median 22:00 – 6:00 o'clock) shows a significant association in form of an exposure-effect relationship across four exposure categories.

	<0.1 µT (100 nT)	0.1-<0.2 µT (100-200 nT)	0.2-<0.4 µT (200-400 nT)	>=0.4 µT (400 nT)
Cases (n)	625	44	14	7
OR_a	1.00	1.33 (0.9-1.97)	2.40 (1.07-5.37)	4.28 (1.25-14.7)

Assessments by Expert Committees

As already mentioned above in the discussion on AC electric fields, the draft report by the US National Council on Radiation Protection (NCRP) recommends under „option 2" exposure limits of 0.2 µT (2 mG) for magnetic flux densities in the frequency range from close to 0 Hz up to 3 kHz (NCRP 1995). For future planning, the draft report also recommends that preschools and schools should not be built in zones with magnetic flux density levels above 0.2 µT (2 mG) or that the installation of new power lines next to existing buildings should not raise the magnetic flux density levels above 0.2 µT (2 mG). In the case of new office buildings or industrial facilities, exposures should remain below 0.2 µT (2 mG).

The ICNIRP Guidelines (ICNIRP 1998) are based on short-term, acute health effects such as the stimulation of peripheral nerves and muscles, shocks and burns, which are

caused by contact with electrically conductive objects as well as increased temperatures of tissue, which result from energy absorption during EMF exposure. For the frequency range from 25 Hz to 800 MHz, the recommended reference value for the AC-magnetic-field exposure of the general public is set at 5/f. At f=50 Hz, the formula gives 5/0.050kHz=100 µT (1000 mG). At f=60 Hz 5/0.060kHz=83 µT (830 mG). At higher frequencies, the threshold value decreases.

In 1999 the US National Institute of Environmental Health Sciences (NIEHS 1999) published a report on the health effects of power-frequency electric and magnetic fields. In this publication the research group comes to the conclusion that the exposure to „Powerline Frequency ELF-EMF" may represent a possible carcinogen. The following relevant recommendations are made: *"NIEHS suggests that the power industry continue its current practice of siting power lines to reduce exposures and continue to explore ways to reduce the creation of magnetic fields around transmission and distribution lines without creating new hazards. We also encourage technologies that lower exposures from neighbourhood distribution lines provided that they do not increase other risks, such as those from accidental electrocution or fire."*

In June 2001, the International Agency for Research on Cancer (IARC), a member organization of the WHO with its headquarters in Lyon, brought together a working group of science experts to scrutinize studies on carcinogenity with regard to static and ELF electric and magnetic fields (IARC 2002). Based on the standard classification of the IARC, which evaluates evidence from humans and animals as well as laboratory experiments, ELF magnetic fields were classified as possibly carcinogenic for humans (Group 2B) due to the epidemiological studies on childhood leukemia.

From 1993 to 2002, the California Department of Health ran the "California EMF-Program" in order to evaluate the potential risks caused by electric and magnetic field emissions from power lines, electrical installations, electric workplaces and appliances (CDH 2002). The final report, published in fall 2002, lists comprehensive scientific data on health effects including a risk assessment. The table below shows the assessment results from the California Department of Health (DHS).

Health Endpoint	Classification	Risk
Childhood Leukemia	2B to 1	Possible to Definite
Adult Leukemia	2B to 1	Possible to Definite
Adult Brain Cancer	2B	Possible
Miscarriage	2B	Possible
Lou Gherig's Disease or ALS	2B	Possible
Childhood Brain Cancer, Breast Cancer, Alzheimer's, Suicide, Sudden Cardiac Death	3	Inadequate

Further Relevant Data on Health Effects

For the evaluation of carcinogenic effects of alternating magnetic fields, the work published by a group at the University of Veterinary Medicine Hannover (Fedrowitz et al. 2004) is highly relevant. These researchers were able to clarify why animal experiments by the Löscher group, in which DMBA (7,12-dimethylbenz(a)anthracene) was used to induce tumors in female rats, showed significant increases in breast cancer risk with the additional exposure to alternating magnetic fields (Baum et al. 1995, Mevissen et al. 1998, Thun-Battersby et al. 1999), but not by another workgroup around Anderson (Anderson et al. 1999, Boorman et al. 1999a, Boorman et al. 1999b, Anderson et al. 2000). It could be demonstrated that the different responses correlate with the genetically different sensitivity of the rats used. In an additional study (Fedrowitz und Löscher 2006), which looked at a variety of rat species, this knowledge could be expanded and confirmed.

Up until recently, the differing results of these animal studies were considered to be uncertain and therefore were not consulted for evaluations. Since these uncertainties could be clarified, the results of these animal studies gain a totally new level of significance. In connection with the animal studies showing chromosomal damage (Lai und Singh 2004), discussed in the paragraph below, it seems appropriate to classify alternating magnetic fields as a definite carcinogen for humans.

In 2004, a study showed (Lai und Singh 2004) significantly increased DNA breakage in rat brain cells that had been exposed to AC magnetic fields at 10 µT (100 mG) and 60 Hz sine wave for 24 hours. The doubling of the exposure period to 48 hours showed even stronger effects, suggesting a cumulative effect. In a second investigation, the possible effect mechanism was studied. For that reason, rats were exposed to AC magnetic fields at 500 µT (5,000 mG) for two hours. Rats that had received Trolox (vitamin E analogue), 7-nitroindazole (inhibitor of nitric oxide synthase synthesis) or Deferiprone (iron chelate) prior to the magnetic field exposure did not show any chromosome damage. The authors (Lai und Singh 2004) hypothesize that an acute exposure to AC magnetic fields initiates an iron-mediated process (e.g. fenton reaction) that directly causes the formation of free radicals as well as indirectly via a metabolic cascade and the nitrogen monoxide (NO).

