

EFFECTS OF ELECTROMAGNETIC RADIATION OF MOBILE PHONES ON HUMAN ORGANISM

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Abstract:

At present, dozens of scientists are inquiring into the effects of mobile phones on our health. Some of them believe that their long-term use increases the risk of developing cancer, Alzheimer's disease, alters the secretion of certain hormones or reduces immunity. About a half of the previous studies did not produce any results, and the other half indicated that radiation from mobile phones may have a negative effect. However, the fact remains that there is no direct evidence of the harmful effects of this radiation. Nevertheless, it should not be forgotten that it has repeatedly happened in history that a chemical substance was considered to be harmless and finally the very opposite was shown. An example might be asbestos, which we often used to meet in everyday life and now ranks among the most dangerous substances. The present paper draws attention exactly to the sphere of negative impact as well as to possible elimination of this radiation.

Keywords:

Electromagnetic field, radiation, mobile phones, health

INTRODUCTION

In the early twenty-first century, we are witnessing the rapid development of wireless information technologies. This century might as well be called the century of wireless revolution, providing us more rapid, more eventful and more comfortable life. Every day we are exposed to innumerable sources generating electromagnetic fields (EMF). It would be interesting to count how many times a day we are in close contact with or in the near zone of electrical machines and of technological equipment generating electromagnetic radiation. As a result of this fact there are various safety measures that should lead to reduction of magnitude of the EMF and/or to reduction of the stage of loading by EMF, surrounding us daily more and more.

The issue of the impact of the electromagnetic field on living organisms has been intensively examined for the past more than 40 years and the effects and consequences of the action of such field have still not been unequivocally specified. A demonstration of the negative effects (cancer, mental disorders, damage of body organs, etc.) would have a dramatic impact on the present life of the contemporary man who is daily exposed to electromagnetic fields of different intensities from various sources. At present, the effects of EMF are in particular studied by the World Health Organization (WHO) and the International Commission on Non-Ionizing Radiation Protection (ICNIRP), which have stipulated **that electric equipment must meet certain limits and must be electromagnetically compatible in order to be used in practice without endangering human health.** [1]

FREQUENCY SPECTRUM

Extensive statistical data have shown that electromagnetic fields are biologically active in their entire frequency range, i.e. they interact with living matter. Electromagnetic fields are divided into non-ionizing and ionizing radiation, see (Fig. 1). **The cut-off frequency is 3.10^{15} Hz.** The present paper focuses on non-ionizing EMF in the range of 0 to 10^{15} Hz, i.e. the part of the ultraviolet, visible and infrared radiation, microwaves, radio frequencies and low-frequency electromagnetic fields. [2]

