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ARTICLE

Low Intensity Microwave Fields and Radiation and Their Interaction with the Human Body

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ABSTRACT

Sources of low-intensity microwave signals formation, which affect the metabolism processes when they interact with human body, are considered in the article. It's noticed that increasing intensity level of the technogenic signals in environment significantly exceeds natural electromagnetic fields and radiation (EMR). The peculiarities of the registration and measurement of low-intensity signals parameters of the microwave range are considered. The processes of the interaction of the microwave signals and human organism are analyzed. Formation mechanisms of the positive and negative microwave flows of the electromagnetic radiation are revealed. Particularly, possible formation mechanism of the microwave EMR fluxes of implants in the human body. The results of the experimental study of the EMR signals levels of the objects contacting with human body, partly materials for bone defects replacement and soft tissues regeneration so as materials for physiotherapy, are given. The use of the term "electromagnetic compatibility" for materials which contacting the human body, is proposed. The expediency of its use is proven. Microwave properties of materials for clothes, minerals and building materials, which can affect the human body and environment, have been also studied.

1. Introduction

1.1 Natural and Technogenic Sources of Microwave Radiation

There is a wide range of the electromagnetic signals of the Sun and space at all which irradiate the Earth. This spectrum covers the range from ultraviolet radiation (UV) with a wavelength of 180…400 nm to long-wave signals in the radio frequency range. Most of the signals in the UV range are absorbed by the Earth's atmosphere, and signals with longer wavelengths pass freely through the Earth's atmosphere.

UV signals are characterized by significant quantum energy (3.1…6.2 eV) and can have both a positive effect (bactericidal effect, increase immunity response, stimulation of photochemical synthesis of vitamin D, other therapeutic effects) and negative (burns, stimulation of processes that cause gene mutation and skin cancer, etc.) [1,2].

The visible part of the spectrum covers optical electromagnetic radiation in the range of 400-750 nm, and

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infrared (thermal) with a wavelength greater than 750 nm. The energy of the quanta of this radiation is less (2.95-1.24 eV), but the depth of penetration into the human body increases, which are widely used in various spheres of human life, in particular for the diagnosis and treatment [3,4].

If the protective reaction of the human body from UV radiation is manifested in the form of tanning on the skin surface, the optical signals of the visible and infrared ranges are better absorbed and more affect the deep layers of skin and inner organs, which is typical for the microwave range, too.

Particular attention should be paid to electromagnetic radiation of cosmic origin in the millimeter range (frequency 30…300 GHz), which includes microwave relict radiation with a maximum intensity at a frequency of 160 GHz [5].

The energy of the quantum signals of the mm range is much less than the signals of the optical range (10^{-5}… 10^{-4} eV), so their effect on the human body at equivalent power will be softer. The Earth's atmosphere selectively responds to frequencies in the microwave range, attenuating most of them, and at some frequencies, in the so-called "transparency windows", some microwave signals are transmitting without changes. The main reasons for the mm signals weakening passing through the atmosphere are their absorption, including resonant, by molecules of water, steam and oxygen. Microwave signals of cosmic origin can be characterized as primary. Solar radiation in the infrared range, passing through the atmosphere, gets to various objects on the earth's surface - water, soil, sand, stones, forest and grass cover and heats them.

It is known that any physical body emits electromagnetic waves in a wide range of frequencies when heated. Such thermal radiation is a noise-like, and the distribution of its energy density by frequency is described by Planck's law.

The maximum temperature of the earth's surface objects when heating can reach ≈ 50 °C. This leads to the formation of low-intensity microwave signals, which can be characterized as secondary.

Man-made (technogenic) sources of electromagnetic microwave radiation (EMR) should include generating structures for mobile communications, special military radio systems, generators for microwave therapy, etc.

Such sources create a significant electromagnetic background in the environment. The power level of signals from such sources ranges from tens of mW to 10^{-6} W [6,7]. At the same time, for microwave therapeutic generators, this level can be less than 10^{-6} W [8,9]. Electromagnetic saturation (pollution) of the ether of the environment is carried out mainly by permanent man-made means of communication and will increase in the future, due to the launch of new mobile communication systems 4G and 5G [10].

1.2 Features of Registration and Measurement of Low-intensity Microwave EMR

Primary and secondary microwave radiation are weak natural electromagnetic signals that constantly irradiate living organisms in their area of influence.

The power of such signals can be determined by Rayleigh-Jeans law.

$$P = 2\pi\beta\left(f,T\right)\frac{f^2}{c^2}kT_oS_0\Delta f \, , \quad (1)$$

where $k = 1,38\cdot10^{-23}$ J/K - Boltzmann constant; T - thermodynamic temperature of the object; f - radiation frequency; $\beta\left(f,T\right)$ - the coefficient of emissivity of the object (for grey bodies $\beta < 1$); Δf - the bandwidth of a measuring device, such as a highly sensitive radiometric system, S_0 - the area of the analysis surface, which is limited by the aperture of the receiving antenna.