In the past years, reactive oxygen species (ROS) and reactive nitrogen species (RNS), which both are referred to as „free radicals" in this paper, gained recognition as one of the central pathophysiological mechanisms for the origin and development of chronic diseases as well as cancer. Free radicals are highly reactive metabolic products, which are produced endogenously (mitochondria, cytochrome P450, macrophages, peroxisomes) and exogenously (iron and copper via fenton reaction, ionizing radiation), constantly being kept in balance by antioxidant regulating mechanisms. When antioxidant control mechanisms become exhausted or overwhelmed, the cellular redox balance will shift towards oxidative stress, resulting in an increased potential of damage to the DNA in the nucleus, to the DNA in the mitochondria, to lipids and proteins. Unrepaired damage of the DNA can result in mutations and further down the road to an increased cancer risk. Apart from the direct damage of nuclear and mitochondrial DNA, interactions with DNA

repair mechanisms can also lead to oxidative damage. Furthermore, free radicals impact cell signaling paths for the control of cellular growths and thus can also impact the development of cancer. The modification of the gene expression initiated by free radicals has a direct effect on cell division and cell self-destruction (apoptosis). DNA damage, mutations, and altered gene expressions are all steps in the process of cancer development (Touyz 2004, Young and Woodside 2001, Klauning and Kamendulis 2004).

With regard to cancer-suppressing effects, melatonin (N-acetyl-5-methoxytryptamine) with its diversity of functions plays an important role. Among other things, melatonin is a neurohormone that is produced by the pineal gland during darkness. It holds an important role in numerous physiological and pathophysiological processes such as the regulation of the circadian rhythm as well as antioxidative and immunomodulating functions. Melatonin suppresses cancer processes in, for example, breast cancer, prostate cancer, ovarian cancer, skin cancer, leukemia and liver cancer (Buyukavci et al. 2006, Henshaw and Reiter 2005, Blask et al. 1999).

There is sufficient, conclusive and integral evidence from in vitro experiments (Ahuja et al. 1999, Ivancsits et al. 2002, Ivancsits et al. 2003, Ivancsits et al. 2005, Winker 2005, Moretti et al. 2005, Wolf et al. 2005) and animal experiments (Beniashvili et al. 1991, Lai and Singh 1997a, Lai and Singh 1997b, Mevissen et al. 1998, Thun-Battersby et al. 1999, Svedenstal et al. 1999, Lai and Singh 2004, Fedrowitz et al. 2004, Fedrowitz and Löscher 2006) that alternating magnetic fields can lead, among other effects, to DNA damage through free radicals, partly in connection with melatonin (reviews see Simko and Mattson 2004, Henshaw and Reiter 2005). Some of these studies could demonstrate exposure-specific associations.

Likewise, there is evidence that alternating magnetic fields can suppress the effect of tamoxifen (breast cancer drug) in breast cancer cells (Blackman et al. 2001, Ishido et al. 2001, Girgert et al. 2005).

Epidemiological studies show that, among other factors, exposure to alternating magnetic fields can increase the risk of certain forms of cancer and neurodegenerative diseases (reviews see Stevens und Davis 1996, Erren 2001, IARC 2001, CDH 2001, Henshaw and Reiter 2005).

Up until recently, the exposure levels of alternating magnetic fields were usually determined as a mean value. Results from California, which were published in 2000, showed for the first time an association between miscarriages and the ascertained maximum value. The two epidemiological studies, a case-control study (Lee et al. 2002) and a prospective cohort study (Li et al. 2002) showed a significant association between the incidence of miscarriages during the first 20 weeks of pregnancy and the level of alternating magnetic fields (60 Hz), measured with a personal monitor for 24 hours. The evaluations were based on the measured peak values in the range of 1.6 µT (16 mG) and above, but not calculated mean values. The 25th percentile was 1.6 µT (16 mG), which means that 75% of the women were exposed to magnetic field peak values from 1.6 µT (16 mG) and up. 40% of all miscarriages were associated with magnetic fields > 1.6 µT

(16 mG). When approximating these numbers for Austria, that would translate into ca. 5,800 miscarriages per year. For comparison, Austria mourns ca. 1,000 road victims per year.

Target Aspects

In a large number of studies, epidemiological researchers could observe a risk increase in connection with increased exposure levels. Bias, confounding or coincidence cannot plausibly explain this risk pattern, which was found in various studies with different populations. Now epidemiological evidence is also supported by evidence of DNA damage in in vitro and in vivo studies as well as by the DMBA model of breast cancer in rats. The currently available effect evidence shows, among others, an increased leukemia risk at values of 0.2 µT (2 mG) and 0.3 µT (3 mG), and in some studies even below this exposure level. As a first approach, the author (Oberfeld) therefore suggests limiting the total exposure from alternating magnetic fields to 0.1 µT (1 mG) with regard to a sliding 8-hour mean value. The latter shall apply particularly to places where we spend substantial amounts of our time such as periods of sleep and work.

There is always the possibility that a specific location is exposed from a variety of external magnetic field sources, which are difficult to control or not at all such as high tension power lines, distribution power lines, ring mains, etc. As a result, it appears to be rather unrealistic to assign the total exposure value to only one field source. For all practical purposes, it is therefore recommended to follow a realistic and pragmatic four-pronged approach. Then 0.05 µT(50 nT/0.5 mG) can be assigned to the specific exposure of each of any four field sources.

Owing to the quadratic addition of magnetic flux densities, it is possible to simultaneously have four sources with 50 nT (0.5 mG) each, thereby taking full advantage of the total immission value of 100 nT (1 mG). The following table illustrates this point:

Immission Field Source 1	Immission Field Source 2	Immission Field Source 3	Immission Field Source 4
0.05 µT (0.5 mG)	0.05 µT (0.5 mG)	0.05 µT (0.5 mG)	0.05 µT (0.5 mG)
Sum 1+2 = 0.071 µT (0.71 mG)			
Sum 1+2+3 = 0.087 µT (0.87 mG)			
Sum 1+2+3+4 = 0.1 µT (1 mG)			

Exposure guidelines as recommended by the ICNIRP, which are based exclusively on stimulation effects and do not include by now proven long-term effects, are unable to ensure the expected and required protection of personal and public health. Even such precautionary considerations, which in 1999 resulted in the Swiss exposure limit of 1 µT (10 mG), are out-dated because the value was derived by simply reducing the ICNIRP exposure limit of 100 µT (1,000 mG) by a factor of 1/100, without consulting the existing data that in the meantime has reached the level of „substantial body of evidence".