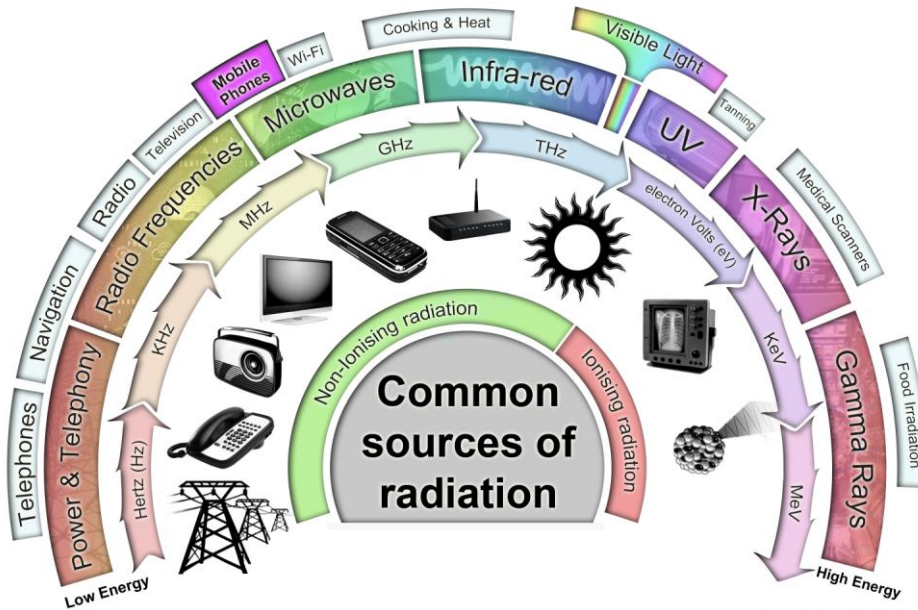


Figure 1: Common sources of radiation

EFFECTS OF RADIATION FROM MOBILE PHONES

Mobile phones are low-power microwave devices transmitting and receiving signals from a network of stationary base stations operating with higher output power. The original mobile phone system used analogue signals for communication between handheld devices and base stations, but now they are rapidly replaced by digital systems. At present, most mobile phone systems operate on frequencies from 800 MHz to 2 GHz, but it is likely that in the future higher frequencies will be used as well. It is possible that within a distance of several meters the limit values of exposure at some antennas of base stations are exceeded, but these are usually mounted on poles or on top of buildings.

Until there was a massive expansion of mobile phones, the public was exposed to emissions of radio frequencies very rarely and these were practically emissions of radio and television broadcasting. However, these signals are weak, often 1000 times lower than the recommended limit values. Finally, even today the mobile phone masts increase the overall exposure only very moderately, because the intensity of the signal in the layers close to the ground is in the same range as in the case of radio and television and often it is even lower. However, mobile phone users are exposed to radio frequencies of a far higher order. **In these cases the exposure values can significantly approach the limit values.**

Although the majority of modern mobile phones (such as those using GSM technology) generate field intensity, which is below the recommended values, a mobile phone user is exposed to radio frequencies several orders of magnitude higher than those normally encountered in a normal environment.

Table 1: Frequency spectrum and incidence of ionizing and non-ionizing radiation

INCIDENCE			WAVELENGTH		NAME OF THE FIELD	TYPE OF THE FIELD
Radioactive decay, radioisotope tracking			corpuscular α , β ; cosmic radiation, protons, mesons		Fast particles	Ionizing
Diagnostics, therapy, radioisotope tracking			γ radiation X-rays		Electromagnetic radiation	
The Sun, artificial sources			ultraviolet radiation	UV A		
				UV B		
				UV C		
Everywhere			visible radiation infra-red (thermal) radiation	IR A		
				IR B		
				IR C		
Radar, heating, telecommunications, satellites, data transmission			millimetre waves			
			centimetre waves			
Television, mobile phones, radar			ultra-high frequencies			
FM radio, radar			very high frequencies			
SW radio, high-frequency heating			10 m to 100 m waves			
AM radio			medium and long waves			
Special communications, geophysical exploration			very long waves			
Light current equipment, TV and PC screens			field with frequencies over 30 kHz		Electric and magnetic fields	
Technological equipment, induction heating			low-frequency field (100 Hz to 30 kHz)			
Transformers, electric heating, electrical appliances			electric and magnetic fields with frequency of electric network (50 Hz)			
Trolleybuses, subway, tramways			Very slowly variable fields			

Because mobile phones are used in the vicinity of the head, it is not quite right to compare the intensity of the radiated field with the derived recommended values. Instead, it is necessary to determine in this case the energy absorbed by the head of the user. A sophisticated computer model of the mobile phone and of the head, as an interconnected system, should provide reliable information about the absorbed energy. The output power of the majority of handheld digital devices is much lower than 1W and performances of the older analogue devices are mainly limited by battery life. Because of these power limitations, it can be assumed that modern mobile phones do not generate absorbable energy at above-limit levels in terms of accepted recommended values. **However, contact with the head and the antenna during a phone call increases the amount of radio frequency energy that should be received by the antenna of the base station.** This then sends a signal to the device to increase the output power, which in turn results in a further increase of energy absorption by the head until the contact of the head with the antenna is interrupted. The increasing use of mobile phones has raised public concern of possible long-term health consequences. The European Commission has set up a panel of experts that should review the current situation and consider directions for future research. The established panel of experts states in its report that it is unlikely that a definitive answer to the questions related to the health effects of mobile phones would be obtained in foreseeable future. The panel of experts believes that an increased number of well-designed and well-conducted studies could provide a sufficient amount of reliable information giving evidence that this type of device does no harm to human health. The panel of experts recommended carrying out further studies of biological effects and of adverse effects of mobile phones on human health. The ICNIRP has taken a stand on the issue of the impact of mobile phones and base stations on health, which was