The integral power P for the microwave range is also described by the Nyquist formula:

$$P = kT\Delta f \quad (2)$$

where $G(f,T)$ - spectral density of the noise signal.

The average power of the noise signal can be measured at a fixed frequency using a high-sensitivity radiometer with bandwidth analysis Δf, which is able to record the EMR of a heated body with emissivity β:

$$P = G(f,T)\Delta f = \beta kT\Delta f \quad (3)$$

where $G(f,T)$ - spectral density of the noise signal.

The human body, at its temperature of 36.6 °C, is also a source of weak microwave signals. The integrated power of the microwave signal of the human body or its areas is in the range of 10^{-13}…10^{-14} W, depending on the state of the organism. Studies have shown that the average value of the radiation level of the palm of the majority of respondents was within (3…6)·10^{-13} Вт [11]. The possibility to measure signals of this level is provided by the use of highly sensitive radiometric systems (RS).

Since the RS has its own temperature characteristic, the output signal power is determined by the temperature difference between the object of study and the measuring system, which is described by the formula

$$\Delta P = 2\pi K_1\left(f\right)\beta\left(f,T\right)\frac{f^2}{c^2}k\left(T_o - T_R\right)S_o\Delta f, \quad (4)$$

where $K_1(f)$ - the conversion coefficient of the receiving antenna, which also takes into account the influence of the radiation source; T_R - temperature of the radiometric system.

Thus, for the registration of low-intensity microwave electromagnetic fields and radiation, as well as the study of their interaction with the human body, the required sensitivity of radiometric systems must be an order of magnitude higher than the level of measuring signals.

Measurement of low-intensity signals is a rather complex technical problem, which is considered and try to be solved by specialists from different countries [7,12].

The authors of this article (review) have developed such systems in the frequency range 37…53 GHz and 53…78 GHz. These systems have a sensitivity of 3*10^{-14} W, which is confirmed by metrological certification by the State Standard of Ukraine. All studies conducted and described by the authors in the article were performed using the developed by their radiometric systems.

1.3 Processes of Interaction of Microwave Signals with Objects of Living Nature and the Human Body

In addition to natural sources of microwave radiation, in the environment there are signals generated by mm-range generators, relay lines, mobile communication systems, and so on. The level of man-made radiation power can significantly exceed the natural microwave background and, accordingly, have a significant impact on highly sensitive biological life forms, such as insects. Some authors note in their studies the harmful effects of a constant man-made electromagnetic background in the environment on the biosphere and living beings [13,14].

At the same time, low-intensity millimeter-wave microwave signals with short-term effects on living beings and the human body can have a therapeutic and stimulating effect, on which microwave therapy is based [15,16]. As noted, millimeter-wave signals are actively absorbed by water and oxygen molecules, which are also present in living organisms. The effect of resonant absorption of millimeter range signals is the basis of millimeter resonance therapy [15].

Millimeter therapy show its efficacy in treatment of gastroenterology problems (peptic ulcer), orthopedic (musculoskeletal disorders), neurologic (neuritis, pain syndromes) and other diseases [17]. The power level of therapeutic signals can be within 10^{-6}…10^{-9} W, and in some cases decrease to 10^{-12} W [18]. Positive changes in human body indexes during the treatment process at the specified power level of signals are fixed laboratory. The extremely low level of signals, which have positive effects on the human body, gave the authors [15] a reason to call this area "quantum medicine". Targets of irradiating microwave signals are biological structures at the cellular level.

Considering the process of interaction of microwave signals of the object of radiation with the human body, it should be noted that, as follows from formulas (1,2), it is determined by the temperature gradient between the human body and the heated object. If the temperature of the object is higher than the temperature of the human body area, $T_o > T_H$, thus a positive irradiating flow of microwave EMR is formed, and if $T_o < T_H$ - flow should be negative. These flows affect human body in different ways [19]. The impact can be spatial (non-contact) or contact.

Positive EMR flows increase the energy of the irradiation area, and negative ones reduce it. The absorption of the energy of the electromagnetic field by the cells of a living organism in the case of a positive flow stimulates biochemical processes and causes a reaction to the radiation in the different levels - cellular, tissue, organ and whole organism. Negative fluxes, on the contrary, due to energy extraction, reduce the excitation of the irradiation area and inhibit biochemical processes in it. It was proven with laboratory tests performed at the Kyiv Oncology Institute of the Ministry of Health of Ukraine on mice irradiated with C37 sarcoma tumor [20]. Positive EMR flows accelerated tumor growth during irradiation by 13.5%, and negative flows during the same time inhibited tumor by 27.4%.

