

Mobile communications and health of population: the risk assessment, social and ethical problems

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Abstract Today world population lives in a new electromagnetic environment, characterized with (i) around the clock enforcement of chronic exposure of all age and gender groups to a wide range of modulated electromagnetic fields (EMF) from base stations; (ii) daily, repeated from early childhood throughout entire life exposure to EMF RF mobile phone the brain and vestibular receptor apparatus and auditory analyzers, located directly “under the EMF beam” in the inner ear. On the other hand, the world science and epidemiology is missing well-planned and executed research results of prolonged exposure of EMF RF on the brain. International recommendations and domestic guidelines do not include changing conditions of RF EMF on the population: the brain has become a critical organ, and the children entered the risk group. The population continues to actively use the mobile phone. In this situation the problem of assessing the risk of mobile communications has become a social and ethical.

Keywords Mobile phones · Electromagnetic fields · Risk assessment

1 Introduction

In the present, the entire population of *Homo sapiens* is living in a principally new technological environment, different from the environment during entire period of evolution (Grigoriev 2006; Grigoriev et al. 2006).

Today for the electromagnetic environment is characterized by:

- a constant, 24 h a day chronic exposure to a wide range of modulated electromagnetic fields (EMF) emitted from base stations to all groups population;
- daily, repeated throughout life, radiofrequency EMF (RF-EMF) exposure of brain and the receptor apparatus of the vestibular and auditory analyzers located directly “under the EMF beam” in the inner ear to cell phone signals.

The result is a total contact of all groups of population with sources of RF-EMF exposure in uncontrolled conditions. In addition, the population has received a new and important mode of RF-EMF exposure on the accumulation of dose and localization to the brain.

The problem of evaluating the current electromagnetic hazard to public health, in our opinion, should be referred to the problems of an urgent decision. The situation in question has arisen unexpectedly in radiobiology and non-ionizing radiation hygiene. It is now clear that the population is in long-term small, non-thermal intensity exposure to RF-EMF.

Our 50 years experience with low doses of ionizing radiation suggests that in this case, at an estimation of danger is necessary to focus primarily on the criterion of the possible development of long-term effects and, consequently, the need for lengthy relevant studies with an emphasis on the use, primarily of adequate to the markers.

However, as will be shown below, the number of foreign scientists continues to argue, unfortunately for many years, against the hazard and the safety of exposure to EMF of mobile radio communications for all population groups. It should be noted that the latter view is formed under conditions depending on the financial impact of the relevant industry.

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It must be recognized that the scientific evidence that assess the risk of newly emerging conditions of RF-EMF exposure on people is not enough, and scientifically sound data on long-term effects of RF-EMF on the brain of mobile phone (MP) user are virtually absent. Meanwhile, the mobile radio communication has been very widespread, actively pursued the policy of “permissibility” use of personal mobile radio communication devices without restriction.

It must be recognized that the scientific evidence for assessing the risk of newly emerging conditions of RF EMF exposure on people is not enough, and scientifically sound data on long-term effects of EMF on the brain RF mobile radio user are virtually absent.

For the risk assessment of mobile communications, one must include the bioeffects associated with prolonged exposure to EMF and local RF user on the brain, and possible long-term effects obtained in the experiment. Are highly relevant, studies aimed at obtaining data on the immediate changes in brain function in children users of MP (the first 8–10 years), and the development of their long-term effects (in later years) (Grigoriev 2005).

In this paper, we present the radiobiological bioeffects caused by RF EMF with very low intensity and attempt to evaluate possible adverse health effects MP user.

2 Functional disorders of mobile phone users

Currently, there are conflicting data on the adverse effects of EMF on the health of mobile phones users. Some users of MT have a large number of complaints: difficulty concentrating, irritability, insomnia, headaches, discomfort, and others (Muscat et al. 2002; Schuz et al. 2006). By the above-listed complaints in these individuals when exposed to EMF may appear arrhythmia, nausea, depression, tremors of hands, skin disorders, stressful conditions, irritability, and other manifestations of neurasthenia symptoms (David et al. 1999; Hallberg and Oberfeld 2006; Huber et al. 2003; Khorseva 2004; Mild et al. 1998). In fact, these authors are discussing so-called electromagnetic hypersensitivity. It is assumed that at the present time among the urban population has 1.5–12% electrosensitive people. Based on the analysis of data obtained in Austria, Germany, Great Britain, Ireland, Sweden, Switzerland and the United States, Hallberg and Oberfeld G believe that as a result of continuous exposure to low-intensity EMF the number of people with electromagnetic hypersensitivity may increase, for example up to 50% of the population by 2020 (Hallberg and Oberfeld 2006).

