Risk Assessment of Chronic Exposures to Non-Thermal Microwaves from Mobile Communication

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1. Introduction

Numerous sources of mobile communication result in chronic exposure of general population to microwaves (MWs) at the non-thermal (NT) levels. Since pioneering investigations published in the beginning of 1970th [1, 2], various biological responses to NT MWs including adverse health effects have been reported by many groups over the world [3, 4]. Numerous experimental data have provided strong evidence for the NT MW effects and have also indicated dependence of these effects on several physical parameters and biological variables: dependence on carrier frequency of "resonance-type" within specific frequency windows; dependence on modulation and polarization; non-linear dependence on intensity within specific intensity windows including super-low power densities (PDs)/specific absorption rates (SARs) comparable with intensities from base stations; narrowing of the frequency windows with decrease in intensity; high sensitivity of the NT MW effects to the duration and intermittence of exposure; dependence on cell density that suggests cell-to-cell interaction during response to NT MWs; dependence on genetic background, physiological variables during exposure and a potential of radical scavengers/antioxidants to minimize the MW effects. There are not yet confirmed observations that gender, individual traits, oxygen concentration, static magnetic fields (SMF) and stray electromagnetic field (EMF) during exposure may be of importance for the effects of NT MWs [5]. Most of these regularities clearly indicate that the MW effects at low intensities cannot be accounted for any type of thermal effects.

Despite of considerable body of studies with NT MWs in biology, only few studies were performed to replicate the original data on the NT MW effects. It should be noted, that the "replications" are usually not comparable with the original studies because of either missing description of

important parameters of exposure or significant differences in these parameters between original study and replication.

2. Risk assessment of signals used in mobile communication

The safety recommendations of some organizations such as ICNIRP [6] are based on thermal effects in acute exposures and cannot protect from eventual non-thermal effects of chronic exposures to the NT MWs from mobile communication. Some national authorities such as RCNIRP have established significantly lower safety recommendations that are based on studies with chronic exposures and acceptance of non-thermal effects [7]. At present, new situation arose when general population is exposed chronically (much longer than previously investigated durations of exposures) to NT MWs from different types of mobile communication including GSM and UMTS/3G phones and base stations, WLAN (Wireless Local Area Networks), WPAN (Wireless Personal Area Networks such as Bluetooth), DECT (Digital Enhanced (former European) Cordless Telecommunications) wireless phones. RCNIRP admit that the established safety standards do not correspond to the present situation when general population is exposed to variety of MW signals with durations of exposure comparable with the lifespan [8].

Most of the real MW signals that are in use in mobile communication have not been tested so far for adverse effects. Very little research has been done with real signals and for durations and intermittences of exposure that are relevant to chronic exposures from mobile communication. In some studies, so-called "mobile communication-like" signals were investigated that in fact were different from the real exposures in such important aspects as carrier frequency, modulation, polarization, duration and intermittence. To what degree such studies are relevant to evaluation of health risks from MWs of mobile communication is not known. For example, GSM users are exposed to MWs at different carrier frequencies during their talks. There are 124 different channels/frequencies, which are used in Europe for GSM900. They differ by 0.2 MHz in the frequency range from 890 MHz to 915 MHz. Mobile phone users are supplied by various frequencies from the base stations depending on number of connected users. The base station can change the frequency during the same talk. We have shown that adverse effects of NT MWs from GSM mobile phones depend on carrier frequency [9-11]. Frequency-dependent effects of GSM MWs on the 53BP1/γ-H2AX DNA repair foci in human lymphocytes from healthy and hypersensitive to EMF persons, human fibroblasts and human stem cells were observed in replicated studies [9-11].

GSM uses GMSK modulation (Gaussian Minimum Shift Keying). Contrary to GSM phones, UMTS mobile phones of the 3rd generation (3G) use essentially QPSK (Quadrature Phase Shift Keying) modulation and irradiate wide-band signals with the bandwidth of 5 MHz. UMTS MWs may hypothetically result in a higher biological effect because of eventual "effective" frequency windows within the bands. We tested one of the real UMTS signals as used by 3G mobile phones in Sweden. UMTS MWs induced significant adverse effects in human lymphocytes, fibroblasts and stem cells [9, 11]. The results obtained were in line with our hypothesis that UMTS MWs may produce stronger adverse effects than GSM MWs because of the nature of signal.

3. Urgent needs and further perspectives in risk assessment

It should be anticipated that some part of population, such as children, pregnant women and groups of hypersensitive persons could be especially sensitive to the NT MW exposures. It is becoming more and more clear that the SAR concept that has been widely adopted for safety standards may not be useful alone for the evaluation of health risks from MWs of mobile communication. How the role of other exposure parameters such as carrier frequency, modulation, polarization, duration, and intermittence of exposure should be taken into account is an urgent question to solve. Solving this question would greatly benefit from the knowledge of the biophysical mechanisms of the NT MW effects. The understanding of mechanisms for the NT MW effects is far away from comprehensive. Many questions remain to be addressed such as whether the effects of NT MWs depend on electromagnetic noise and static magnetic field during exposure. Besides fundamental importance, this knowledge would facilitate the development of safe mobile communication.

