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ORIGINAL ARTICLE

Protect children from EMF

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Abstract

The twenty-first century is marked with aggressive development of the wireless communications (satellite, mobile phones, Internet, Wi-Fi). In addition to thousand of satellites that deliver radio and TV signals, large satellite and base station networks secure intensive instant delivery of audio and video information. It is fair to say that the entire civilization, both biosphere and mankind are exposed to continuous exposure of multitude of radiofrequency (RF) signals. It should be taken into account that the entire world population is exposed to exponentially increasing RF radiation from base stations and satellite antennas. While several years ago the potential hazard was connected with placement of mobile phones close to human head, today “smart phones” represent small, but powerful computers continuously receiving audio and video data. The largest group of users is the children and teenagers who “need” to communicate nearly 24 h a day. This is even more important because cell phones and tablets may be seen in the hands of children as little as two years in age. There is no way to assess and predict the potential damages of children brain, vision and hearing under exposure to RF radiation. The WHO precautionary principle and IARC classification must be applied in discussing the potential hazard of the use of today’s and tomorrow’s communication devices.

Keywords

Children protection, Wi-Fi radiation

History

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Life is an electromagnetic event

The contemporary natural sciences, such as biology, physics, geology possess convincing evidence that life on the Earth is an electromagnetic event. From the first primitive cell that originated in the presence of a number of physical factors with terrestrial and space origin, including magnetic and electromagnetic fields, to the twenty-first century structure of living creatures, various biochemical and physiological activities have been evidenced. Practically there is not a single biochemical process that is not connected with transport of charges. Even a small conformational change in a macromolecule leads to a charge redistribution and eventual very small electrical current (Markov, 1988).

The exponential increase of the industrial use of electrical power and the communication technologies place the biosphere and mankind in conditions dramatically different than in the middle of the twentieth century. These EMF are characterized with their continuous and comprehensive action through the entire living activity of any organism (Chizevskii, 1976; Kholodov, 1976; Pressman, 1968; Serduk, 1977).

By 2010 in the USA, 285 million mobile phone subscribers would have been registered (for a little bit more than 300 million inhabitants). The estimate for the world is more than five billion mobile phone users at approximately seven billion

people living on this planet. The latest prediction is that by 2017 one half of the world population will use Internet.

The fast development of satellite communications, followed by wireless communications and recently Wi-Fi technology dramatically changes the electromagnetic environment. To continuous action of complex and unknown (by sources, amplitudes, frequencies) electromagnetic fields are exposed entire biosphere and every organism living on this planet. It is usually neglected, the complex influence of radio and TV transmissions, satellite signals, mobile phones and base stations and wireless communications.

What we know about electromagnetic radiation?

First, we need to answer the question: Why radiation? The answer appears easy – because in physics every source of electromagnetic field is included in the category of radiation. Second, because of the nuclear physics and technology, a lot is known about the ionizing radiation. However, these are only superficial similarities.

Electromagnetic fields are frequently discussed under the umbrella “radiation” in the category of non-ionizing radiation. For that reason, the research of effects of electromagnetic field is going in parallel with studying the effects of ionizing radiation. As basic physics teaches, radiation constitutes energy, and for that reason the energy interactions with any physical or biological body is connected with damage or heating of the body structures when the intensity of the radiation is above certain threshold level. Yes, this is correct

for ionizing radiation. For decades the same approach has been applied in non-ionizing research. For example, the idea of thermal effects in bioelectromagnetics had been introduced and became the subject of intensive discussions, related to specific absorption rate (SAR) as useful criteria. It is clear that SAR requires a threshold value determination. We will return to the issue of thermal or nonthermal effects of EMF later in this paper.

What science actually knows about non-ionizing radiation? Basically NOTHING. Even the simplest and longer studied behavior of natural magnetic, electric and electromagnetic fields are far of complete knowledge.

More than 45 years ago, in 1976 brilliant Soviet magnetobiologist Kholodov wrote a book ‘‘Man in the magnetic web.’’ Long before the occurrence of mobile communications, Kholodov pointed out that the entire biosphere is immersed in the ocean of the electromagnetic waves.

Somebody may wonder why we are writing this section. There is one reason only – to demonstrate that for a long time science has knowledge about the complex character of the electromagnetic environment in biosphere. Unfortunately, one thing is what science knows, the other thing is what industry is doing in order to run novel technological advancement for wireless communications.

