

Feasibility of Future Epidemiological Studies on Possible Health Effects of Mobile Phone Base Stations

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The increasing deployment of mobile communication base stations led to an increasing demand for epidemiological studies on possible health effects of radio frequency emissions. The methodological challenges of such studies have been critically evaluated by a panel of scientists in the fields of radiofrequency engineering/dosimetry and epidemiology. Strengths and weaknesses of previous studies have been identified. Dosimetric concepts and crucial aspects in exposure assessment were evaluated in terms of epidemiological studies on different types of outcomes. We conclude that in principle base station epidemiological studies are feasible. However, the exposure contributions from all relevant radio frequency sources have to be taken into account. The applied exposure assessment method should be piloted and validated. Short to medium term effects on physiology or health related quality of life are best investigated by cohort studies. For long term effects, groups with a potential for high exposure need to first be identified; for immediate effect, human laboratory studies are the preferred approach. Bioelectromagnetics 28:224–230, 2007. © 2006 Wiley-Liss, Inc.

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INTRODUCTION

The introduction of mobile phones using the digital GSM 900/DCS 1800 systems in the 1990s has led to a wide use of this technology and subsequently to an increase in the environmental exposures to radio-frequency (RF) fields. Latest developments in mobile communications, for example, UMTS, will only intensify this process. In addition, the contributions to RF exposure from new technologies, for example, WLAN, WiMax, or Bluetooth will have to be considered. Today more than 2 billion people are using mobile telephones world-wide; about 450 million in Europe. The increased use of mobile phones has necessitated an increased deployment of base stations. Base stations are often situated close to dwellings or houses and have become the focus of concern of parts of

the population in recent years. These concerns resulted in the demand for epidemiological studies on the potential health effects of the RF emissions of base

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stations. The feasibility of such studies was questioned by some in the scientific community. It has been argued that several methodological problems, for example, lack of validated and reliable exposure assessment methods challenge the feasibility of such studies. The purpose of this paper is to address the feasibility of future epidemiological studies on health or well-being from environmental RF sources by evaluating existing studies in this field and exposure assessments used. An extensive report of this work can be found on the internet [Neubauer et al., 2005].

Exposure to Base Stations Compared to Other RF Sources

One of the crucial questions of feasibility of epidemiological base station studies is whether the base station exposure is negligible compared to exposure from all other RF sources. Obviously, short-term exposures from other sources in the microwave frequency range are often much higher than from base stations. For example, the spatial peak SAR value in the brain during usage of a mobile phone can reach 1 W/kg which is more than four orders of magnitude larger than the corresponding value in a person exposed to an incident field of 1 V/m, that is, the brain's exposure from the first 4 s of a phone call corresponds to the cumulative exposure over 24 h in a 1 V/m incident field at 2150 MHz [Regel et al., 2006]. The ratio for the whole-body average exposure between mobile phone exposure (averaged absorption of 0.03 W/kg) and a base station antenna for a sitting man of 80 kg is about 50 [Regel et al., 2006], that is, about 30 min of mobile phone use corresponds to 1 day exposure from a base station at an incident level of 1–2 V/m [Regel et al., 2006]. Similar conclusions were made (Dale and Wiart, 2004) by taking into account power control, traffic, and discontinuous transmission. The 24-h averaged whole body exposure arising from the usage of a mobile phone with a peak local SAR of 1 W/kg for 20 min and from base station exposure with an incident field of 2 V/m is of similar magnitude. However, the averaged local exposure in the head induced by the mobile phone is considerably higher than that of the base station.

Thus, one can conclude that exposure from base stations might be relevant if one is interested in total exposure time above a very low threshold, for example, for whole body averaged SAR levels of about 10 μ W/kg, approximately corresponding to >0.5 V/m incident plane wave exposure. At these very low levels, temperature considerations are likely to be meaningless [Adair et al., 2005]. It may also be relevant for 24-h whole body exposure or if an effect is assumed to be frequency and/or signal specific. In general, if the focus is on rather high and local exposure levels at a specific

body site (in particular at the head), mobile phone exposure or the contributions from other local sources, for example, other handheld transmitters or industrial or medical applications, are most relevant.