Therefore, according to the currently available scientific evidence for long-term effects, evaluations by the ICNIRP guideline of 100 µT or the Swiss exposure limit of 1 µT (10 mG) are completely irrelevant. A medical evaluation, which ignores this evidence, does not evaluate according to the currently available medical knowledge.

At this point it is important to note that the conclusion of a possible, probable or definite causal association between cause and effect does not require a complete model of the cause-and-effect mechanism.

Future investigations should also take transients and harmonics into consideration. This could lead to a different, that is, stronger evaluation.

Electromagnetic Waves – Radiofrequency Radiation (RF) and Microwave Radiation (MW)

Properties

In contrast to ELF electromagnetic fields, the electric and magnetic field become coupled in the case of electromagnetic waves: the electric field causes the magnetic one and vice versa. The resulting electromagnetic waves wirelessly propagate through space, adopting increasingly quasioptical properties from the MHz range and up. These include, for example, reflection on conductive surfaces or refraction at edges. For this reason, these radiofrequency waves are used for the transmission of information (data). They can be transmitted from an antenna and at another location they can again be received with an antennae. The information can be „ imprinted on" a carrier wave through various types of modulations such as by changing the frequency, amplitude, or phase.

Frequencies above 30 kHz are generally referred to as high frequency or RF radiation. In North American language usage, „radiofrequency radiation" (30 kHz to 300 MHz) is distinguished from „microwave radiation" (300 MHz to 300 GHz).

At present, mobile phone base stations in Europe usually transmit GSM signals in the 920-960 MHz and 1805-1880 MHz bands as well as UMTS-FDD signals in the 2110-2170 MHz bands. In North America, GSM signals are transmitted in the 820 - 890 MHz and 1850 -1990 MHz bands as well as UMTS signals in the 1750 MHz and 2150 MHz bands.

Sources

Transmitters such as broadcasting, television, mobile phone base stations for GSM, UMTS, etc, mobile phone handsets, cordless phones (CT1, DECT/GAP), trunked radio systems (TETRA, Tetrapol), digital data communications, Bluetooth, wireless local area networks (WLAN), radar stations, directional radio systems, microwave ovens, baby monitors and cameras, wireless keyboards and ordering systems, high-speed computers.

Effects

In the following discussion about biological and health effects, we will present and discuss epidemiological findings of mobile phone networks because they allow for an immediate insight into occurring symptoms. They will be supported by results from exposure studies of radar and radio stations.

Even though the exposure from a mobile phone handset is considerably higher than from mobile phone base stations, at present the more severe effects are observed in the latter. The main reason for this observation is most likely to be found in the longer exposure

duration and a missing opportunity for the organism to regenerate. It is, for example, possible to spend several hours at 95 dB in a nightclub, but for restorative sleep a continuous sound level of around 35 dB or lower is necessary. At any rate, the difference is 60 dB, which translates into a factor of 1,000,000!

Studies about the health effects of electromagnetic waves go back to the 40s in the 20th century. Those studies were mainly concerned with high-dosage exposures and the question of excessive heating of a body or the development of cataracts, for example, in radar exposed persons. For this purpose various animal experiments were carried out, which showed cataracts at increasingly lower dosages provided that the lenses were not analyzed right after the radiation exposure, but only after a waiting period of several weeks (source: Richardson 1948, quoted in Becker 1990). Even at that time, non-thermal effects were already discussed in connection with the development of cataracts.

In 1959, a new physical method for the production of chromosomal damage was presented in the journal Nature (Heller and Teixeira-Pinto 1959). The authors used pulsed shortwaves with a frequency of 27 MHz, exposing garlic root cells, growing in a bowl of water, to this field for 5 minutes. No temperature increase could be measured in the water. The analysis was performed 24 hours after the radiation exposure. The highest number of chromosomal breaks occurred at pulse rates between 80 and 180 pulses per second.

In a review paper about the effects of electromagnetic waves (Sage 2000), evidence is presented for the following areas: effects on DNA, chromosome aberration and micronuclei, effects on ornithine decarboxylase (ODC), gene transcription and induction, stress response (heat shock proteins), cellular effects of microwave radiation (calcium ions), immune system cellular effects, blood-brain barrier, blood pressure, reproductive tract, cancer, symptoms reported using mobile phones, neurological effects, psychoactive drugs, serotonin, eye damage, behavioral changes, learning and memory, cognitive functions, and sleep.

Based on the available literature on electromagnetic waves, Neil Cherry comes to the conclusion that electromagnetic radiation from, for example, mobile phone base stations constitutes a probable risk factor for the following diseases: cancer, especially brain tumors and leukemia but also all other types of cancer, heart arrhythmia, cardiac infarcts, neurological effects including sleep disturbances, learning disabilities, depression, and suicide, miscarriages, and malformations (Cherry 2000).

Studies on Mobile Phone Base Stations

With regard to an association between mobile phone base stations and direct health effects, there are worldwide four epidemiological studies as well as one experimental short-term exposure study, all of which follow different publication standards.

1) In France, a questionnaire, listing 16 non-specific disease symptoms, was sent to 530 persons, who had responded to an appeal for participation (Santini et al. 2002). In this

study, Santini used self-selection. Thus it can be assumed that the persons responding to the survey were those who are more likely to suspect negative health effects from mobile phone base stations. This implies the disadvantage that the study results cannot be extrapolated to the general population. Yet it offers the advantage that potential effects can be detected earlier. In an opposite approach, one would select only healthy young adults, who must not show any negative health effects from mobile phone base stations.