It was 20 years ago when Robert Kane published his book, *Cellular Telephone Russian Roulette*, which in a remarkable way presented the first years of development of cellular phone technology. The book provides information about the years of research preceding the introduction of mobile phones, including scientific findings of cancer initiation or DNA damage by microwaves. Those studies, published by respected scientists, have been quickly forgotten as the industry ‘‘spin doctors’’ discounted the importance of each finding. These studies are alarming in their findings of radiation exposure, DNA damage, chromosome damage, tissue damage, radiation absorption, cataract formation, tumor formation, memory loss, motor skills degradation, and more. ‘‘Never in human history has there been such a practice as we now encounter with the marketing and distributing of products hostile to the human biological system by an industry with foreknowledge of those effects’’ (Kane, 1995).

Thermal vs. nonthermal effects, emission, absorption, SAR

We want to emphasize in the very beginning that the potential hazard of the mobile communication is related more to the nonthermal effects of this physical factor, unknown to mankind until half a century ago. The cellular telephone delivers a power density of radiofrequency (RF) radiation about two billion times greater than that occurs naturally in the environment and living organisms did not develop mechanisms for protection against RF radiation. Since the mobile phones are designed to operate at the side of the user’s head, a large part of the transmitted energy is radiated directly into that person’s brain therefore influencing central nervous system.

The absorbed energy potentially could cause within the brain dangerous and damaging biological effects. The small

cellular telephones effectively deposit large amounts of energy into small areas of the user’s head and brain. However, this energy by all means is below the thermal threshold.

The ‘‘thermal’’ vs. ‘‘nonthermal’’ discussion will continue for several decades. It is based upon the consideration of ‘‘radiation’’. Yes, time varying electromagnetic fields are radiation since they have spatial and time characteristics. *If we assume that the RF effects have thermal character, the question arises ‘‘What are the threshold level, what is a temperature elevation that should be detected prior we conclude that ‘‘thermal’’ effect occurs.’’ Searching carefully the literature and all guidelines and standards we were unable to find such criteria. The engineering committees simply talk for thermal nature of biological and health effects and reject any notion that these effects might be non-thermal.*

However, unlike ionizing radiation, the biological effects of EMF have no threshold character. There is abundance of reports, both in basic science and clinical trials that weak electromagnetic and static magnetic fields cause observable biological responses. In magnetobiology literature have been published hundreds of papers discussing the genotoxicity and modifications in DNA and other important biological molecules.

Moreover, even in radiobiology it had been known for many years that the low doses of ionizing radiation may have significant effects on living tissues which do not have ‘‘thermal’’ character. Recently, Sage (2012) published a remarkable review of the similarity of low dose effects of ionizing and non-ionizing radiation on initiation of genotoxic effects and both types of effects are not thermal.

The major guidelines and standards established by the engineering community, IEEE (Institute of electrical and electronic engineers) in 2005 and ICNIRP (International commission on non-ionizing protection) in 2009 provide approach and terminology which are not accepted by physics and biological communities, but nevertheless remain the guiding rules (mainly for the industry).

Talking about ‘‘guidelines’’ and ‘‘standards’’ we should point the strange fact that most of the values in these models are derived using cubic form. The engineers forgot that in biology such forms do not exist. Moreover, it is easier to develop models with spherical than with rectangular geometry.

One can only wonder why these institutions speak about potential ‘‘health effects’’ of RF instead of ‘‘health hazard’’. The misuse of the term ‘‘health effect’’ completely neglects the fact that a physical/chemical factor could have either positive (beneficial) or negative (hazard effect). Probably, this is done by purpose not to alarm the general public about the hazard of use of microwave radiation in close proximity to the human brain.

One more point: the use of epidemiological instead biological data to support the statement ‘‘These studies have not provided any sign that RF EMF emitted by cellular phones increases the chance for carcinogenesis’’ (Nikita and Kiourri, 2011). We certainly do not agree, moreover the statement is incorrect.

The problem with assessment of thermal effects cannot be resolved by statistics. In principle, thermal effects in given

tissues are local and for many individuals are not detectable. Well, how thermal effects could be detected in cohort of hundreds or even thousand of individuals?

The information obtained by these numbers basically do not relate to biology, to the process of occurrence of one or another modification of the living tissue. But the epidemiological team claims “there isn’t consistent evidence for occurrence of the modification”. They also state “there is no conclusive and consistent evidence that non-ionizing radiation emitted by cell phone is associated with cancer risk” (Boice and Tarone, 2011). It is remarkable that this paper was published after IARC defined RF as “possible cancerogenic for humans”.