Most of the adult users of mobile phones are well aware that some EMF could provoke adverse health effects. For example they apply caution when using microwaves,

electric oven or other electrical units in their everyday life. They also know that mobile phones use EMF, but there is no way that they detect this radiation (human body does not have receptors for microwaves). Therefore, a question arises: we have a potentially dangerous radiation, how we may evaluate it? In addition, should we trust manufacturers, instruction for use and claims that the specific radiation does not represent hazard. Without answers of these concerns, people became scared, sometimes it leads to not necessary stress. Part of these users have a sense of anxiety, stress had a condition that is accompanied by the appearance of different complaints. We call this state as “Situational stress” (Grigoriev 1995, 2002). Given this, in our opinion, is most likely that part of the above is the result of user complaints “Situational stress”.

Objective data on the effect of EMF on the body of the MT users have been obtained only at volunteers in the real MT use. This could be explained with the facts that these exposures were for a short daily intervals, repeated for several days only. From physiological point of view the response reactions were compensatory, not pathological. The modification of important functions was transient, they did accumulate and 2–4 h after exposures the normal functioning is restored. This is classical radiobiological response. At prolonged exposure to mobile phone, EMF changes in the central nervous system and cardiovascular system have been observed. Specific changes of brain function, such as decreased memory (IARC/A/WHO 2011; Krause 2000; Lahkola et al. 2007; Preece et al. 1999; Salford et al. 1997), changes in the bioelectrical activity of the brain (Dec et al. 1997; Freude et al. 1997; Lahkola et al. 2007; Thuroczy and al 1997; WHO 2003), changes in the blood flow of the brain (WHO 2003), have been reported.

We have also investigated the effect of EMF on brain MT (Grigor'ev et al. 1999). The study included 10 males healthy volunteers aged 23–47 years. Using physiological, biochemical, physiological and clinical parameters of the subjects before, during and after the exposure to MP we assessed the effects of RF-EMF This set of techniques has been previously developed by the authors to study the reactions of the central nervous system and body as a whole to meet the challenges of low-intensity EMF for standardization of wide range of frequencies.

Exposure time was 5, 10 and 30 min. The sham and true EMF exposure was applied in a randomized order. We used three standards MP: NMT-450, GSM-90 and GSM-1800. For most volunteers during and after EMF exposure some changes in the spectra of the EEG was amplified, mainly alpha range. However, these changes did not go beyond the normal functioning of the brain and were interpreted by us as a defensive reaction to the biologically weak stimulus for central nervous system.

It is noteworthy that the pattern of change depended on the initial background bioelectric activity of the brain. These changes had a tendency of accumulation in the case of repeated impacts, but the severity of these changes depended on the time of EMF exposure: 5, 10 or 30 min.

There was no reliable functional response from the CAS (blood pressure, pulse rate, ECG), endocrine system, electromyograms did not change. This could indicate a threshold effect of low intensity EMF on the brain. The restoring of marked changes occurred in the first two hours.

Summarizing the results of studies on volunteers, we can conclude that they do not allow to predict the development of adverse bioeffects at prolonged EMF exposure on the brain of users, but provide some considerations for possible summation of the bioeffects.

3 RF-EMF and brain (experimental study)

Clear and sustained changes in the function of the brain under EMF exposure of MP on brain were obtained in experiments on animals. It is shown that under the influence of RF EMF small changes in the permeability of the BBB occur, which can lead to damage of neurons in the brain of rats (Salford et al. 2003; Sandstrom et al. 2001).

We obtained data on the role of modulation of the carrier frequency in the development of bioeffects in the brain, in particular, acute effects of RF EMF at total exposure to a very low intensity causing the imprinting (Grigoriev 1999; Grigoriev and Stepanov 2000). The imprinting is an original aspect of memorizing: at birth the organism fixes in the memory that has seen for the first time.