published in its statement. **In its statement the Commission concludes that there is no unequivocal evidence of an increased risk of cancer, but that the results obtained so far speak for continuing research in this sphere.** WHO within its international project dedicated to issues of electromagnetic fields is cooperating with the European Commission, ICNIRP and other international institutions and national authorities on addressing the issues related to the impact on human health caused by the exposure to radio frequency fields emitted by mobile phones and their base stations. Microwaves are used for transmitting data, where parabolic microwave antennas generate directional straight beams of rays used for data transmission. They operate at frequencies from 2 GHz to 40 GHz. Parabolic antennas are mounted on buildings or on towers, and because the beam diameter is small, exposure can be taken into account only in the case of exposure to the main beam, which is only possible at a distance of hundreds of meters from the antenna. The output power used in this case is low (sometimes up to 8 W, but often less than 1 W) and the exposure of the population will be far less than the prescribed limits.

PROTECTING THE POPULATION AGAINST THE EFFECTS OF RADIATION FROM MOBILE PHONES

For assessing the harmfulness of electromagnetic radiation of electronic devices on the human body, appropriate Slovak technical standards (STN) have been worked out, which determine exposure values for the population and/or employees affected by that radiation and stipulate maximum exposure values as basic preventive measures against damage to their health. The European standard ENV 50166-2, elaborated by the European Committee for Electrotechnical Standardization (CENELEC) in 1995 [3] and adopted by the European Union (EU), can be considered as the basic document for the field of high frequency electromagnetic radiation (10 kHz to 300 GHz).

Recommendations of this standard have been verified and gradually accepted in every particular state of the EU. Following the above mentioned standard, issues related to electromagnetic radiation of electronic equipment in the Slovak Republic have been addressed in the following legislative documents:

- Act. № 355/2007 Coll. on protection, support and development of health and on amendment of certain laws,
- Regulation of the Government of the Slovak Republic № 329/2006 Coll. on minimum health and safety requirements for the protection of employees from risks related to exposure to electromagnetic field,
- Decree of the Ministry of Health of the Slovak Republic № 534/2007 Coll. on details and requirements for sources of electromagnetic radiation and for the limits of exposure of population to electromagnetic radiation in environment.

Based on the above-mentioned laws the so-called action values of continuous exposure to electromagnetic fields produced by radiation from mobile phones can be established. For the inhabitants of the Slovak Republic the following variables and their action values are applicable:

1. Intensity of the electric field E , for which the action values E_A for the frequency band of 400 MHz to <2000 MHz are determined by the relation [4]

$$E_A = 1,375 \sqrt{f \text{ MHz}} \text{ [V/m]}, (1)$$

where: $f \text{ MHz}$ is the frequency of the carrying radiated electromagnetic energy [MHz].

For radiation of mobile phones in the frequency band of 900 MHz the value $E_A = 41,25 \text{ V/m}$ and for 1800 MHz it is $E_A = 58,33 \text{ V/m}$.

2. Intensity of the magnetic field H , for which the action values H_A for the frequency band of 400 MHz to <2000 MHz are determined by the relation [4]

$$H_A = 0,0037 f_{\text{MHz}} [\text{A/m}]. \quad (2)$$

For radiation of mobile phones in the frequency band of 900 MHz the value $H_A = 0,111 \text{ A/m}$ and for 1800 MHz it is $H_A = 0,157 \text{ A/m}$.

3. Magnetic induction B , for which the action values B_A for the frequency band of 400 MHz to <2000 MHz are determined by the relation [4]

$$B_A = 0,0046 f_{\text{MHz}} [\mu\text{T}]. \quad (3)$$

For radiation of mobile phones in the frequency band of 900 MHz the value $B_A = 0,138 \mu\text{T}$ and for 1800 MHz it is $B_A = 0,195 \mu\text{T}$.

4. Flux density of the output power of the equivalent plane wave S_{eq} , for which the action values S_{aeq} for the frequency band of 400 MHz to <2000 MHz are determined by the relation [4]

$$S_{Aeq} = f_{\text{MHz}}/200 [\text{W/m}^2]. \quad (4)$$

For radiation of mobile phones in the frequency band of 900 MHz the value $S_{aeq} = 4,5 \text{ W/m}^2$ and for 1800 MHz it is $S_{aeq} = 9,0 \text{ W/m}^2$.

The above-mentioned values of electromagnetic field are mutually equivalent (for carrier frequencies $f > 10 \text{ MHz}$ it is sufficient to evaluate one of them) and their action values are for the needs of evaluation of the exposure period related to a **6-minute interval**.