2. Investigation of the Interaction of Low-intensity Microwave Signals of Objects in Contact with the Human Body

The authors studied the emissivity of a number of dielectric objects that come into contact with the human body, including

- materials for medical use (dental materials, implants, physiotherapeutic materials);
- materials for clothing;
- materials for jewelry;
- building materials.

In the course of the research, the emissivity of the material was determined, its power level at the heating temperature of 36.60 was compared with the power of the human body. By the difference between radiation levels of the human body and material the possible impact on the human body was supposed and evaluated.

2.1. Research of EMR of dental filling materials

Different filling materials are used in dentistry for crown restorations and root canals sealing [21]. Since the

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creation of EMR flows of opposite directions is possible, as mentioned above, it is advisable that the materials and tissues of the tooth were compatible.

The electromagnetic parameters of these materials (emissivity, grayness coefficient) must coincide (or differ slightly) with the corresponding parameters of the restored tooth tissues.

10 samples of materials were prepared for research [22], among them №№1-7 filling materials: 1- «Foredent» (SPOFA, Slovenia), 2- Endion (VOCO, Germany), 3- Endomethazone» (Septodont, France), 4-AH Plus (Dentsply, USA), 5-«Spectrum» (shadow A3,5) (Dentsply, USA), 6- «Compolux» (Septodont, France), 7- «Cavitan - plus» (SPOFA, Slovenia); samples №№8 - 10 - natural structures: 8 - enamel and 9 - dentin of the extracted for medical indications tooth, and 10 - spongy bone tissue received in surgical interention for medical indications. Samples 1 - 4 are used for root canals sealing, samples 5 - 7 intended for crown restorations. Emissivity of samples 1 - 4 were compared with emissivity of the sample 9, which them contact in. Electromagnetic radiation of the samples 5 - 7 was compared with sample 8 emissivity.

The study of experimental samples was performed using high-sensitivity RS at frequency 52 GHz. The obtained results of radiation intensity measurements of the studied dental materials are concentrated in the range $(1{,}8\text{-}3{,}1)\cdot 10^{-13}$ W/см^2.

The biocompatibility of tooth materials and tissues was determined by comparing their emissivity coefficients, which was calculated by the formula:

$$\beta_M = Đ_M / P_{cbb} \qquad (5)$$

where P_M- radiation power of the material; P*cbb* - the radiation power of an absolutely black body, which is calculated by the formula

$$Đ_{cbb} = \beta\left(f/c\right)^2 kT \qquad (6)$$

where f - signal frequency; c- light speed.

The calculated values of the coefficients of emissivity of materials are given in Table 1:

Table 1. The coefficient β of the material relative to the level of radiation of an absolutely black body

№	1	2	3	4	5	6	7	8	9	10
β	0,71	0,6	0,46	0,41	0,46	0,51	0,48	0,46	0,67	0.58

Comparison of the coefficients of emissivity of filling materials and natural tooth tissues recorded the largest deviation in the pair 4 and 9-38%, then - 10,8% in the pair 6 and 8; the next - 7,8% in the pair 1 and 9 and perfect coincidence in pair 5 and 8. When using, preference should be given to materials with a greater coincidence of emissivity, because the positive and negative flows of the microwave EMR are minimal. Such a verification technique of dental materials compatibility is promising and deserves to be used in the development of new dental materials.

2.2. Microwave Properties of Materials for Incorporation in the Human Body

Modern surgical medical practice widely uses implants to replace separate elements of the bones, vessels, eye and even some entire organs. For these purposes materials of both natural and synthetic origin are used. These can be metals, synthetic polymers, bioceramics, various powdered fillers for bone defects and materials for soft tissue regeneration in some injuries. Widely used biotissues of animal origin, hybrid and composite materials, such as metal, as a base, coated with a dielectric, the characteristics of which are close to human biotissue [22]. Recently, research has been conducted using promising nanomaterials [23].

The use of biomaterials is associated with long-term research and testing for compatibility with human biotissues. The main indicators to which attention is paid are biological tolerance, resistance to biocorrosion, chemical stability, antimicrobial activity. This fully applies to all types of implant materials (Figure 1).