The study showed that the number of non-specific symptoms increased as the self-determined distance from mobile phone base stations decreased. In the symptom category „very frequently,“ a significant increase in such symptoms as fatigue, irritability, headaches, sleep disruptions, depressive tendencies, concentration difficulties, memory loss, and dizziness could be observed in comparison to the reference group (> 300 m distance). The table and graph further below illustrate this clearly.

The increase of symptom incidence in the distance group 50-100 m corresponds with the equally frequent field-strength maximum in those particular urban areas. Thus, it could be shown that these health complaints have a physical cause, namely electromagnetic radiation from mobile phone base stations.
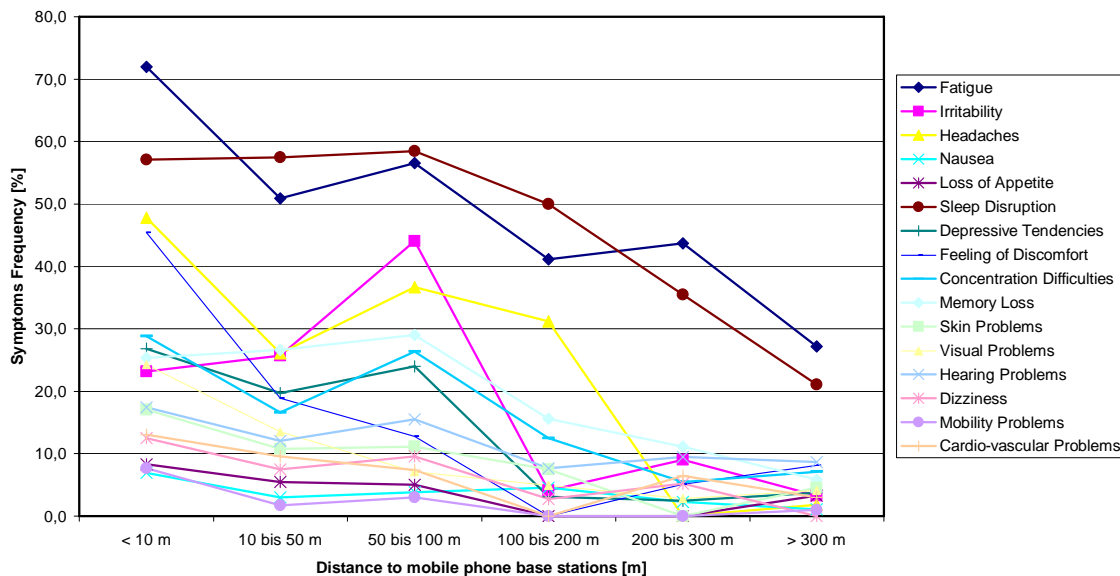
Symptoms	Distance to Mobile Phone Base Station in meter (m)					
	< 10 m	10-50 m	50-100 m	100-200 m	200-300 m	>300 m
Fatigue	72*	50.9*	56.6*	41.1	43.7	27.2
Irritability	23.2*	25.7*	44.1*	4.1	9	3.3
Headaches	47.8*	26.1*	36.7*	31.2*	0	1.8
Nausea	6.9	3	3.8	4.6	2.3	1.1
Loss of Appetite	8.3	5.5	5	0	0	3.3
Sleep Disruption	57*	57.5*	58.5*	50*	35.5	21.1
Depressive Tendencies	26.8*	19.7*	24*	3.1	2.5	3.7
Feeling of Discomfort	45.4*	18.9	12.8	0	5.1	8.1
Concentration Difficulties	28.8*	16.6	26.4*	12.5	5.5	7.1
Memory Loss	25.4*	26.6*	29*	15.6	11.1	5.8
Skin Problems	17.1*	10.8	11.1	7.5	0	4.6
Visual Problems	24.3*	13.5	7.1	4.9	2.8	4.1
Hearing Problems	17.4	12	15.5	7.7	9.5	8.7
Dizziness	12.5*	7.5*	9.6*	2.7	5.2	0
Mobility Problems	7.7*	1.7	3	0	0	1
Cardio-vascular Problems	13*	9.6	7.4	0	6.5	3

*) Significant difference (p < 0.05) in comparison to reference group > 300 m or non-exposed for the symptom category „very frequently“

Table: Incidence (%) of Complaints by Respondents (n=530) Living in the Vicinity of Mobile Phone Base Stations as a Function of Distance

Symptoms experienced by people in the vicinity of cellular phone base stations
By R. SANTINI & coll. December 2001
Symptoms (category=very frequent) related to the distance to mobil phone base
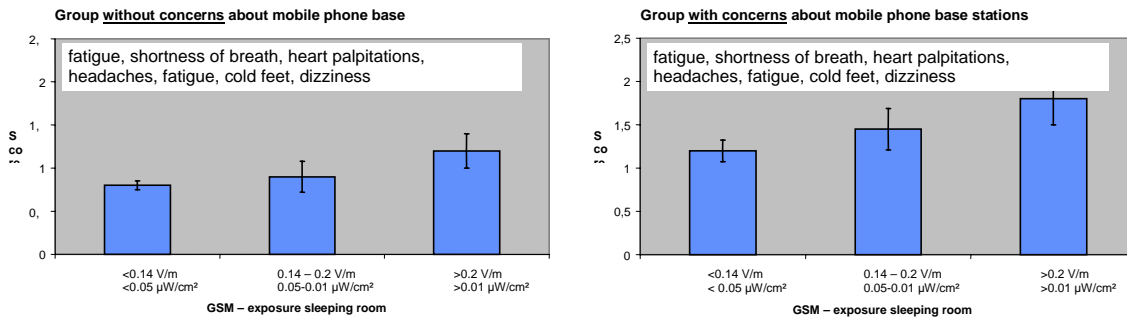
Graph: Incidence (%) of Complaints by Respondents (n=530) Living in the Vicinity of Mobile Phone Base Stations as a Function of Distance

2) In a cross-sectional study from Austria (Carinthia and Vienna), the authors studied persons, who have been living in the vicinity of a mobile phone base station for longer than one year (Hutter et al. 2002). Subjective symptoms and complaints, sleep quality and memory capacity were inquired about or tested for, respectively. The RF exposure in the bedroom of the study participants was measured for various selected frequencies including mobile phone radiation as well as radio and TV stations. The maximum for the sum total of all GSM mobile phone frequency bands was 1.4 mW/m² (0,14 µW/cm²).