Hundred and twenty-nine embryos of chickens were exposed on day 16 in an incubation (9.3 GHz; 5 min

exposure, $S = 40 \mu\text{W}/\text{cm}^2$ with a quantization of 10 and 40 Hz, meander, pulse duration of 2.5 ms). Besides, there were series with a continuous irradiation (CW) and sham exposure. The imprinting suppression (up to 50%) was found in newborn chicken only for series of EMF exposure at 10 and 40 Hz (Table 1). In case of CW exposure ($S = 40 \mu\text{W}/\text{cm}^2$) and in control group, the imprinting disturbance was not found.

With the purposes of examination of possible effect of modulated EMF of small intensity on a more composite functioning system the model of an isolated frog heart was used (Aphrikanova and Grigoriev 1996). A composite regimen of modulation was utilized at low level of intensity. The principle of modulation frequency change in time was applied at a constant country exposure of frequency setting. An irradiation was conducted on experimental installation generating microwave with frequency of 9.3 GHz. As the dimensions of frog heart are comparable to a wavelength of radiation, an irradiation was conducted in conditions which are near to maximal absorption of the radiation energy.

Applied EMF were with various frequency of modulation from 1 up to 100 Hz at a depth of modulation of 30 and 100%; a pulse shape was rectangular, $S = 0.016 \text{ mW}/\text{cm}^2$. Distance to the object was selected in a way to provide uniform irradiation. The general plan of experiments is shown in Table 2.

The examinations were conducted during radiation and within 24 h after exposure. 180 frog hearts were utilized in total. It has been estimated a beat frequency of heart during each 30 min within 6 h from the moment of the isolated heart preparation, during exposure, and also within day after an irradiation. Simultaneously, observations were conducted in control (sham exposure) in the same terms. It is

Table 1 Imprinting in chickens after an EMF irradiation of embryos for continuous and modulated regimens

Series no.	Series name	PFD, $\mu\text{W}/\text{cm}^2$	Exposure time	No. of embryos	No. of chickens with imprinting
1	Control–sham exposure	–	–	83	81 (97%)
2	Continuous exposure	40	5	27	23 (89%)
3	10 or 40 Hz modulated exposure	40	5	19	9 (50%)

Table 2 General characteristics of conditions of experiments

Test No.	Animal numbers		PFD, mW/cm^2	EMF mode and exposure time, min			Total exposure time, min
	Test	Control		CW	Pulsed, Hz	Time at each mode, min	
1	28	28	0.016	–	6–10	1	5
2	32	32	0.016	–	1–10	1	10
3	20	20	0.016	–	1–10, 20, 30, 40, 50, 60, 70, 80, 90, 100	1	19
4	10	10	0.016	CW	–	5	5

important for an assessment of a response on an irradiation that heart in Ringer solution can be pruned within 2 days.

Besides, the morphological criterion of a state of erethitic tissues of heart was the assessment of process of a vital staining of frames of an interatrial septum by a stain of azine group with neutral red. The method of an intravital staining has enabled to judge vitality of frames by granule forming criterion, and also about a state of their permeability (on a degree and dynamics of staining). Other vital stain, methylene blue, was used for the assessment of a state of choline energetic synapses on independent neurons of a Ludwig node.

Intact uncolored hearts for 24 h of observations have decelerated the rate on the average on 7%; the cardiac standstill was not present. Half-hour stays of a quarantined drug heart in solution of a stain in itself have resulted in the modification of its function. The figure of constrictions was decreased by 30, and 14% of hearts ceased to be pruned (Fig. 1). At a stimulation of the stopped hearts by strong light or mechanical stimulus of pacemaker range (venous sinus) the beat was recovered. After the arrest of process of a staining of heart the rate of constrictions was gradually accumulated reaching the initial level. Only to the end of experiment in the hour 24, the heart beat number was sunk on the average on 20%.

The response of hearts irradiated in a continuous regimen, was inappreciable, and differed from the colored unirradiated hearts a little.