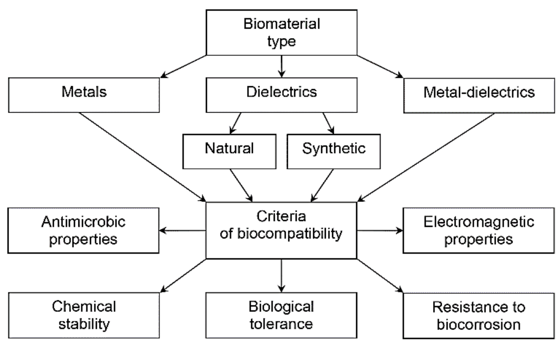

Figure 1. Classification of biomaterials and criteria for their compatibility

When implants made of foreign materials are introduced into the body, a biophysical interaction occurs between them and the biotissue, including through electromagnetic radiation. The electromagnetic properties of biomaterials have not yet been studied, although they can significantly affect the processes of their interaction with living organisms. The study of dielectric and combined materials for low-intensity fields and EMR has revealed another important criterion to pay attention to: the electromagnetic compatibility of the biomaterial with the biotissues of the human body.

The flows of electromagnetic energy generated by the implants with respect to the biotissue can be neutral, pos-

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itive or negative. It's especially important for biotissues cells, which are able to respond to EMR of the low intensity. Irradiating (electromagnetic) parameters of implants can significantly differ from the same characteristics of the alive tissues. When the flows of the implant and the biotissue are equal, full electromagnetic compatibility occurs. Significant deviation from it, in one direction or another, for a long time can lead to a violation of the electromagnetic state (homeostasis) of adjacent cells and the appearance of complications in the area of implant placement.

Figure 2 shows the scheme of formation and interaction of electromagnetic flows of positive (Figure 2a) and negative (Figure 2b) directioncreatedby installed bone implant 3 with in contact nearby biotissues of the human body - bone 1 and soft tissues 2. Symbols in the figure: P_1, P_2 - - radiation power per unit area of bone and soft tissue, P_3 - radiation power per unit of implant surface.

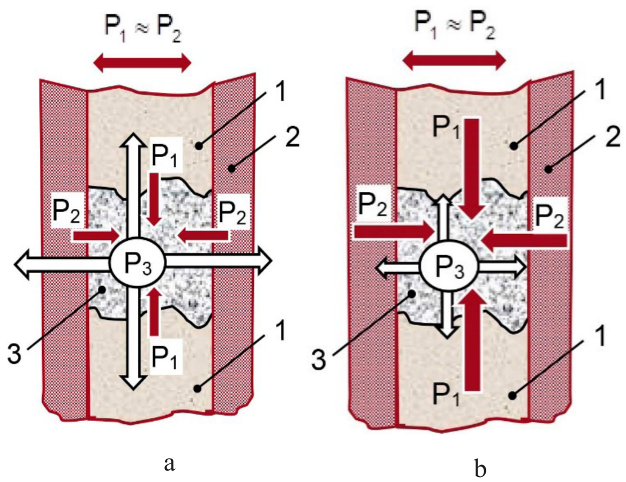

Figure 2. Schemes of Formation: a) positive flow when $P_3 > P_1 \approx P_2$ and b) negative flow when $P_3 > P_1 \approx P_2$

EMR power of bone P_1 and neighboring soft tissues P_2 physiologically consistent with each other in natural way, and the radiation level of the implant P_3 in the variant of Figure 2a is increased, so the surrounding biotissues receive constant additional irradiation. In the variant of Figure 2b, in contrast, the implant absorbs EMR of the surrounding tissue because its radiation level is lower.

The specified energy transfer in the form of a microwave EMR from an object with higher emissivity β*1* to an object with a lower level of parameter β*2*, at certain values and with prolonged action can both improve and worsen the conditions and course of reparative processes in the body. This process thus determines the clinical effectiveness of the study materials. The increase in microwave radiation is equivalent to the appearance of an inflammatory process, due to excess energy at the site of implant placement. If they should know researched electromagnetic interaction of material and biotissue, choice of implant become more effective.

The authors [24] conducted research of the EMR of some biomaterials used to replace bone defects in dental implantation. Value of the EMR of these materials was measured and compared to the radiation level of the human body. Studied materials were heated to the temperature 36,6 °C (equivalent human body temperature) and measurements of the EMR at the frequency 52 GHz were conducted.

Designation of research objects (Table 2): 1- the average value of human EMR (H - human): before each study of materials, measurements of the respondents' own radiation (study participants) were performed under the same conditions for comparison; 2 - Osteoplast K; 3 - Bone powder - (ground tubular bone of animal origin); 4 - Osteoplast T; 5 - Polihemostat - powder; 6 - Calcium salt of orthophosphoric acid $Ca_3(PO_4)_2$; 7 - Calcium salt of orthophosphoric acid with the addition of silver ions $Ca_3(PO_4)_2 + Ag$; 8,9 - Bioactive glass (500-1000 microns), Bioactive glass (500-1000 microns) ; 10 - Biomin GT -700; 11 - Biomin GT-500.