Independent from potential fears due to the vicinity of mobile phone base stations, significant associations between the power density of GSM mobile phone base stations and cardio-vascular symptoms were found. The latter include fatigue, shortness of breath, palpitations, headaches, quick fatigue, cold feet and dizziness (Proceedings Rhodos: Hutter et al. 2002). In the 2006 publication (Hutter et al. 2006), individual symptoms were evaluated. Significant associations were observed for the symptoms: headaches, concentration problems as well as cold hands and feet. It is important to make two major comments: The symptoms occurred at exposure levels well below 1 mW/m² (former Salzburg Precautionary Exposure Limit outdoor). Furthermore, the selection of the study participants was representative; the selection was not based on any groups with higher susceptibility. This means that the study results are representative for the general population.

Graphs: Exposure-Effect Relationship between Cardio-Vascular Symptoms and GSM Mobile Phone Exposure Levels in Bedrooms

3) In a cross-sectional study from La Nora, Murcia, in Spain, residents in the vicinity of two GSM mobile phone base stations were studied (Navarro et al. 2003). The study participants were recruited based on self-selection. Questionnaires were made available at the pharmacy and at the hairdresser. The questionnaire was identical with the one used by Santini, the symptoms inquired about were all in line with the "microwave syndrome". The power density was measured as a broad spectrum across the bed (400 MHz – 3,000 MHz). The spectrum analysis showed the dominance of two GSM base stations at 900/1800 MHz. The participants were classified into two exposure groups: distance > 250 m with an average RF exposure of 0.1 mW/m² (0.01 µW/cm²) and distance < 250 m with an average RF exposure of 1.11 mW/m² (0.11 µW/cm²). The latter group with the higher exposure levels also had a significantly higher score for 9 symptoms.

	n=47	n=54	p-value
Average Exposure	0.1 mW/m² (0.01 µW/cm²)	1.11 mW/m² (0.111 µW/cm²)	<0.001
Average Distance	284 m	107 m	<0.001
Irritability	1.04	1.56	<0.05
Headaches	1.53	2.17	<0.001
Nausea	0.53	0.93	<0.05
Loss of Appetite	0.55	0.96	<0.05
Feeling of Discomfort	0.87	1.41	<0.02
Sleep Disruptions	1.28	1.94	<0.01
Depression	0.74	1.3	<0.02
Dizziness	0.74	1.26	<0.05

n: number of participants in group
p-value: The p-value is the probability value. For $p < 0.05$ results are considered significant.

Table: Comparison of Groups: Exposure to GSM Base Stations and Various Disease Symptoms (Score)

4) The above mentioned cross-sectional study by Navarro et al. was re-analyzed by the author (Oberfeld) with a logistic regression model for individual levels (Oberfeld et al.

2004). Significant associations between measured power densities and 13 symptoms in an exposure-effects relationship were found. The table below shows the results adjusted for age, gender, and distance.

Symptoms	Medium Exposure 0.05 – 0.22 V/m (6 – 128 µW/m²)			High Exposure 0.25 – 1.29 V/m (165 – 4,400 µW/m²)			p for the trend
	OR	95%-CI	p	OR	95%-CI	p	
Fatigue	28.53	3.03 – 268.78	0.0034	40.11	4.56 – 352.44	0.0009	0.0039
Irritability	3.12	0.91 – 10.68	0.0704	9.22	2.86 – 29.67	0.0002	0.0009
Headaches	5.99	1.50 – 23.93	0.0113	6.10	1.80 – 20.65	0.0037	0.0050
Nausea	5.92	0.60 – 58.68	0.1288	12.80	1.48 – 110.64	0.0205	0.0499
Loss of Appetite	6.66	0.62 – 71.52	0.1175	27.53	3,07 – 247.03	0.0031	0.0030
Sleep Disruptions	10.39	2.43 – 44.42	0.0016	10.61	2.88 – 39.19	0.0004	0.0008
Depressive Tendencies	39.41	4.02 – 386.40	0.0016	59.39	6.41 – 550.11	0.0003	0.0016
Feeling of Discomfort	4.29	1.14 – 16.15	0.0314	10.90	3.16 – 37.56	0.0002	0.0007
Concentration Difficulties	8.27	2.01 – 34.01	0.0034	19.17	4.91 – 74.77	0.0000	0.0001
Memory Loss	2.35	0.62 – 8.89	0.2090	7.81	2.27 – 26.82	0.0011	0.0031
Skin Problems	7.04	1.06 – 46.62	0.0429	8.22	1.39 – 48.51	0.0201	0.0628
Visual Problems	2.48	0.65 – 9.44	0.1830	5.75	1.68 – 19.75	0.0054	0.0186
Hearing Problems	3.89	0.99 – 15.21	0.0510	1.63	0.45 – 5.95	0.4572	0.1285
Dizziness	2.98	0.62 – 14.20	0.1712	8.36	1.95 – 35.82	0.0042	0.0117
Mobility Problems	1.32	0.30 – 5.84	0.7114	2.07	0.57 – 7.50	0.2690	0.5211
Cardio-vascular Problems	9.42	0.93 – 95.07	0.0572	17.87	1.96 – 162.76	0.0105	0.0333

Table: Association between Broadspectrum Electric-Field Measurements (dominated by GSM 900/1800 Mobile Phone Base Stations) and Various Disease Symptoms

The distance between residence and mobile phone base stations as estimated by the study participants was entered into the model as a measure for possible concerns and it hardly affected the statistic model. This data, too, cannot be extrapolated to the general population because of self-selection. However, the study results can be applied to an as-of-yet unquantifiable subgroup within the general population, which independent from possible concerns suffers from significant disturbance of their general well-being and health due to the RF exposure from mobile phone base stations.