In 2012 one of us (Markov, 2012), discussed the fact that the long-delayed publication of the INTERPHONE data resulted in the strange situation: two groups of participants in this project published two papers that basically contradict each other. We are close to saying that the conclusion of epidemiological studies should not be trusted, especially that in most cases the investigators are funded by the industry.

Another critical point of consideration is that different tissues have specific absorption “windows” and epidemiology is not able to distinguish the effects of different RF fields.

At the same time, the energy absorption characteristics that make the 750 and 915 MHz frequencies so desirable for hyperthermia and diathermy treatments have the similar absorption characteristics that make the first cellular phone transmission band of 825–845 MHz so dangerous (Kane, 1995).

Let us remind to the readers that one of the first papers on the absorption of non-ionizing electromagnetic energy was published by Schwan and Piersol (1978), in which they connected absorption with the tissue composition. It is important to remember that this composition is a very complex one and varies from organ to organ, from person to person. From biophysics point of view, the energy absorption also depends on the depth of penetration for the specific frequency range (for 825–845 MHz the penetration depth into brain tissue is from 2 to 3.8 cm) (Polk and Postow, 1986).

These specifics were recognized early and for more than half a century, a very serious group of scientists have investigated the importance of SAR. The SAR is assumed to provide a measure of absorbed energy in a given tissue. **Absorption, not delivery.** This term is particularly advantageous since the energy absorption in biological bodies and specific organs is nonuniform and frequency dependent.

However, up today, SAR is more often used to describe the energy delivered by the source of the electromagnetic field. One can only wonder how a device may be characterized by SAR. Let us repeat, the SAR identifies the amount of energy that is absorbed in a gram of tissue. Therefore, any characterization of the delivered energy by SAR is false and should not be done. One cannot use SAR instead of the incident power density. It appears that the safety standards should include both incident power and SAR. In addition, in evaluation of potential hazard one must consider the SAR received by the specific target tissue/organ. We should not forget that continuous exposure to RF radiation could cause an accumulation of changes initiated by RF.

More than 40 years ago, Michaelson (1972) wrote “It should be understood that a cumulative effect is the accumulation of damage resulting from repeated exposures each of which is individually capable of producing some small degree of damage. In other words, a single exposure can result in covert thermal injury, but the incurred damage repairs itself within a sufficient time period, for example, hours or days, and therefore is reversible and does not advance to a noticeable permanent or semi-permanent state. If a second exposure or several repetitive exposures take place at time intervals shorter than that needed for repair, damage can advance to a noticeable stage.”

In other words, the repeated exposure of a particular body area, such as a small region of the brain, to a specific EMF signal could lead to irreparable damage. Having in mind the existence of “hot spots” for energy absorption, then each damaging exposure to RF radiation provides further new opportunities for damage to become permanent. Part of the problem is that an exposed person would never know of the penetration and damage. We will return to specific problems with the RF effects on children brain, but here need to be emphasized on the fact that the children’s heads are much smaller than the adult heads and therefore the potential for brain damage in children is much higher than expected in the adult models.

Another important issue is that different RF signals have different depths of penetration. It was first reported by Lin (1976) who concluded that 918 MHz signal constitutes a greater health hazard to the human brain than does 2450 MHz signal with a similar incident power density.

Aside from the thermal issues, the nonlinear properties of biological tissues could provide condition for conformational changes in various important biological molecules via nonthermal effects (Markov, 2006). These changes could modify the entire signal transduction cascade. From the physics and thermodynamics view point, biological tissues represent nonlinear systems (White et al., 2011).

Unfortunately, industry and government have chosen to concentrate the arguments about safety on the nearly impossible task of proving that low-level RF radiation does not cause cancer. Once again, today we know that low-dose non-ionizing radiation may have significant detrimental effects. If so, why one should expect that RF signals under “thermal threshold” can provoke hazardous biological responses.

It was not surprising that in 2011 WHO after careful consideration of scientific evidence classified RF from cellular phones as a possible cancerogene.

Children in today’s RF environment

It is known that human head is a complex structure of many different tissue types. Each of the tissues – skin, bone, cerebrospinal fluid, fat, brain, dura, etc. – absorbs and reflects RF energy in its own way. In addition, the human head is far from having uniform shape, volume, and structure.

Therefore, “hot spots” are to occur with RF exposure in the most sensitive parts of the head. Some of them depend on the radius of curvature of the human head. It is easy to assume that the radius of the curvature is different for a baby, a little child, a teenager, or an adult individual. In addition, RF

energy is absorbed within a fraction of a second which can be enough to modify the structure of selected brain cells and molecules.