This implies that studies focusing on base station exposure only cannot be recommended. (A study solely focusing on base stations would require that the strongest environmental sources are only base stations in the whole area and period of investigation, but, in practice, this is a rather unlikely scenario.) Rather, there are certain circumstances where exposure contribution from a base station is relevant and should be taken into account together with all other RF sources. In contrast, there are circumstances where exposure contribution from a base station is negligible and does not have to be considered, for example, a study on brain tumors from use of mobile phones.

Below we discuss studies in which exposure from base stations should be considered and introduce the main challenges of base station exposure assessment.

Crucial Aspects in the Assessment of Base Station Exposure

The goal of exposure assessment in an epidemiologic study is to find a good metric representative of the exposure of interest. Thus, the first priority is not to obtain an exact value for the total exposure during the past, but rather to divide the study collective as accurately as possible into exposed or non-exposed groups (or in groups which are exposed to a varying degree), with a minimal overlap [Rothman and Greenland, 1998].

Up to now, distance between base stations and a residence has been used most often as an exposure proxy [e.g., Santini et al., 2003]. Power density in the radiation beam decreases with increasing distance. However, actual radiation level at a given site is a function of numerous factors, such as output power of the antenna, direction of transmission, attenuation due to obstacles or walls, and scattering from buildings and trees. In an Austrian study, 64 frequency selective measurements were performed at different locations in the vicinity of different base stations [Neubauer, 2003]. The measured power densities versus the distance to the base station are given in Figure 1. This demonstrates that the power densities measured at the same distance from different base stations vary by four orders of magnitude. Thus the distance alone is not an adequate surrogate to assess exposure [Mann et al., 2000; Rösli et al., 2002; Bornkessel and Schubert, 2005].

Another proxy used in previous studies was spot measurements, either frequency selective [Hutter et al., 2006] or broadband [Navarro et al., 2003]. At present it is unknown how representative spot measurements are

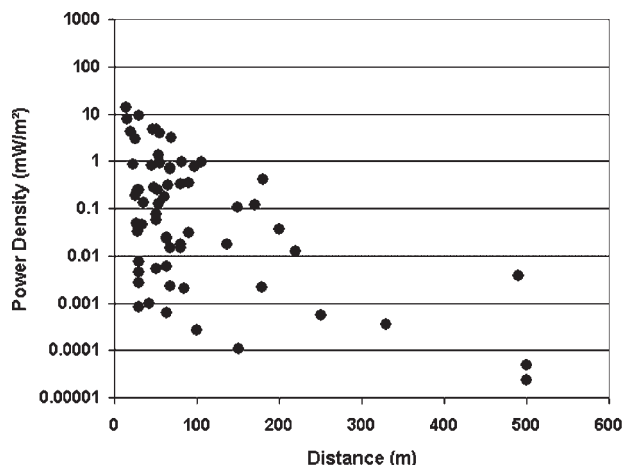


Fig. 1. Relation between power densities allocated to the broadcast channels of different GSM base stations and the distance from the respective base station [Neubauer, 2003]. The exposure levels were measured at different locations around the base stations, that is, both indoors and outdoors, both in the main beam and outside of it. The power densities are not normalized to the transmitted power of the base stations, therefore the given results reflect the variation of exposure that can be expected.

for personal exposure over a long-time period. Thus, continuous monitoring of exposure may complement spot measurements. The disadvantage of monitoring devices capable of collecting detailed information is that their use is restricted to one fixed place and continuous measurements are not feasible when applied in a large study group over an extended time period.

Thus a reliable exposure assessment method for a large epidemiologic study of RF exposure is yet to be developed. We will discuss later in this paper considerations relevant to the development of such a method.

OUTCOME EVALUATION

Which Outcome Should be Studied?

Previous research is fraught with many methodologic shortcomings [Kheifets and Shimkhada, 2005; Kheifets et al., 2005] and has addressed only few outcomes. Thus it does not provide leads that need to be followed, nor is it sufficient to exclude any of the outcomes from consideration. Given the paucity of data, selection of the outcome may be based on anecdotal reports and/or on analogy from ELF research.

Epidemiological Studies on Chronic Diseases

Chronic diseases such as cancer or neurodegenerative diseases can be rigorously ascertained, however require estimates of long-term exposure due to long

latencies. At present, it is not possible to assess long-term exposure contribution from base stations [Schüz and Mann, 2000]. Thus, studies on chronic diseases should focus on other RF exposure sources which are dominant and where a long-term exposure assessment can be done reliably, e.g., in the vicinity of strong transmitters or in occupational settings. In these circumstances, exposure from base stations is negligible and does not have to be taken into account. Any study of rare diseases should be designed to have sufficient statistical power to detect effects of interest. The validity of the exposure metric to be applied has to be demonstrated in pilot or validation studies.