According to the determined levels of EMR materials, the relative coefficient of emissivity have been calculated by the formula

$$K_1 = P_M / P_H \, , \tag{7}$$

where P_M - EMR power of the studied material, and P_H - the average level of human radiation power. The results of the experiment for indicated parameters are presented in Table 2.

Table 2. The coefficient K1 of the material relative to the level of human radiation

№	1	2	3	4	5	6	7	8,9	10	11
K_1	1,0	0,98	0,95	0,92	0,90	0,14	0,13	0,13	<0,01	<0,01

In the process of radiometric studies of these biomaterials revealed a number of features related to the human body and the properties of some materials. A number of materials have a emissivity of approximately the same (difference within 10%) with the human body. This probably causes a very small transfer of energy in the form of microwave radiation from a body with a higher level to a body with a lower level power of the EMR. Thus, materials that have a relative emissivity slightly lower than the level of human emissivity (Osteoplast K, Osteoplast M, Osteoplast T, Polyhemostat) are likely to interact more physiologically with the tissues of the human body. Using of such materials in dental implantation create almost identical positive flows of EMR from implants to body tissues, and this can lead to increased treatment efficiency.

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Other materials (calcium salt of orthophosphoric acid with the addition of silver in various quantities, Biomin GT - 500, Biomin GT - 700, bioactive glass) - on the contrary, have a low relative coefficient of emissivity (the difference from the human body by one or two orders of magnitude), may cause the formation of a negative microwave flow. The presence of a negative microwave flow from alive tissues to the implanted material can, in turn, lead to chronic inflammation, pain, and so on.

Thus, to improve the prognosis of engraftment and long-term successful use of implants, increase the effectiveness of treatment in general, it is necessary to take into account the level of microwave EMR flows of materials and the possible impact on the patient's body.

2.3 Electromagnetic Microwave Properties of Materials for Physiotherapy

Heat treatment is one of the most common procedures in physiotherapy, which uses a variety of dielectric materials, including minerals, peat, sand, mud and some materials of oil fields - naphthalene, ozokerite and paraffin. Among these materials, ozokerite and paraffin should be singled out. Each of them, alone or in a mixture, are most often used in physiotherapy treatment technologies. High (highest among physiotherapy materials) heat capacity, heat retention capacity and low (lowest among physiotherapy materials) thermal conductivity of ozokerite determine its high efficiency. According to medical special literature, there are three impact factors that affected the area of treatment: thermal, mechanical and chemical [25-27]. The therapeutic effects that occur, above all, include anti-inflammatory and vasodilating effects, as well as acetylcholine -like, estrogen - like and chemical effects of ozokerite.

Heat treatment technologies provide the preheating of the material (applicator), its application to the surface of the patient's skin and exposure time during the material is cooling to the patient's body temperature. The temperature of the applicator does not exceed 50 °C usually. At the same time, as follows from formulas (1,2), the increase in temperature of the material leads to the occurence of heat-related low-intensity microwave radiation, which, among other factors, has an impact on the human body and needs to be studied.

The authors of [28] conducted a study of EMR of the ozokerite applicator, the process of its formation and changes in the microwave field during the physiotherapy procedure.

From the point of view of physics, the process of heat treatment should be considered as a violation of thermodynamic equilibrium in a system consisting of the surface of human skin and the applied applicator. Energy exchange in any system, parts of which have different temperatures can be carried out through the processes of thermal conductivity, convection and radiation. In our case, convection can be ignored, and the exchange of energy between the surfaces of the applicator and the patient's skin is carried out mainly due to the phenomena of thermal conductivity and electromagnetic radiation.

In Figure 3 (a, b, c) shows two arbitrary objects (O_1 and O_2, with temperatures T_1, T_2), the applicator (A) and the patient's body (H), which are in thermal contact. In a state when the thermodynamic equilibrium is violated ($T_1 \neq T_2$) and the energy flows P_1, P_2 are not balanced, the direction of energy transfer depends on their temperature ratio.

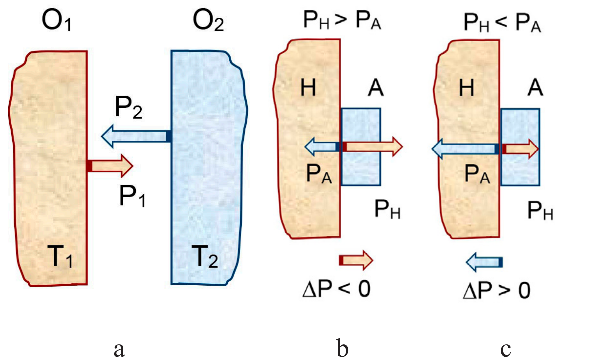

Figure 3. Distribution of energy flows between an arbitrary tangent objects: (a) – applicator and patient's body; b) negative energy flow; c) positive energy flow;