In the European standard ENV 50166-2 there is another quantity defined, by means of which it is possible to evaluate the emission of electronic equipment in the frequency band of 10 kHz to 300 GHz. It is the so-called “specific absorption rate” termed SAR (Specific Absorption Rate).

SAR is defined as the time derivative of the energy gains (dW) absorbed in increments of mass (dm) contained in volume (dV) with specific density ρ , by the relation [3]:

$$SAR = \frac{d}{dt} \left[\frac{dW}{dm} \right] = \left[\frac{dW}{\rho \cdot dV} \right] \quad \text{W/kg} . \quad (5)$$

By using the electric field intensity E , it is possible to express SAR for the frequencies $f > 10 \text{ MHz}$ of the carrying radiated electromagnetic energy by the relationship [5]:

$$SAR = E^2 \frac{\sigma}{\rho} \quad \text{W/kg} , \quad (6)$$

where: σ is the conductivity of the environment, in which the electromagnetic energy is propagated [S/m], ρ is the specific density of the environment, in which the electromagnetic energy is propagated [kg/m^3].

According to the European standard ENV 50166-2, for the use of mobile telecommunication devices (hence also of mobile phones) the recommended maximum SAR is of 2 W/kg , at the same time all SAR values are to be averaged over any 6-minute period.

Another important fact, which has to be taken into account when using mobile phones is the depth of penetration d of the electromagnetic energy into the tissue of the head of the user. It is determined by the relationship [6]:

$$d = \frac{1}{\omega \sqrt{\frac{\epsilon_H \mu_0}{2}} \sqrt{\sqrt{1 + \left(\frac{\sigma_H}{\epsilon_H \omega}\right)^2} - 1}} \text{ m} . \quad (7)$$

where: $\omega = 2\pi f$ is the angular frequency of the carrying radiated electromagnetic energy [Hz], $\epsilon_H = \epsilon_0 \cdot \epsilon_r$, $8,854 \cdot 10^{-12} \cdot \epsilon_r$ is the permittivity of the tissue of the head [F/m], where for the frequency band of 900 MHz $\epsilon_r = 41,5$ and for the frequency band of 1800 MHz it is $\epsilon_r = 40,0$ [5], σ_H is the conductivity of the tissue of the head, where for the frequency band of 900 MHz $\sigma_H = 0,97$ S/m and for the frequency band of 1800 MHz it is $\sigma_H = 1,40$ S/m [5], $\mu_0 = 4\pi \cdot 10^{-7}$ is the permeability of vacuum [H/m].

According to (7) the depth of penetration for the frequency band of 900 MHz is $d = 3.62$ cm, and for the frequency band of 1800 MHz it is $d = 2.43$ cm. The distribution of the intensity of electric field E of the electromagnetic radiation of mobile phones in the tissue of the human head is shown in (Fig. 2).

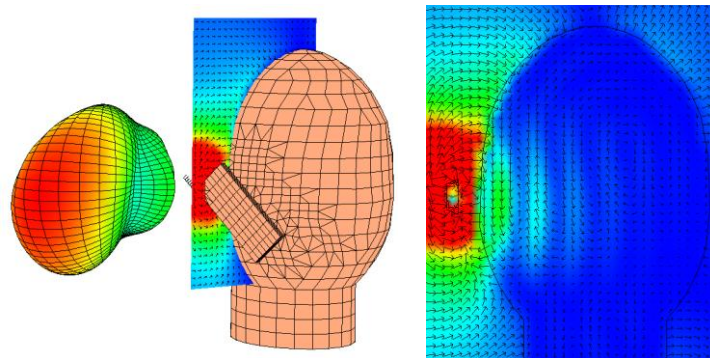


Figure 2: 3D radiation diagram and E field distribution outside the head and 2D electric field distribution inside and outside the head. Frequency: 900 MHz

If we take into account the typical location of the phone and of the head, we find that the most irradiated parts of the head are those contained within the near field, that is, the area above and behind the ear, on the side where the mobile phone is used. This applies for the analogue mobile phone. The situation with the digital phone is a little bit different, given that this kind of mobile phone uses more frequencies. This means that the limit of the near field is not concentrated into one point, but due to several frequencies it is concentrated into several points.