Epidemiological Studies on Well-being and Quality of Life

The public is generally more concerned about unspecific symptoms of ill health and reduced quality of life due to base station exposure, rather than chronic diseases [Schreier et al., 2006]. Well-being is included in the WHO definition of health, but is particularly difficult to study because it is based on a subjective evaluation. Validated questionnaires on well-being, quality of life or specific symptoms (e.g., headache, sleep disturbances) provide a measure of unspecific symptoms of ill health. Different cultural backgrounds should be taken into account. It is well known that people with objectively worse health conditions sometimes rate better on quality of life questions than healthy people. Thus, quality of life or symptom reporting is usually most effective in a longitudinal or cross-over study design where within-subject changes are analyzed.

One has to be aware that the use of self-reports is very problematic if study participants are aware of their exposure status. Moreover, a Nocebo effect should be taken into account. The Nocebo effect is the inverse of the Placebo effect and means that adverse symptoms occur due to expectations (due to concerns). The Nocebo effect has to be addressed when designing studies of self-reported outcomes. Laymen assess their exposure to a base station primarily based on distance. As correlation between actual exposure and distance is poor, this may offer opportunities to distinguish between psychological mechanism (based on the subjective exposure assessment) and physical mechanism (based on real exposure). The development of such study designs including truly exposed subjects, subjects who perceive exposure but are unexposed, subjects who do not perceive an exposure but are exposed, and truly unexposed subjects is encouraged, as it is then possible to separate between physical and psychological effects. It is furthermore recommended that, for soft outcomes, diagnostic methods that are as

objective as possible, for example, actigraphs to measure the activity pattern.

Studies of the effect of long-term exposure from base stations on well-being are problematic. Long term exposure assessment from base stations is not reliable at present. Moreover, long term change in well being is difficult to measure [Michel, 2004].

Effects from RF exposure on well-being that occur immediately or within a few minutes are better investigated in human laboratory studies. In such studies, randomization and blinding allow control for bias and confounding to a large extent. In addition, exposure conditions can be fully designed and monitored.

Electromagnetic hypersensitive individuals often state that their symptoms appear after weeks or months of exposure to a mobile phone base station [Röösli et al., 2004]. Such long latencies are difficult to investigate by human laboratory experiments. Thus, such associations need to be addressed by epidemiological studies. In principle, several types of studies can be used to investigate effects occurring within weeks to months (medium term effects): field trials (including interventions), cross-sectional studies and prospective cohort studies. In both field trials and cross sectional studies, it is essential that subjects are selected randomly from the population and that non-participation can be assessed and evaluated. Otherwise, selection bias might be a severe limitation. Table 1 summarizes methodological strengths and weaknesses of each study type according to the type of outcome and time scale of effect manifestation.

Overall we conclude that epidemiological studies are preferred to address medium term exposure effects, for example, effects occurring after a few weeks up to some months. At the moment there is no reliable method is available to assess medium term exposure. Thus, for a given study, an exposure assessment protocol should be developed. This should be tested in a pilot or validation study. The following aspects should be considered in the development of such an exposure assessment method.

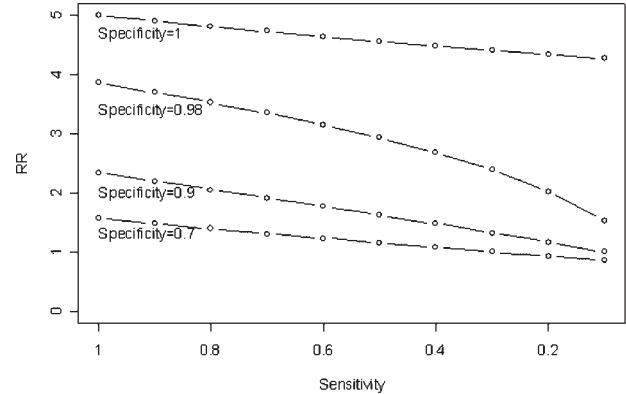


Fig. 2. Modeled relative risks (RR) for different assumptions about sensitivity and specificity of the exposure assessment for a specific example with a low proportion (4.8%) of highly exposed individuals. (True rate ratio is assumed to be 5.)