Based on empirical evidence, the Salzburg Public Health Office recommended in February 2002 for the sum total of the continuous exposure to GSM 900/1800 mobile phone base stations not to exceed 0.02 V/m or 1 µW/m² (new Salzburg Precautionary Exposure Limit indoor) and 0.06 V/m 10 µW/m² (new Salzburg Precautionary Exposure Limit outdoor). The above data support this approach.

5) The TNO Physics and Electronics Laboratory was commissioned by three Dutch ministries (health, environment, trade and industry) to study UMTS and GSM. On 30 September 2003, the study results were published (Zwamborn et al.2003). In this double-blind study, participants of two different groups were lead individually into an RF chamber where they were exposed to RF radiation transmitted from two base station
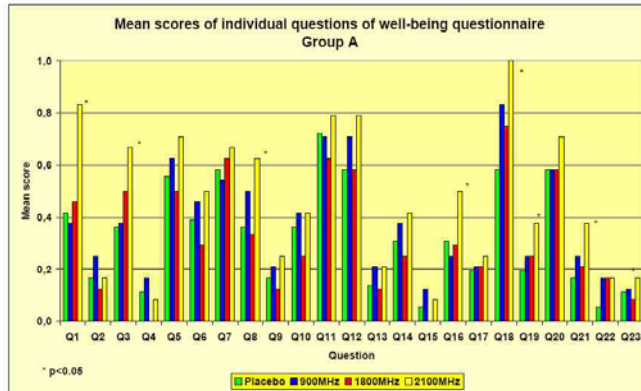
antennae, located three meters away. For all participants, the maximum exposure value for any signal was 1 V/m or 2.65 mW/m² (0.265 µW/cm²), respectively. This exposure level is typically found in the main beam of a standard mobile phone sector antenna (10 W antenna input power, isotropic antenna gain 17 dBi) at a distance of ca. 125 m. From the three different signals (GSM 900 MHz, GSM 1800 MHz, UMTS 2100 MHz), only two signals were used per participant and only one placebo period without exposure. The sequence of the exposure and non-exposure periods was not known to the participants under study and the study supervisors dealing with the application of the actual exposure experiment (double-blind design). Each exposure period was timed for 15 minutes, followed by a 30-min break. Prior to the application of the test, there was a supervised training period without any exposure.

Two groups with 36 persons each were studied. Group A included persons who had reported their health problems with mobile phone base stations to an environmental organization. Group B included persons who did not have any health complaints with regard to mobile phone base stations. As endpoints for this study, four computer-aided tests (reaction time, memory comparison, selective visual attention and double-step task) as well as a questionnaire concerning their well-being (23 questions) were used.
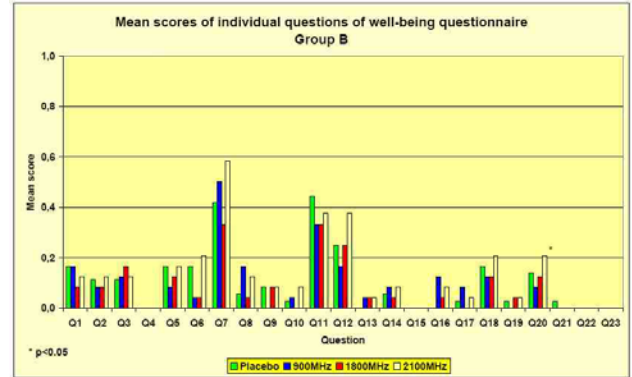
With regard to the effects on cognitive functions, statistically significant changes were observed, but without a clear pattern concerning type of exposure (GSM, UMTS), cognitive subfunctions and group association.

The results of the questionnaire concerning their well-being, however, showed a clear picture. The sum score of all questions showed a significant increase in health complaints in both groups during UMTS radiation exposure. In group B, the sum score increased from 2.44 (placebo) to 3.08 (UMTS). In group A, the sum score increased from 7.47 (placebo) to 10.75 (UMTS). With regard to the 23 individual questions on well-being, group A showed a significant increase in the level of complaint for eight questions in comparison to the sham exposure:

- Q 1 „Dizziness"
- Q 3 „Nervousness"
- Q 8 „Chest pain or difficulties breathing or a feeling of not getting enough air"
- Q 16 „Certain body parts feel numb or tingle "
- Q 18 „Certain body parts feel weak"
- Q 19 „Cannot concentrate"
- Q 21 „Feeling easily distracted"
- Q 23 „Having very little attention"

Graph: Group A: Mean Score for the Individual Questions of Well-being Questionnaire. Source: TNO report 2003

Graph: Group B: Mean Score for the Individual Questions of Well-being Questionnaire. Source: TNO report 2003

It is interesting to note here that the degree of symptoms differed clearly between group A (complaints during GSM exposure) and group B (no complaints during GSM exposure); and this difference could not only be observed during the training and sham exposure periods, but especially during exposure periods. This is another piece of evidence that electrosensitive persons do exist.

The clear response of group-A participants to the UMTS-FDD signal (W-CDMA), which was applied for only 15-min intervals, is of great importance. This type of signal is currently being used in the installation of the UMTS network. In the TNO study a signal generator produced a type of UMTS signal that consisted of only four dominant control channels being active and no user channel. This exposure situation would occur in a UMTS base station when no phone calls are transmitted and only the continuously transmitting control channels would be active. In real life, this would most likely occur at nighttime.