At irradiation in the modulated regimen, the sharp decrease in heart beat number was found, and the number of the hearts which have ceased to beat (Fig. 1) was also increased. The greatest effect was obtained at a frequency drift of modulation in a band of 6–10 Hz and time of exposure of 5 min. Under these conditions, there was a retardation of a rhythm to the subsequent cardiac standstill

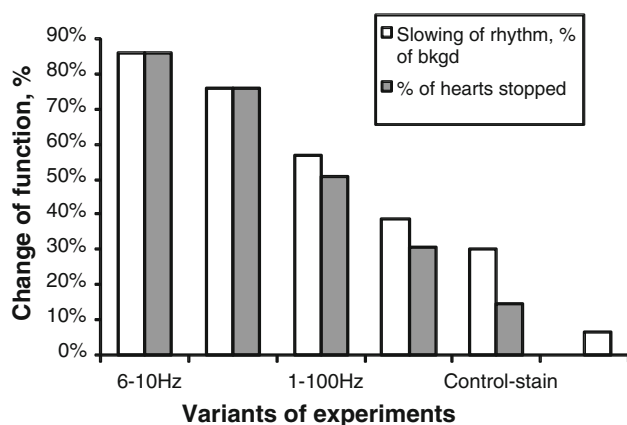


Fig. 1 Change in the number of beating and stopped isolated frog hearts, EM irradiated using the continuous regime and for various pulse modulations from 1 to 100 Hz

at 85% of hearts (at a continuous regimen—38%). The effects were particularly reversible.

Within 2–3 h after MP EMF exposure in neurons and muscle elements of heart, the violation of granule forming process was observed. The great number of neurons has gained the angle forms and diffuse coloring of a core and cytoplasm. In muscle fibers, the number of stain beads was diminished, cytoplasm was slightly tinted, and a number of muscle cores were also colored in intensively red color. Simultaneously, the appearances of a gelatinization of synapses on cells of a Ludwig node and intensive tincturing of Schwann cells in region of a taper of an axon were observed. Such results can speak about violation of vitality of the irradiated frames of heart and about the development of process of pyronecrosis.

Thus, in all series of the MP EMF irradiation of hearts with changeable frequency of modulations in range from 1 up to 100 Hz, it has rendered much major effect on function of heart, rather than irradiation in a continuous regimen of generating.

4 Long-term effects from mobile phone users

Forecast of development of a cancer in users of cellular (mobile) phones is a significant area of research. There are conflicting reports on the development of the brain tumors among users of MP.

Data on increased risk of brain tumors in mobile phone users were reported in numerous papers (Hardell and Mild 2003; Hillert et al. 2002; Lee et al. 2003). In a number of other epidemiological studies, however, such correlation was not reported (Ahlbom et al. 2009; Johansson 2008; Panda et al. 2007; Suvorov et al. 2002).

Summarizing the results of epidemiological studies, we concluded that there is no absolutely reliable evidence of brain tumors when exposed to EMF in people using MP for a long time. On the other hand, considered the results will not be eligible to make a definitive conclusion about the absence of such danger. An important decision of International Agency of Research on Cancer (IARC) on May 31, 2011, EMF states a mobile phone may have a carcinogenic effect on tumor (Johansen et al. 2002).

5 Mobile communications and health of children. Children are at the risk group

Currently, mobile phones are widely used by children. On one hand, it is necessary, on the other, it is an element of uncontrolled communication between children and finally is prestigious for the child to be the owner of an expensive mobile phone. For the first time during the whole period of

civilization it is the mass constant electromagnetic radiation of a critical system of the body—the brain and nervous structures of the inner ear of the child and adolescent (Grigoriev 2005). With the support of parents, children and adolescents are exposed to conditions analogical with professionals and are at risk of being in the zone of constant determining the impact of harmful type of radiation—RF EMF. In this case, the potential risk to the health of children is very high (Fig. 2).

We have additional arguments that suggest that children require special consideration when assessing risk:

- To know that children are more sensitive to all factors of the environment than the adult organism, “Children differ from adults. Children are uniquely vulnerable when they grow and develop, they have ‘windows of susceptibility’: periods when their organs and systems, perhaps especially sensitive to certain environmental factors” (WHO, Backgrounder 2003).
- Developing brain is exposed to irradiation during the formation of higher nervous activity;
- Today children will be using mobile phones for longer periods than adults of this generation.