H - patient's body; A - applicator; PH - patient's energy flow; PA - applicator energy flow

For example, if the patient's temperature is higher than the applicator temperature (cooling applicator), the flow of heat energy will be directed from the patient's skin and can be considered negative in relation to the person (Figure 3b).

$$\Delta P = P_A - P_H < 0 \quad (8)$$

If, on the contrary, the applicator is heating, as in the case of heat treatment, the flow will be directed to the patient, and it can be considered positive (Figure 3c)

$$\Delta P = P_A - P_H > 0 \quad (9)$$

EMR power measurements were performed at a frequency of 52±0,1 GHz with an analysis band of 100 MHz. For comparison, the average level of radiation power of the human palm surface (limited antenna aperture plane 2 cm^2) was determined for three respondents, which was $P_H = (4,5 \pm 0,5) \cdot 10^{-13}$ W. Given the area of the aperture of the measuring antenna, this corresponds to the EMR flow density 2,25·10^{-13} W/см^2.

The absolute values of the EMR power level were determined using a certified reference noise generator, which is part of the radiometric system. According to the results of measurements at the maximum therapeutic temperature of 50 °C (Figure 4) it is seen that the level of radiation of pure ozokerite is slightly higher than in the human palm. The power level of EMR of pure paraffin at the same temperature does not exceed 20% relatively to the level of radiation of human skin. This can cause the formation of a negative EMR flow, the intensity of which increases with increasing the percentage of paraffin in the mixture with ozokerite.

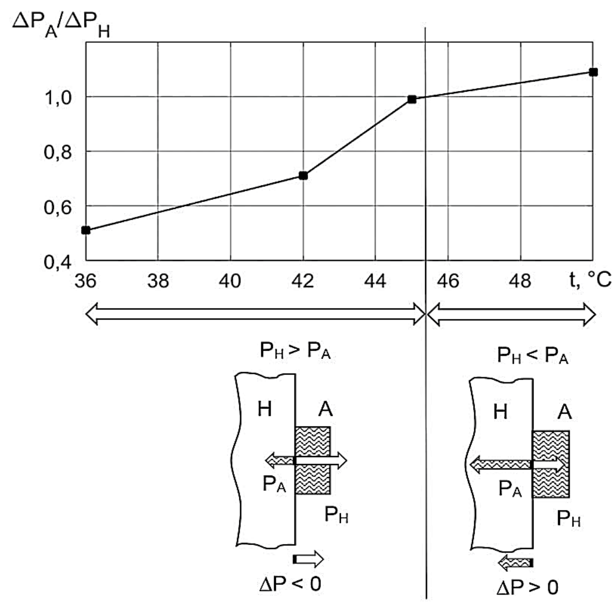

Figure 4. Dependence of relative power on temperature and distribution of electromagnetic energy flow for ozokerite applicator during cooling

From the graph of the temperature dependence of the power of its own radiation of pure ozokerite during its cooling, presented in Figure 4, it is seen that a change in temperature can lead to a change in the redistribution of electromagnetic energy between the applicator and the skin. Thus, on the graph, in the temperature range from 50 to 46 °C, a positive flow of EMR is formed

($\Delta P > 0$), and in the temperature range from 45 °C to 36 °C - negative flow of microwave radiation ($\Delta P < 0$), the intensity of which increases with further cooling.

Experimental studies have shown that ozokerite, paraffin and mixtures thereof form a low-intensity EMR in the millimeter range. This factor, together with the thermal effect, affects the patient's body, creating and enhancing the therapeutic effect.

The addition to ozokerite the paraffin, which has a low emissivity, increases the intensity of the negative flow. The total power of the ozokerite applicator, for example, with the size of 100 cm^2 may be approximately 3*10^{11} W, which is for high convergence with low-intensity levels used in millimeter therapy [8,9]. Experimental studies of EMR of materials for ozokerite-paraffin therapy have shown the complexity of electromagnetic microwave processes that affect and interact with the electromagnetic field of the human body, which need to be taken into account during physiotherapy.

Quite often in the treatment the wormwood cigarettes (moxa) for irradiation and cauterization of biologically active points (BAP) are used. Our experimental studies have shown that moxa is a generator of low-intensity natural microwave radiation, the level of which exceeds human EMR by 15…20 dB [11]. In general, it should be noted that the combustion of organic matter, in addition to infrared radiation, is also accompanied by a fairly high microwave energy flow.