Here we should clarify that the term “hot spot” does not mean “hot” in the sense of heating. The term indicates that the spot is most sensitive to RF radiation among the tissues and parts of the head. Following publication in literature one should be convinced that a small portion of EMF energy cannot produce heating capable of initiating conformational changes or alteration in signal transaction pathways.

Long before the introduction of cellular telephones, scientists obtained data indicating that children absorb approximately 50% more radiation within their heads than adults (Durney et al., 1978).

The nonuniform energy absorption was initially characterized by Schwan (1972). He suggested that as a child’s head diameter is smaller, the energy absorbing “hot spots” become more pronounced. Clearly, this indicates an increased risk of “hot spot” absorption within the brains of women and children, with small children being at maximum risk a “hot spot” absorption within their brains. It had also been reported by Schwan (1972a,b) that maximum “hot spot” energy absorption occurs in the frequency region around the cellular telephone frequencies. Remember, there were no cellular telephones in use at that time. However, these statements are still valid. The question is: *Why engineers prefer to forget them.*

Unfortunately, the engineering approach towards the hazard of RF for children does not take into account the specifics of child’s head. In ICNRP publication 66 of 1994, an adult human model was scaled for reference of 10-year-old child. In 2011 Nikita and Kiourri stated that “in the case of canonical models, the child model is perfectly proportional to an adult model”. This is possible only in theoretical (more likely mathematical) modeling where no one cares about the specifics of geometry, composition, and development of children head and brain. Koulouridis and Nikita (2004) obtained children model through uniform deformation of spherical adult head models. We should remind the engineers and mathematicians that neither adult head is spherical, nor the brain composition of adult and children is homogeneous. Several more recent publications on cell phone dosimetry in children (Christ et al., 2010a, b; ICNIRP, 2009) reported higher SAR for children brain which is correctly attributed to geometrical difference in the head of children and adults.

Very important is that children’ brain as the entire organism of children is in a process of development for many years and no one can predict the long-lasting problem that might occur as a result of exposure to RF in the early age.

Usually discussion about potential RF effects on human brain starts and ends with the probability of brain cancer occurrence. We believe that this is very superficial approach. Yes, brain is a major player in the central nervous system. *Main, but not the only.*

For the first time during the whole history of civilization, the most critical system of the body—the brain and nervous structures of the inner ear of the child and adolescent are exposed to unknown risk of RF EMF. In this case, the potential risk to the health of children is very high (Grigoriev, 2012).

Exposing brain and located in the inner ear nerve structures, such as receptors and transmission pathways (securing the normal functioning of hearing and vestibular analyzers) children undergo serious risk (Grigoriev, 2005).

Recently, Grigoriev and Khorseva (2014) published a 230 pages book “Mobile communications and children health” that summarizes the existing knowledge in potential hazard of RF on children. For objective reasons, most of 439 cited publications are on short time exposure. Even epidemiological data are concerning relatively short time of exposure. Grigoriev and Khorseva provided data of eight-year continuous psycho physiological investigation of school students that indicate alterations in the functioning of visual and hearing analyzers under RF mobile telethons exposure. It also reported the correlation between the RF exposure and worsening of cognitive functions.

Data are available also on the effect of RF EMF on children in prenatal period and in the first years of children development when they do not use mobile phones, but are exposed to signals in the environment (mostly when mother uses mobile phone).

Today, the world exhibits increased frequency of detection of autism in children in developed countries. A question arises – could this “epidemy” be related to elevated electromagnetic background?

However, the mobile phones are just a part of the problem. The fast development of satellite communications, followed by wireless communications and recently Wi-Fi technology dramatically changes the electromagnetic environment. To continuous action of complex and unknown (by sources, amplitudes, frequencies) electromagnetic fields are exposed entire biosphere and every organism living on this planet. We usually neglect the fact that radio and TV transmissions, satellite signals, mobile phones and base stations, wireless communications generate and propagate variety of signals that act simultaneously.

Talking on the potential hazard of Wi-Fi technologies, one should not forget that it includes not only mobile phones, but what is more important – all means of emitters and distributors of Wi-Fi signals, mainly antennas, base stations, satellites. In many public locations, internal systems are introduced in order to facilitate the work performance. Well, this might be understood. However, why Wi-Fi communications are secured in the subway tunnels? It obviously requires high and oriented power to which are exposed all passengers in the trains. Just to make comfortable the users of mobile phones or other Wi-Fi gadgets. And again and again – the largest cohort of users of these items are children.