The baby before birth is also exposed to EMF in the process of embryonic development. In the first days and months after birth, the baby may also be periodically irradiated with EMF as woman in labor at this time actively using the mobile phone and, as a rule, during feeding. In

addition, if a premature baby is born, when it is in the incubator, it is also subjected to electromagnetic radiation.

In children and teenagers the EMF RF short-term exposure may change thinking activity (Levallois et al. 2002; Salford et al. 1997), sleep (Huder et al. 2000; Hudnitskij et al. 1999), electrical activity of the (Hudnitskij et al. 1999; Koivisto 2000).

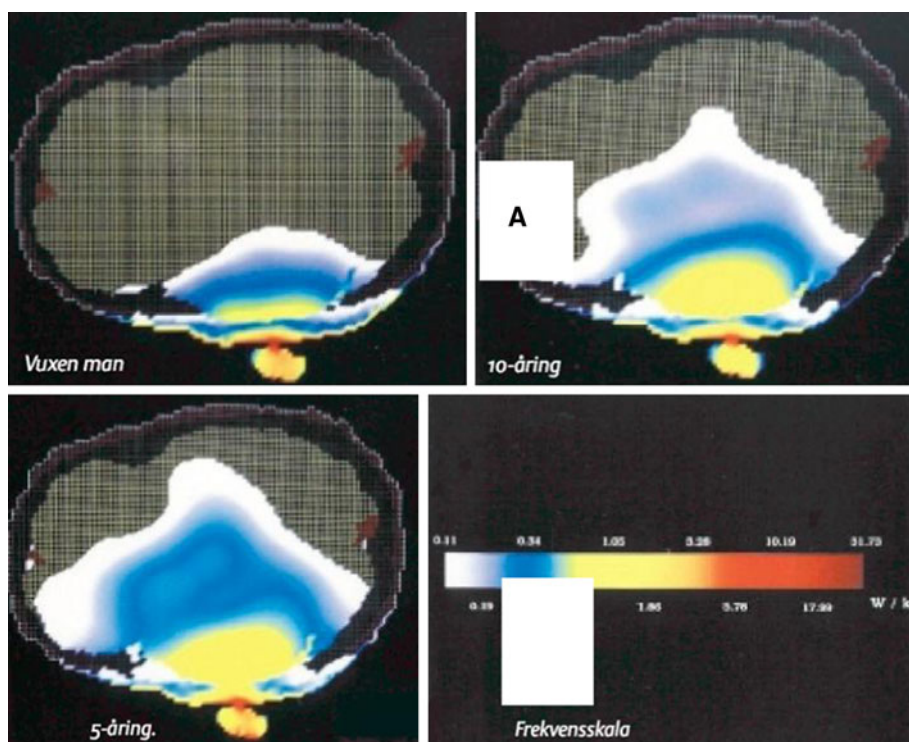
We have our own experience of long-term observation of children who are MP users. In 2006, we began long-term physiological studies of children of primary school who are MP users (supervisors of the study Grigoriev, Khorzeva).

It should be noted that in these studies, apart from the main group in which children use mobile phones, was formed a control group whose children did not have MP and did not use them. This is the world’s first study, which has “pure” control group. The study was performed at the Lyceum #10, Khimki, Moscow Region following the monitoring of psychophysiological indicators of child mobile phone use described elsewhere (Khorzeva et al. 2011a, b).

The cohort of children in grades 1–4 was formed. Complex diagnostics of neurodynamic characteristics of children included psychophysiological indicators, assessment of neuropsychological status and level of language development, as well as analysis of anamnestic and biographical data.

In 2010, the number of children under observation has reached 196 (147 in the test and 49 in the control group)

Fig. 2 The distribution of absorbed energy in the mind of an adult user and children age 5 and 10 years using a cell phone (Handhi et al. 1996)



aged 5–12 years. The observations of 147 children distributed as follows: 81 children—the first year of observation, 37 persons. The second year of observation, 28 children—the third year of observation and 1 person—4 years.