2.4 Investigation of Microwave Fields and EMR of the Materials for Clothing

Radiothermal (radiometric) quality control of clothing materials (fabrics, leather, films, composites, etc.) is based on comparing the level of EMR of human skin with the level of EMR of the test material heated to the average human body temperature (310 K) [29]. The closer the level of EMR of material to the level of EMR of human skin, the better the electromagnetic compatibility of the clothing material with the human body, and the feeling of comfort of the dressed person is fuller [30].

Figure 5 presents a model of physical processes that occur at the interface of material and the human body.

To estimate the level of EMR of the material heated to the average temperature of the human body (310 K), the spectral power density of thermal EMR $G_1(f,T)$ at the average frequency of the millimeter wavelength range (52 GHz) was taken. The spectral power density of the EMR was determined by the power measured by the modulating RS divided by the bandwidth of the intermediate frequency amplifier (Δf = 100 MHz).

$$G_M(f,T) = \frac{P_{MRS}}{\Delta f}\left(\frac{W}{Hz \bullet cm^2}\right) \quad (10)$$

In the process of experimental research were used 14 types of textile materials made of natural, chemical and mixed fibers [30]. Designation of research objects: 1 - average value of human EMR (H - human); 2- wool (100%); 3 -linen (100%); 4 - wool (70%) + silk (30%); 5 - wool (45%) + silk (55%); 6 - cotton (100%); 7 - silk (100%); 8 - viscose (100%); 9 - cotton (65%) + polyester (35%);

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10 - cotton (60%) + polyester (40%); 11 - cotton (55%) + polyester (45%); 12 - cotton (47%) + polyester (53%); 13 - viscose (55%) + polyester (45%); 14 - polyester (100%); 15 - polyamide (100%).

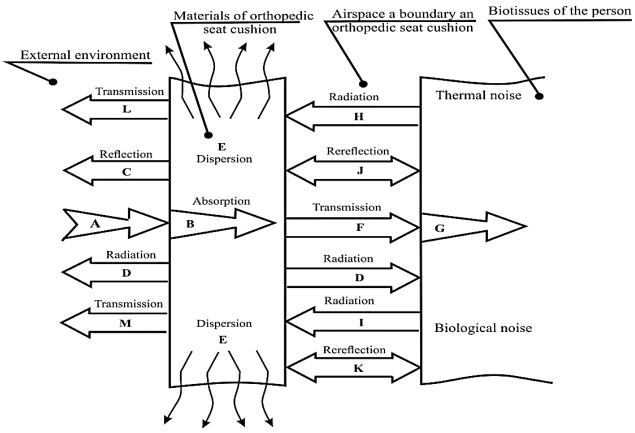

Figure 5. Model of interaction of electromagnetic currents at the material-human boundary

Designation on the Figure 5 A - EMR from external sources; B - input EMR to the material; C - reflected from the material EMR; D - radiothermal EMR of material; E - scattering flows; F - EMR, that passed through the material; G - EMR absorbed by the human body; H, I - radiothermal and biological radiation of the human body; J, K - repeated reflected from the material and skin radio thermal and biological EMR; L, M - radiothermal and biological EMR of a person passing through the material.

The spectral density of noise microwave radiation power of the studied materials is given in Table 3. Analysis of the obtained values allows us to conclude that fabrics made of natural fibers (wool, linen, cotton and silk) have a level of EMR close to the level of EMR of human skin.

Table 3. Spectral power density of radiation of textile materials.

№	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
G_M $10^{-21}\frac{W}{Hz \cdot cm^2}$	5.2	4.3	4,1	4,0	3,9	3,8	3,6	2.8	2.4	2.2	2,1	1.9	1,7	1,5	1,3

Therefore, these materials are most compatible with the human body. In addition, they do not interfere with the electromagnetic exchange of man with the environment, because they absorb and emit electromagnetic energy as well as human skin. At the same time, the increase in the percentage of chemical fibers in the material significantly reduces the level of EMR at the same temperature and negatively affects the electromagnetic exchange, which reduces the feeling of comfort of clothes made of these materials.

Study of materials dyed with natural dyes, also was carried out. Dyes were obtained from the medicinal herbs. An increase in the level of EMR was recorded, it approached the level of the human skin's own radiation. Materials comfort increased too, by 8-10%. It was determined by the formula:

$$\Theta = \left(1 - \frac{G_H(f) - G_M(f)}{G_{cbb}(f)}\right) \cdot 100\% \quad (11)$$

where $G_H(f)$ - EMR level of the human skin; $G_M(f)$ - EMR level of materials, рівень ЕМВ матеріалів, impregnated with natural dyes from medicinal herbs; $G_{cbb}(f)$ - EMR level of the absolutely black body for temperature T=310 K.