It is clear now that this popular technology that allows an electronic device to exchange data wirelessly (using RF signals) including high-speed Internet device that use Wi-Fi can be connected to a network resource such as the Internet via wireless network access points that have a range of about 20 m indoors and a greater range outdoors.

Generally speaking, it is not known to which extent the Wi-Fi radiation alters physiology of normal, healthy organisms. The situation became more complex when we are discussing the influence on children, on aging adults or on sick individuals. Especially for children we should consider that they are exposed to all spectrums of EMF pollutants in the

biosphere and for them such electronic toys as cell phones, tablets and wireless games are very attractive. Due to the age specifics, children cannot evaluate the potential hazard of the mobile phone. Rather they consider it as a wonderful tool for communication and entertainment. Taking into account the technological development in the wireless communications, will be fair to say that children at the age of 3–4 will be using mobile communication for many more years and with longer daily duration than their parents in the respect of entire life (Markov and Grigoriev, 2013).

It is reasonable to remind the position of the WHO “CHILDREN ARE DIFFERENT FROM ADULTS”. Children have a unique vulnerability. As they grow and develop, there are “windows of susceptibility”: periods when their organs and systems may be particularly sensitive to the effect of certain environmental threats (WHO, Backgrounder N 3, 2003, 5 p.).

Unfortunately, there is lack of scientific data and analysis of the estimation of the potential hazard of mobile communications. Nobody has thoroughly investigated potential damages in the brain of children which potentially could occur in their developing brain. (Grigoriev, 2005; Grigoriev and Khorseva, 2014; Markov, 2012). Studies of potential of development of the long-range modification of the brain functions in children whose brain have been exposed to continuous irradiation with high frequency EMF are completely absent. Therefore, we should start from zero. At the same time international and governmental agencies responsible for standards are slow in responding to the exponential growth of technologies and in principle completely neglect the hazard for children (Grigoriev, 2008; Markov, 2012).

Precautionary principle and children health

We had participated in a series of International meetings organized by Michael Repacholi in the late 1990s and early 2000s on harmonization of standards. These meetings were held under the umbrella of WHO “precautionary” principle. There were enough reasons to approach the RF from mobile communications with a fear, with skepticism. It is difficult to accept that we are cautious when trying new food or new drink until it is found that the food or drink is suitable for us, but we easily accept any new technological development. Moreover, we are happy and proud with the new electronic tool. For birthday or for Christmas more and more children receive electronic gifts – cell phones, tablets or even laptops.

Very few parents are aware about the potential hazard for their children when RF driven electronic toys are in the hands of little boy or girl, who even cannot read yet. We would like to finish this paper with an appeal to parents – be cautious with new electronic tools. Follow a couple of simple rules and educate your children how to use these fancy items:

- Consult the store personnel about the EMF from any device you plan to purchase
- Read in the store instructions for use. Especially small prints
- Explain to your child how to use the electronic item
- Make sure that the child understand the necessity to keep the device away from the brain and genitals

- Be sure that during the night electronics is away from the child (better outside the room)
- Specifically, be careful that the electronic device is not under pillow of the child

These “rules” could be continued, but the most important is to apply a precautionary principle and prevent any potential hazard and damage from the use of mobile communication device. Everybody should remember that any new generation of smart phones is essentially a more powerful computer that constantly receives and transmits data.

In conclusion: two general problems

As it was shown above, the development of mobile communications, Internet, Wi-Fi and other wireless communications place the mankind in complicated electromagnetic background. Unfortunately, the elevation of the levels of electromagnetic pollution leads to less strict regulations in the wireless communications. Let summarize two important problems: precautionary principle and epidemiology in the evaluation of the hazard of RF exposure.

Precautionary principle was briefly described above. The WHO has this term in the various documents, and it was in the background of the EMF project of the WHO. European Union suggests applying *precautionary principle when there are reasonable grounds of concern*.

However, while European Union clearly supports this principle, the USA basically rejected it. European Union takes a step further identifying the role of government for implementation (including financially) of the precautionary principle. Unfortunately, at 21 August 2014 the Center for Disease Control and Prevention removed from the “Frequently asked questions about cell phones and your health” the precautionary advice (WHO, 2014).

Epidemiology cannot be criteria for biological and health hazard, especially when the mechanisms of action of RF from wireless communications are considered as “thermal effects”. It is not possible thermal effects to be a subject of statistical elaboration.

Obviously, a lot is supposed to be done in evaluation of potential hazard of wireless communication for population and especially the hazard for children.

Declaration of interest

The authors declare no conflicts of interest. The authors alone are responsible for the content and writing of the article.

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