The following functional changes (preliminary results) in MP users have obtained:

- Fatigue (39.7%)
- Reduced ability to work in school and at home (50.7%)
- Decrease the stability of voluntary attention (production—14.3%, accuracy 19.4%)
- Weakening of semantic memory (accuracy—19.4%, increasing the time—30.1%)—change the speed auditory-motor reaction (55.5%)
- Violation of phonemic perception (all children-users)

Violation of phonemic perception authors interpreted as a deviation in the development, which affects the performance (Khorseva et al. 2011a, b; Klieceisew 2001).

In the study of Khorseva et al. (2011a, b) has been reported regular violations of phonemic perception. Similar results were obtained in India for the study of audition, but for the adult users of the MP (Preece 2002).

Thus, the preliminary results of three observations suggest that MP EMF may have a negative impact on psychological and physical health of children.

At the International Congress in London, was presented the material, which showed that if a child has been using the MP from being 8 to 10 years old, when reaches 21 years of his life he has 5 times more probability to develop brain tumors (Hardell et al. 1999; 2002). Thus, the children almost every day for a long time (years to maturity) is subjected to significant electromagnetic effects on their brain. At the same time mobile phones are not controlled sources of electromagnetic radiation.

There is no scientific data base for assessing the risk of this type of exposure. In fact, children are worst user of MP than the professionals. These materials and their analysis allow us to conclude that children are currently at risk group.

6 Mobile phones and the problem of standardization

At present the basis for regulatory standards for RF-EMF developed by ICNIRP, IEEE, CENELEC and some National Commissions were only on the results of experimental studies of generalized ICNIRP and IEEE criteria and received in terms of acute and thermal levels of RF-EMF (Bernhardt 1999; Chou et al. 2003). Based on this methodology, the evaluation of RF EMF, in which was based on thermal effects in RF-EMF acute exposure, a number of normative documents have decided: ICNIRP

Guidelines 1998, IEEE Stand. C95.1-2005, CENELEC EN 50166-2. 2000.

We have formulated the following public health postulate: “In developing the standards of hygiene for the population must be taken into consideration the actual conditions of the normalized impact factor in the population (local or total exposure, acute or chronic, single, continuous or repeated exposure, the functional significance “critical organ” or “critical system” of the body, the impact on all segments of the population or only to certain limited groups of the population” (Grigoriev 2008). In agreement with this postulate, we can make a clear conclusion: premises foreign regulations mentioned are not fully complying with basic hygiene requirements. In reality, the population has never found at high (thermal) RF EMF levels and even more in conditions of acute exposure. At present the population exposed to a constant around the clock to chronic exposure to EMF in the RF during their lifetimes and intermittent exposure of the brain frequencies.

Earlier in the Soviet Union and now Russia the evaluation of RF-EMF has taken into account the real situation of chronic exposure to population-based, above all, clinical and physiological data obtained in the conditions of professional activity, as well as experimental studies in animals, chronic exposure to low (no thermal) intensity. These methodological approaches take into account the effects of EMF only from base stations.

Domestic regulations are only general recommendations limiting the use of mobile phones by children and adolescents. The existing regulations do not incorporated real scientific data base, describing the possible long-term exposure RF EMF bioeffects of brain vast majority of all groups, including children.

7 The general conclusion

Mobile communications has become an integral part of our lives. All groups are practically exposed to significant electromagnetic radiation. For the first time large portions of civilization are daily fractional RF EMF irradiated brain mobile phone users. Children were included in the risk group and under the terms of the electromagnetic loads on the body can be equated to the professionals. Existing scientific baseline data to assess the electromagnetic safety of MT is not enough. No data on the possible development of long-term effects in children after prolonged exposure of the developing brain of EMF in the near field antenna are available. We must begin the study with “a blank sheet of paper”.

Radiobiologists, hygienists and scientists working in the field of basic sciences were not prepared for this situation,

to the emergence of a fundamentally new source of electromagnetic fields.

On the one hand, there is a total uncontrolled exposure of the general population, which can be considered as significant. On the other hand, we do not observe pronounced adverse effect of the EMF RF on health. However, we believe that bioeffects added and the process is latent.

In this regard, we must persevere in the relevant scientific research and have a sound regulatory framework that takes into account the changed realities of the electromagnetic effects on the population. The problem went on to develop morally unacceptable harm, especially when it comes to future generations. We are in the area of scientific uncertainty.

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