CRITERIA FOR EXPOSURE ASSESSMENT

Sensitivity Versus Specificity

The fact that only a small proportion of the population is exposed to substantially higher levels from radio frequency sources implies that specificity in exposure assessment is important. One should make sure that those who are considered as exposed, are in fact exposed. If the sensitivity is low and a part of the truly exposed individuals is counted as unexposed, it would not create much bias in the risk estimation (see Fig. 2). The vast majority of the unexposed group would still be unexposed.

Exposure Metrics

At present, biological mechanisms related to low level of exposure from base stations are unknown; several exposure metrics might have to be evaluated: (i) focus on exposure above a certain threshold only; (ii) a cumulative exposure measure assuming a linear dose-response association without a threshold; and (iii) exposure variability might be relevant for adaptation process. Theoretically, a mixture of these three concepts is also conceivable, for example, when the

TABLE 1. Overview on Methodological Strengths (+) and Weaknesses (-) of Various Study Design (~ Means Medium)

	Laboratory	Field	Cohort	Case-control	Cross-sectional	Ecologic
No exposure misclassification	+	~	-	-	-	-
Control of selection bias	+	~	~	~	-	-
Control of confounding	+	+	~	~	~	-
Transferability of results	-	+	+	+	~	~
Power	-	~	+	+	+	+
Immediate effects	+	~	~	-	+	-
Short term effects	~	+	+	~	~	-
Long term effects	-	~	+	+	-	-

exposure-response association is a non-linear function of the exposure level. In this case it would be preferable to calculate weighted cumulative exposure according to the shape of the exposure-response association.

Different Signal Characteristics

How do we deal with different signal characteristics from different sources? In principle there are two opposite viewpoints of the consequence of different physical properties of RF and microwave fields. One viewpoint is that physical characteristics apart from intensity are not relevant. The opposite viewpoint is that specific frequencies, intensities and/or modulation affect human health. Assuming a non-specific effect from microwave exposure implies that in an epidemiological study all microwave exposure can (and should) be taken into account. The consequences of not including all sources are:

1. If the considered exposure contribution is substantially larger than the omitted one, the exposure misclassification would be minor.
2. More serious consequences can be expected if the considered exposure contribution is small compared to other sources. If so, two cases can be distinguished: (a) exposure to other sources is not correlated to the considered exposure source(s). This is a typical case of non-differential exposure misclassification. The consequences would be a substantial loss of power and generally a substantial underestimation of the true exposure-response association. With a high likelihood such a study would not find an exposure-response association should one exist (false negative finding). (b) If exposure to other sources is correlated to the exposure of interest and is related to the outcome, the study result can be biased in any direction. In this case, exposure to other sources could be treated as a confounder (assuming it is associated with the outcome). It has to be taken into account that exposure from the handset may be negatively correlated with base station exposure. In rural areas of Sweden where base stations are sparse, the output power level used by mobile phones is on average considerably higher than in more densely populated areas [Lönn et al., 2004]. This suggests that information on an individual's use of mobile phones needs to be obtained as a co-factor in a base station study.

In contrast, assuming a specific microwave effect implies that to focus on only one specific source is justified, even if the exposure contribution from other

sources is much higher. However, scientific evidence for the existence of a specific signal is weak, and thus all sources should be evaluated. A source specific analysis of the exposure response association may be performed, but would have to be interpreted cautiously as it would involve multiple comparisons.

Exposure timing may also be a relevant parameter. This can involve different scales, for example, life time or 1 day. For many exposures, childhood exposure is more important than exposures later in life [Kheifets and Shimkhada, 2005; Kheifets et al., 2005]. Possible explanations include: higher susceptibility and longer time to develop a disease and accumulate exposure. It is also conceivable that exposure during certain times of the day is particularly relevant as many human processes follow a circadian rhythm. One could speculate that exposure during the night might be most important because of possibly increased susceptibility. With respect to base stations, exposure during nights is more relevant because contribution from base stations is usually larger than from mobile phones (which are not used during sleep). Additionally, the outcome may determine the relevant exposure time period. The relevant exposure time is different for a study on immediate occurrence of headache due to exposure compared to a sleep disturbance study.