A study done in Switzerland 2006 (Regel et al. 2006), which was intended as a replication of the TNO study did not find an association between symptoms and the UMTS signal investigated.

Studies on Health Effects from Mobile Phones

In the health discussion about mobile phone use, the questions concerning tumor risks and risks of neurological disorders are given priority.
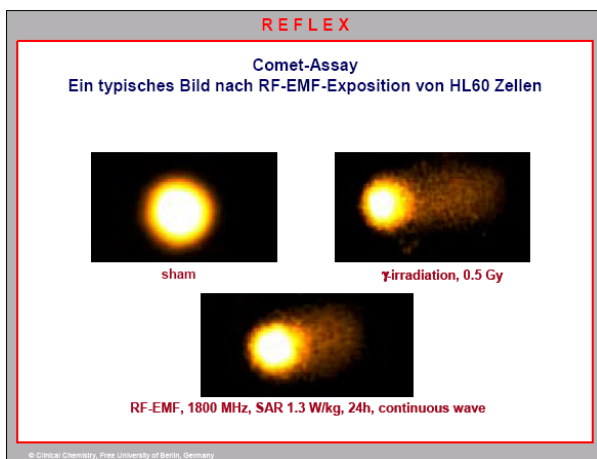
Lai and Singh (1995, 1996, 1997) could show in rats that DNA single- and double-strand breaks occur in chromosomes after a 2-h exposure (SAR 1.2 W/kg) at 2,450 MHz, which could be prevented through melatonin. This finding supports the notion that genotoxic effects caused by non-ionizing radiation are indirectly mediated by free radicals. This effect mechanism was also shown for alternating magnetic fields (60 Hz) in animal experiments (Lai and Singh 2004).

The exposure of genetically altered mice to GSM-900 radiation (SAR 0.13 – 1.4 W/kg) for two 30-min periods daily over 18 months showed a 2.4-fold increase in lymphoma risk (Repacholi et al. 1997). The replication study was not usable due to shortcomings in methodology – e.g. in contrast to the first study too high lymphoma rates in the unexposed group (Utterige et al. 2002).

A recent study on cell cultures, the EU co-financed REFLEX study "Risk Evaluation of Potential Environmental Hazards From Low Energy Electromagnetic Field Exposure Using Sensitive in vitro Methods" (REFLEX 2004), observed chromosome damage due to exposure from electromagnetic waves. The damage to the genetic material (DNA) in the chromosomes is a serious finding, which usually leads to legal rulings to reduce such risks.

At an exposure level (specific absorption rate - SAR) of 1.3 W/kg over 24 hours, human HL-60 cells showed single- and double-strand breaks as well as micronuclei formation at the frequency of 1800 MHz. For cells it is much more difficult to repair double-strand breaks than single-strand breaks. With 1.3 W/kg, the SAR value is well below the partial-body threshold of 2 W/kg (general public) or 10 W/kg (occupationally exposed persons) as recommended by the ICNIRP for the head region during mobile phone use.

Genotoxic events can result in cellular death, mutation, replication errors, permanent DNA damage and genome instability with an increased risk of cancer and accelerated aging. In another experiment it could be demonstrated that the addition of vitamin C prevented the micronuclei formation caused by RF radiation.
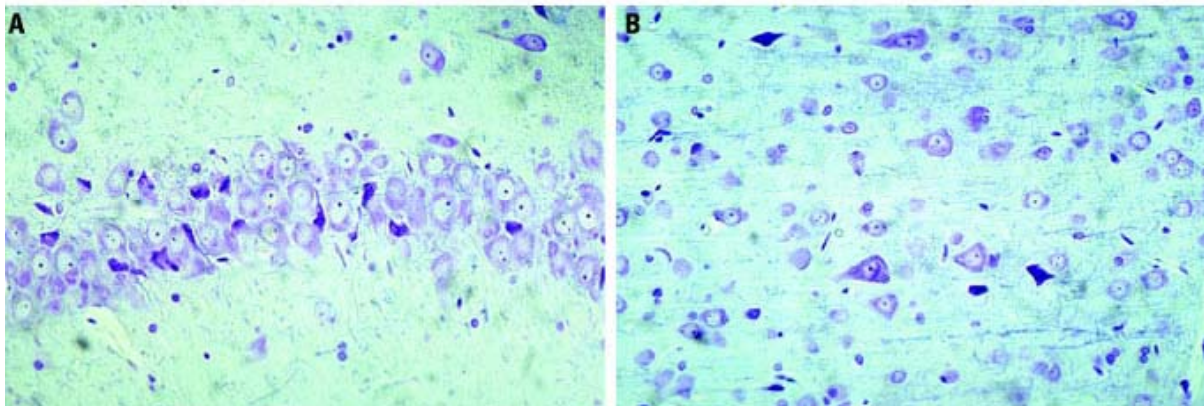

A typical image after RF-EMF Exposure of HL60 cells
Graph: Chromosome damage in comet assay through RF radiation 24 h, 1800 MHz, SAR 1.3 W/kg or 0.5 Gy γ-radiation in a HL-60 blood cell line.
0.5 Gy are equivalent to ca. 1,600 lung x-rays. Source: REFLEX 2004

In a study at the University of Lund, Sweden, rats were exposed to GSM mobile phone radiation (900 MHz) for two hours just once. And after 50 days, their brains were studied for damage (Salford et al. 2003). At an absorption rate of only 0.02 W/kg, significantly more „dark neurons", damaged nerve cells, were found. It says in the study: „*The intense use of mobile phones by youngsters is a serious consideration. A neuronal damage of the kind described here may not have immediately demonstrable consequences, even if repeated. In the long run, however, it may result in reduced brain reserve capacity that might be unveiled by other later neuronal disease or even the wear and tear of aging. We cannot exclude that after some decades of (often) daily use, a whole generation of users may suffer negative effects, perhaps as early as in middle age.*"