So far, most laboratory and almost all epidemiological studies did not control the important features of the NT MW effects and therefore, very limited conclusion regarding health effects of MWs from mobile communication can be drawn from these studies. It should be noted that one group of epidemiologists with a long-lasting experience in studying relationship between mobile phone usage and cancer risk have consistently been concerned regarding importance of the type of MW signal and the exposure duration [12-15]. The group of Hardell was the first epidemiological group in attempting to study separately the MW signals from cordless phones, analogue phones and digital phones. As a rule, analogue phones had the highest association with the cancer risk. Cordless phones were associated with the risk for brain tumors, acoustic neuroma, and T-cell lymphoma stronger or in the same degree as digital and analogue

phones despite significantly lower SAR values were produced by cordless phones [12, 14-16]. This important result can be considered as an independent conformation, at the epidemiological level, of the observations from specially designed *in vitro* and *in vivo* studies that the NT MW effects depend not solely on SAR/PD but also on other parameters. It should be also noted that epidemiological data are controversial and methodological differences are a subject of debates between various research groups [16, 17]. However, the approach of the Hardell's group is more valid from the mechanistic point of view and this should be taken into account when comparing with results with other epidemiological groups that are either not aware of or ignore the complex dependencies of the NT MW effects on variety of physical and biological parameters [17].

The data about the effects of MWs at super low intensities and significant role of duration of exposure in these effects along with the data showing that adverse effects of NT MWs from GSM/UMTS mobile phones depend on carrier frequency and type of the MW signal suggest that MWs from base-stations/masts can also produce adverse effects at prolonged durations of exposure and encourage studies using real signals from base stations/masts [18].

The dependence of adverse effects of NT MWs on carrier frequency and type of signal should be taken into account in settings of safety standards and in planning of *in vivo* and epidemiological studies. One important conclusion stemming from the available *in vitro* and *in vivo* studies is that epidemiological studies should not be given priority for risk assessment before proper design of these studies will be available as based on mechanistic understanding of the NT MW effects. This conclusion is based on two principle arguments. First, it is almost impossible to select control-unexposed groups because whole population in many countries is exposed to wide range of MW signals from various sources such as mobile phones and base stations/masts of various kinds, WLAN, WPAN, DECT wireless phones and given that duration of exposure (must be at least 10 years for cancer latency period) may be more important for the adverse health effects of NT MWs than PD/SAR. It should be stressed, that inappropriate definition of control-unexposed groups is a typical flow in those epidemiological studies that are not based on mechanistic issues regarding the NT MW effects [19]. Subjective dividing of telephone users into "exposed" and "unexposed-control" groups make such studies inconclusive. It is clear, that such epidemiological studies cannot be used as a background for risk assessment. Second, the adverse effects of "detrimental" signals are masked because people are exposed to various signals/frequencies including non-effective or even hypothetically beneficial. Therefore, current

epidemiological studies may be either inconclusive, if results are negative (no risks were found), or underestimate significantly the hazard of using specific detrimental signals, if results are positive.

The RNCNIRP proposed that guidelines and risk assessment for NT MWs should be urgently developed by studies based on the next priorities [7]: (1) Acute and chronic bioeffects of real MW signals as currently in use (GSM, UMTS/3G phones and base stations…) should be tested in experiments with primary human cells and using appropriate techniques. In these tests, a potential of specific MW signals to produce adverse effects should be evaluated. Those "ineffective" signals and frequency channels/bands, which do not affect human cells, should be identified for further development of safe mobile communication. (2) Studies with animals and volunteers under controlled conditions of chronic exposures to both detrimental and ineffective MW signals as revealed by *in vitro* studies with primary human cells. The data from the acute exposures of volunteers have very limited value for risk assessment because possible accumulation of effects during real chronic exposures is not evaluated. (3) Development of reliable and relevant methods to control personal exposures. (4) Based on mechanistic studies, epidemiological investigations of various postponed adverse health effects should be planned. Because NT MWs affect variety of cell types such as brain cells [20, 21], blood cells [9-11, 22-24], skin and fibroblasts [9, 25-28], stem cells [9, 29, 30], reproductive organs and sperm quality [31-35], prenatal development and fertility [36, 37], different types of cancer (tumors of various localization and leukemia) and also other relevant diseases should be tested. Recent data suggest that different cancer types have a fundamentally common basis that is grounded on epigenetic changes in stem cells [38]. Therefore, the experimental findings regarding effects of NT MWs on stem cells [9, 29, 30] may be especially important for cancer risk assessment.

The collaborative efforts of scientific groups within special national and international programs are needed for risk assessment of the NT MW exposures. This collaboration should involve scientists with diverse expertise including those having experience in studying the mechanisms of the NT MW effects. Otherwise, misleading conclusions or inconclusive results may be expected.

Acknowledgements

Financial support of the Swedish Council for Working Life and Social Research, the Swedish Radiation Protection Authority, the Russian Foundation for Basic Research is gratefully acknowledged.

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