Future Directions in Epidemiological Exposure Assessment

At present, many questions remain with respect to RF exposure assessment. Given the limited knowledge, no general recommendations on exposure assessment can be made. In order to design a suitable exposure assessment method, there is an urgent need for data on exposure profiles in various groups of the population (e.g., by age, region or occupation), and the contribution of different sources to the total RF exposure needs to be assessed. Personal exposimeters are one of the best approaches to learn about the population exposure (instead of exposimeter, the expression dosimeter is often used in literature on RF exposure assessment. Such devices measure the exposure and not a dose; therefore, the expression exposimeter is used instead of dosimeter in this paper). They are simple to handle and can be carried easily throughout a whole day. Thus, they offer a possibility for estimating personal exposure over a longer time period, for example, 24 h or even longer. A few systems allow frequency selective exposure assessment which makes the distinction between contributions from different types of exposure sources possible, for example, mobile phone use, exposure from base stations, radio, and TV frequencies. However, the expense of providing a personal exposimeter to each

subject in a large epidemiological study is a factor. Thus, combining personal exposimeter measurements with information from diaries kept by the participants gives an opportunity to identify different exposure patterns associated with relevant personal characteristics and behavioral patterns, for example, while at home, traveling, use of cordless phones, etc. Such data might be very valuable for developing reliable exposure proxies. In addition, personal exposimeter measurements may be combined with numeric calculations of the RF field. Ideally such models will be based on three-dimensional topography and take into account several parameters such as gain of the antennas, input power, side lobes, down tilt and height of the antennas. Use of such models is helpful to examine the field distribution in the vicinity of RF sources and to investigate the absorbed field in the body in-depth.

In conclusion, to develop a most reliable exposure assessment for an epidemiological study all available techniques should be used: frequency selective exposimeters, spot and continuous monitoring systems and analytic and/or numeric tools.

CONCLUSIONS

In many countries throughout the world almost the whole population is exposed to RF fields to one degree or another. There is increasing public concern that adverse health effects may arise from exposure to RF sources, including base stations. The results of epidemiological studies on mobile phones or broadcasting stations are inconclusive so far. Pushed by public concern, several methodologically poor epidemiological "base station studies" have been performed. Better epidemiological studies on possible health effects from RF exposure are therefore needed. It is therefore important to define methodological requirements for studies capable of providing meaningful scientific contributions.

Epidemiological studies focusing on base station exposure only cannot be recommended. Rather, all relevant RF sources should be taken into account. Exposure from base stations is not relevant if one's focus is on a specific body site (particularly the head). However, exposure from base stations may be significant if exposure above a very low threshold is considered to be relevant, for example, >0.5 V/m incident field corresponding to about $10 \mu\text{W/kg}$ whole body SAR, for the 24 h whole body exposure and for a frequency and/or signal specific exposure. At present, methodology for the assessment of long-term exposure from base stations has not been developed. Difficulties include high spatial and temporal variability of the electromagnetic fields. Another problem that makes

long-term exposure very problematic is the rapid change in wireless communication technologies. Novel exposure assessment protocols, for example, examination of exposure conditions of representative populations at regular intervals, need to be developed and tested before studies of chronic diseases such as cancer or neurodegenerative diseases can be envisaged. Immediate effects are preferably investigated in human laboratory studies. In contrast, exposure contributions from base stations can be investigated in epidemiological studies which focus on effects occurring within weeks and months, for example, well-being and quality of life. At the moment there is no reliable method available to assess medium term exposure, but the development of reliable methods appears feasible. Thus, for a given study an exposure assessment protocol should be developed. In order to develop a reliable exposure assessment method, we recommend taking advantage of all available techniques: frequency selective personal exposimeters, spot and continuous monitoring systems and analytical or numerical tools. A newly developed exposure assessment method should be tested in a pilot or validation study before, applied in being an epidemiological study.