Graph: Section A Pyramidal Cell Band, Section B Cortex. Among the normal neurons (large cells) increasingly more deep blue, shrunken nerve cells, so called „dark neurons," are found (magnification x 160). Source: Salford et al. 2003
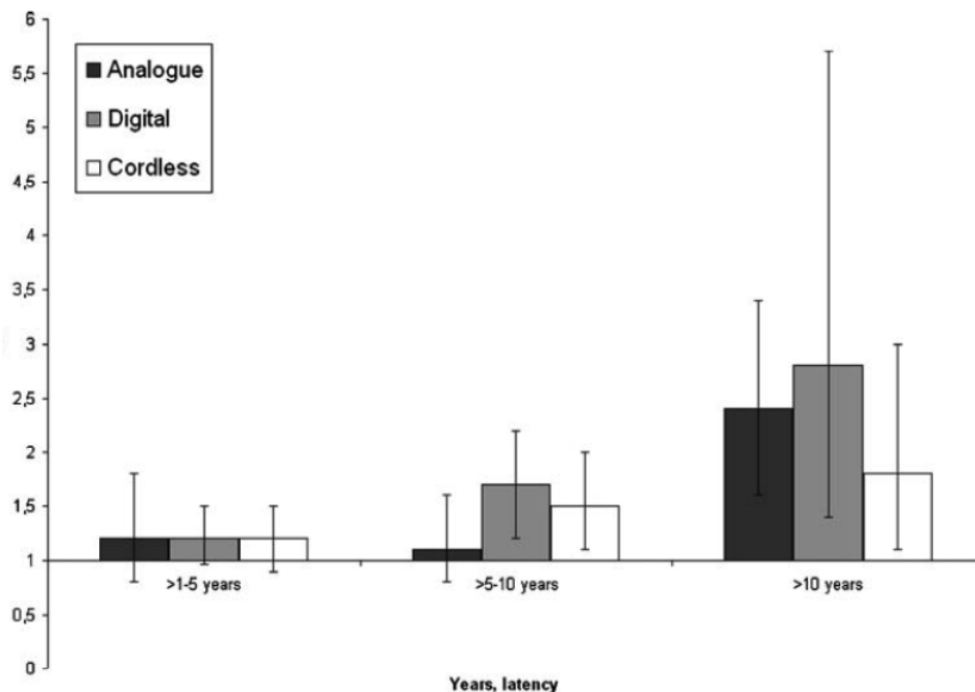
In a case-control study, Hardell (et al. 2002) studied 1,617 patients of both sexes between the age of 20 and 80 who had been diagnosed with a brain tumor between 1 January 1997 and 30 June 2000. Exposures to mobile and cordless phone radiation, ionizing radiation, organic solvents, pesticides, asbestos, etc. were investigated. The use of an analogue mobile phone showed a higher risk with an odds ratio (OR) of 1.3 (95% CI 1.02-1.6). When patients had started using analogue mobile phones more than 10 years ago, the risk increased to an OR 1.8 (95 %CI 1.1-2.9).

In an additional analysis (Hardell et al. 2003), increased risks for the tumor type astrocytoma were found for the dominant use (ipsilateral) of digital mobile phones (GSM) with an OR 1.8 (95% CI 1.1-3.2) and cordless phones with an OR=1.8 (95% CI 1.1-2.9). For astrocytomas a significantly increased risk was also found at the ipsilateral side for the duration of use for all three types of phones.

The findings about acoustic neuromas are confirmed by another study from Sweden, which also showed an increased risk in dependence of duration of analogue mobile phone use (Lönn et al. 2004). After ten years, the OR of the side used for mobile phone calls came in at 3.9 (95% CI 1.6-9.5). This translates into a four-fold increase in risk.

The latest studies by Hardell et al. (2006) show now an about three-fold increase in risk for malignant brain tumors (astrocytomas grade III and IV) in study participants who have been using their mobile phones for more than 10 years. In the case of cordless phones the respective risk was doubled. With increasing duration of usage (accumulated hours), the risk also increased. The age group < 20 years shows the highest risk. To complete the picture, it should be pointed out here that methodology problems exist in studies of the Interphone Project by the WHO, which can contribute to making it much more difficult to detect risks (Hardell and Mild 2006).

After a 10-year research period on the health risks associated with mobile phones, it is now confirmed on all levels of natural sciences (cells, animal experiments, observations in humans) that for usage duration of more than 10 years the risk to develop malignant brain tumors increases three-fold. Due to the cumulative risk, a further risk increase is to be expected.

Graph 1: Odds ratio and 95% CI bars for three categories of latency period for use of analogue, digital, and cordless telephones, respectively, Source: Hardell et al. 2006.

Mobile and cordless phones should, if at all, only be used for very short calls of an important or urgent nature.

In summary, it can be said that the biological and health effects of RF radiation that are independent of the thermal effect principle, which the ICNIRP and WHO recommendations are based on, can be considered as proven and that research should focus on the issue of exposure-effect relationships for various technical applications and

signal forms at the low-exposure range, combination effects with e.g. alternating as well as static electric and magnetic fields or the establishing of additional effect mechanisms and above all finding more compatible alternatives.

Target Aspects for Mobile Phone Applications

For the protection of personal and public health, the author (Oberfeld) suggests the following target values based on the latest scientific findings and empirical data: Permanent exposures to pulsed RF/MW signals (as from DECT cordless phone base stations (2.4 GHz/5.8 GHz) , WLAN (WiFi) transmitters, Bluetooth transmitters and GSM and UMTS base stations) measured with peak detector should not exceed 0.06 V/m (0.001 µW/cm²) outdoors and 0.02 V/m (0.0001 µW/cm²) indoors. In general, cordless and mobile phones should only be used for important and urgent calls. Children and adolescents should use cordless and mobile phones, if at all, in emergencies only.

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