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STUDIES ON THE IMPACT OF MOBILE PHONES ON HEALTH

Norwegian and Swedish scientists say that they have found a possible link between the use of the mobile phone use and fatigue, headaches and burning sensation of the ear and skin. This is confirmed by the study, which was conducted by Dr. Gunnhild Oftedal from the Norwegian Technical University in Trondheim and by Swedish scientists. The research was conducted through questionnaires that were distributed to randomly selected people from a list of mobile operators who used a mobile phone for their work. 12,000 questionnaires were sent out in Sweden and 5000 in Norway. 7,803 Swedes and 3,828 Norwegians returned completed questionnaires. The evaluation of the questionnaires revealed that 31% of Norwegians had encountered at least one of the symptoms, as opposed to 13% of Swedes. The reason for this large discrepancy is the difference in the number of questionnaires and the difference in the nature of the population. Symptoms reported by both groups were similar. Ear

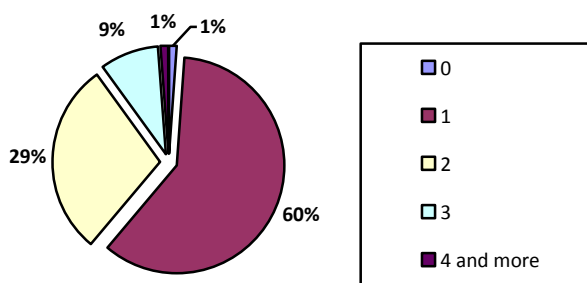
burning sensation was noticeable during calls. Other symptoms such as headache, appeared within 1.5 hours after the call and persisted for 2 hours. 48% -78% of Norwegians indicated, depending on the type of the symptom, that the call had to take 5 minutes or more in order to induce the symptom. The same fact was also observed by Swedish respondents, where the ratio ranged from 38% to 68%, depending on the type of the symptom. **The Danish Cancer Society** published a study, which denied a link between the use of mobile phones and emergence of tumors of the brain. Data from Finland, Norway and Sweden between the years 1974 and 2003 were analyzed, with focus on the years 1998 to 2003. This study examined the time span of about five years, when there was maximum increase in mobile communications. **In 2007, the National Institute of Sweden, published the results of a research** led by Kjell Hansson Mild, carried out on a sample of 4400 persons. The results showed that people who used a mobile phone regularly for ten years, approximately for one hour per day, experienced increased incidence of certain types of malignant tumors by up to 240 per cent.

What is the conclusion? The majority of studies carried out so far failed to demonstrate a clear negative impact of mobile phones on human health. Most of them, however, were carried out for a short time only and some of the longer lasting research projects show that mobile phones still have an impact on our health.

A SURVEY OF THE USE MOBILE PHONES

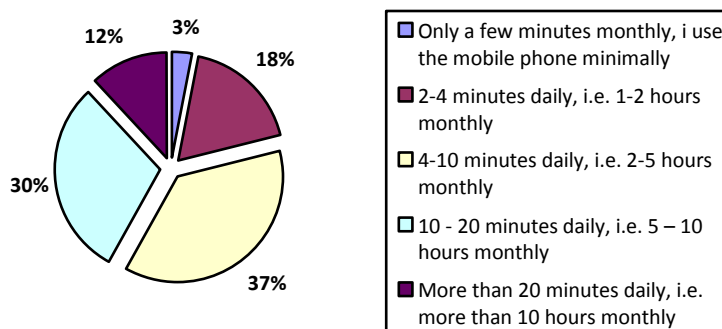
According to existing statistics, the number of mobile phone users all over the world is above 1.5 billion. 130 randomly selected respondents answered a few simple questions about the use of mobile phones.

How many mobile phones do you actively use?



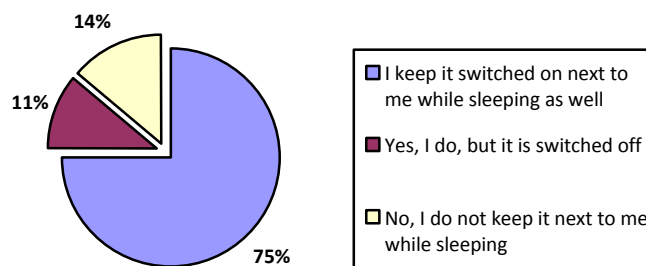
Comment: Respondents were asked about the number of mobile phones used by them, the result is a clear indicator that today's life is almost impossible without this device. Approximately 60% of respondents use only one mobile phone, but it is surprising that people actively use several mobile phones. This phenomenon may be a consequence of the active presence of three mobile network operators in the Slovak market, each of them offering favourable conditions for phone calls within its own network.