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REFERENCES

- Adair ER, Blick DW, Allen SJ, Mylacraine KS, Ziriak JM, Scholl DM. 2005. Thermophysiological responses of human volunteers to whole body RF exposure at 220 MHz. *Bioelectromagnetics* 26:448–461.
- Bornkessel C, Schubert M. 2005. Entwicklung von Mess- und Berechnungsverfahren zur Ermittlung der Exposition der Bevölkerung durch elektromagnetische Felder in der Umgebung von Mobilfunk Basisstationen Zwischenbericht 'Analyse der Immissionsverteilung', IMST GmbH, Bundesamt für Strahlenschutz, Deutsches Mobilfunk Forschungsprogramm (DMF). Available from: http://www.emf-forschungsprogramm.de/forschung/dosimetrie/dosimetrie_abges/dosi_015_AB.pdf.
- Dale C, Wiart J. 2004. Exposure comparison between a mobile phone and a base station at 900 MHz, 1800 MHz & 2100 MHz. BEMS 26th annual meeting, Washington, DC June 20–24, 2004, *Bioelectromagnetics Society Abstract Book*: pp 322–323.
- Hutter H, Moshhammer H, Wallner P, Kundi M. 2006. Subjective symptoms, sleeping problems, and cognitive performance in

- subjects living near mobile phone base stations. *Occup Environ Med* 63:307–313. doi: 10.1136/oem.2005.020784.
- Kheifets L, Shimkhada R. 2005. Childhood leukemia and EMF: Review of the epidemiologic evidence. *Bioelectromagnetics* 26(7):51–59.
- Kheifets L, Repacholi M, Saunders R, van Deventer E. 2005. Sensitivity of Children to EMF. *Pediatrics* 116(2):303–313.
- Lönn S, Forssen U, Vecchia P, Ahlbom A, Feychting M. 2004. Output power levels from mobile phones in different geographical areas; implications for exposure assessment. *Occup Environ Med* 61:769–772.
- Mann SM, Cooper TG, Allen SG, Blackwell RP, Lowe AJ. 2000. Exposure to radio waves near mobile phone base stations. NRPB–R321, National Radiological Protection Board. Available from: http://www.hpa.org.uk/radiation/publications/archive/reports/2000/nrpb_r321.pdf.
- Michel G. 2004. Symptom reporting: Exploration of situational and individual predictors. PhD thesis, University of Fribourg, Switzerland.
- Navarro EA, Segura J, Portoles M, Gomez-Perretta de Mateo C. 2003. The microwave syndrome: A preliminary study in Spain. *Electromagn Biol Med* 22:161–169.
- Neubauer G. 2003. Dosimetrie in der Mobilkommunikation: Die Exposition der Bevölkerung und Probleme bei deren Ermittlung, doctoral thesis, Technische Universität Graz, Institut für Materialphysik.
- Neubauer G, Rössli M, Feychting M, Hamnerius Y, Kheifets L, Kuster N, Ruiz I, Schüz J, Überbacher R, Wiart J. 2005. Study on the Feasibility of Epidemiological Studies on Health Effects of Mobile Telephone Base Stations—Final Report. March 2005, ARC–IT–0124, Available from: www.mobile-research.ethz.ch/var/pub_neubauer_pref14.pdf.
- Regel S, Rössli M, Negovetic S, Schuderer J, Berdinas V, Huss A, Kuster N, Achermann P. 2006. Effects of UMTS Base Station Like Exposure on Well-Being and Cognitive Performance. Submitted at *Environ Health Perspect* 114(8):1270–1275.
- Rothman KJ, Greenland S. 1998. *Modern epidemiology*, 2nd edition. Boston, MA: Little, Brown and Company.
- Rössli M, Wanner M, Braun-Fahländer C. 2002. Comparison of measurements and calculations of electromagnetic radiation from GSM mobile phone base stations. *Epidemiology* 13:196.
- Rössli M, Moser M, Baldinini Y, Meier M, Braun-Fahländer C. 2004. Symptoms of ill health ascribed to electromagnetic field exposure—a questionnaire survey. *Int J Hyg Environ Health* 207(2):141–150.
- Santini R, Santini P, Santini P, Danze JM, Le Ruz P, Seigne M. 2003. Survey study of people living in the vicinity of cellular phone base stations. *Electromagn Biol Med* 22:41–49.
- Schreier N, Huss A, Rössli M. 2006. The prevalence of symptoms attributed to electromagnetic field exposure: A cross-sectional representative survey in Switzerland. *Soz Präventiv Med* 51(4):202–209.
- Schüz J, Mann S. 2000. A discussion of potential exposure metrics for use in epidemiological studies on human exposure to radio waves from mobile phone base stations. *J Expo Anal Environ Epidemiol* 10:600–605.