How many hours on average do you call from your mobile phone for 1 day / 1 month?



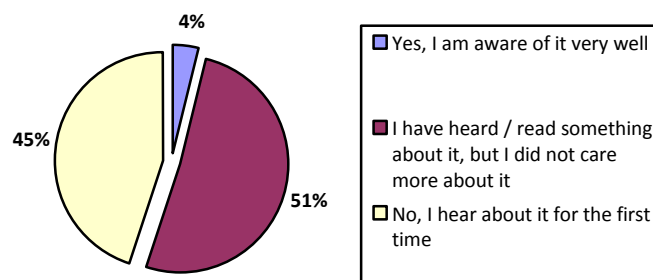
Comment: It is evident from the survey that the approximate duration of phone calls in minutes per day / an hour per month is greater than acceptable. Up to 12% of respondents are on the phone on average for more than 20 minutes a day / 10 hours per month, which is definitely above the recommended limit values. Another question from the questionnaire shows the regularity of phone calls longer than 10 minutes. Up to 67% of respondents are on the phone longer than 10 minutes, on a regular basis every 2 to 3 days. According to various scientific studies, the length of phone calls, i.e. holding a mobile phone emitting electromagnetic radiation right next to the head is one of the factors that can lead to negative effects on the human body, especially the brain and the eyes. The aforementioned negative effects may also have carcinogenic nature.

While sleeping, do you keep your mobile phone switched on in the vicinity of your bed?



Comment: The mobile phone is perceived in the modern era as a device, which we need to have at hand at all times. It is a device that in addition to convenient communication offers us other conveniences; it can be used as a camera, a game console, GPS navigation, and also as an alarm clock. Up to 75% of respondents fall asleep each night with their mobile phone switched on close at hand. The most convenient place for storing the mobile phone close to the bed is apparently the bedside table, thus the head of those people is about 50 cm away from the potential source of electromagnetic radiation at night.

Are you aware of the potentially harmful effects of electromagnetic radiation, the sources of which are all appliances and devices in your vicinity, which you regularly use?



Comment: Respondents were also asked whether they were aware of the potential harmful effects of electromagnetic radiation, the sources of which are all equipment and appliances in their households. As a result, we have seen the ignorance of people and/or their lack of interest in facts, which can extend and improve their lives. The issue of the potential health hazards and harmful effects of electromagnetic radiation will never be mentioned on the package, in which we buy the source of radiation, unless required to do so by law. This, however, is a long-distance run. The law limits the amount of radiation that the device can produce and giant companies producing enormous numbers of these devices will never agree with displaying a warning to the consumer on the package as it happened with cigarettes. The effects of radiation are certainly not positive, maybe they are negative, but time will tell the truth. It seems that people expect correct laws, properly determined limits, and considerateness of producers who prefer healthy people to their own profit. In addition to that, we encounter views of people responding to any issue of potential health hazards induced by modern technologies by simply stating that little by little everything around us is harmful, and therefore it does not make sense to protect ourselves. Maybe this is the reason why 51% of respondents had no interest in the past to be more informed when they learned about the issue of negative effects of electromagnetic radiation.

This survey shows, albeit indirectly, that the majority of mobile phone users use these devices in excessive quantities or regularly stay in their immediate vicinity. Therefore, they should, in the interest of protecting their health and the environment, in which they live and work, practice certain measures focused on reducing adverse effects.

CONCLUSION



Electromagnetic radiation is all around us. Wireless phones, Internet, mobile phones and transmission towers used for their operation spring up like mushrooms. People use these devices daily and to avoid exposure to electromagnetic radiation is practically impossible. And since the number of electromagnetic radiation sources increases every year, we are getting into a situation when caution is important. In order to protect our own health, it is appropriate to use all available means and facilities to eliminate electromagnetic radiation around us.

ACKNOWLEDGEMENT

The paper was prepared with financial support from Grant Agency VEGA 1/121/12 and KEGA 049TUKE-4/2012.

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	<p><i>3rd ICEEE International Scientific Conference on Environmental Engineering 20 – 23 November 2012, Budapest, Hungary Óbuda University Rejtő Sándor Faculty of Light Industry and Environmental Protection Engineering</i></p>	
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