Thus, the measurement of low-intensity EMR of textile materials not only contributes to a more objective analysis of the processes of interaction that occur at the boundary between the material and human skin, but also opens the possibility of instrumental choice of ways to improve the quality and comfort of these materials.

2.5 Features of Radiative Ability of Minerals and Semiprecious Stones

Minerals are used in such a highly specialized technology of heat treatment as lithotherapy. In addition, precious minerals are used as jewelry, which are placed on the surface of the body. Heating of minerals leads to the formation of low-intensity microwave EMR. The authors [11] conducted a study of the emissivity of a number of minerals. Experimental conditions: EMR levels were measured at a frequency of 60 GHz at a temperature of objects 310 K, which corresponds to the upper limit of normal human body temperature. Figure 6 shows the distribution of radiation intensity of different minerals in comparison with the level of radiation of the human body and water.

According to their emissivity, the minerals can be divided into two groups, as shown by the dotted line in Figure 6: minerals that at a temperature of 310 K have a higher level of radiation than the human body, and lower. Minerals with higher radiation include jade, onyx, agate, amethyst, amber and jasper. These minerals in thermal contact with the human body generate a microwave signal that is excessive for human skin and this creates a positive flow of EMR. Thus, these minerals provide energy to the body in the case of lithotherapy or constant wearing on the human body. The second group of minerals includes sulfur, fluorite, flint, amazonite, rock crystal, calcite, topaz, morion. When these minerals are heated to body temperature, their radiation levels are lower than the own human radiation and they form a negative flow of energy. Water has the same quality. Some minerals, such as chalk and quartz single crystal, have almost the same level of

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radiation as humans and are electromagnetically balanced relatively to the human body.

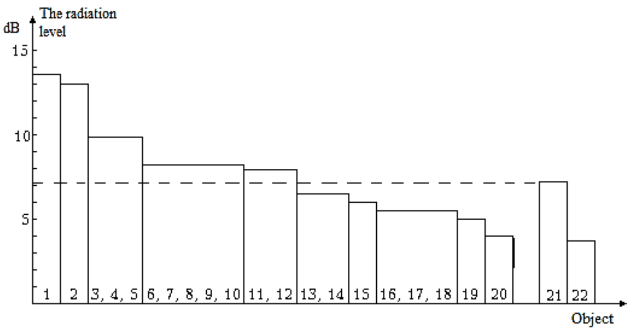

Figure 6. Distribution of emissivity of minerals and other objects

Minerals and objects of research are assigned the corresponding digital indexing: jade stone - 1, onyx - 2, agate - 3, shell rock - 4, tubula bone of animal origin - 5, amethyst - 6, amber - 7, jasper - 8, pyrite - 9, fibula bone of animal origin - 10, quartz (single crystal) - 11, chalk - 12, sulfur - 13, fluorite - 14, Moscow flint - 15, amazonite - 16, rock crystal - 17, calcite (feldspar)- 18, topaz - 19, morion (quartz)- 20; number 21 - EMR level of the human palm, number 22 - EMR of the water.

As can be seen from Figure 6, jade has a significantly higher level of radiation (13.5 dB) than human skin (7 dB). EMR of the quartz (morion) is at the level of the EMR of water. Human bones, shell rock and jade stone include Calcium salts (for example, calcium phosphate in the human bones). Perhaps, this is the cause of the increased level of the EMR of these objects. At the same time, it is known that Ca atoms actively respond to thermal effects. Thus, the root mean square displacement of Ca atoms during thermal oscillations is equal to 0.114 angstroms [32]. In response to thermal stimulation, Ca ranks among such active elements as Li, Na, K, Rb and Cs, some of which (K, Na, Ca) are actively used by biological objects in the process of their life support. Obviously, the increase in the level of radiation of the considered objects (bone, shell rock and jade) is connected with the increase of their "grayness" coefficient. Human bones play a peculiar role of generators and waveguides of microwave oscillations and provide the formation and transmission of electromagnetic oscillations within a biological object, in contrast to human skin, which actively absorbs low-intensity signals in the mm range.

2.6 Microwave Radiation of Building Materials

The authors [11] also studied some building materials - brick, sand, plaster, granite, shell rock, wood - which are most common in living and working spaces, on the street, in places of human recreation, etc. Studies have been conducted to assess possible levels of secondary radiation, which occurs under the influence of heating by sources of heat of physical bodies and the environment in contrast to the background radiation generated by objects at ambient temperature.

Research technology: materials were heated to a temperature corresponding to the maximum allowable temperature gradient, 50…60 °C which can be obtained, for example, as a result of direct exposure to solar radiation on the material in summer, or heating from steam heating pipes in winter. Evaluation of the emissivity was performed by RS at a frequency of 60 GHz. The results of experimental studies are shown in Figure 7.

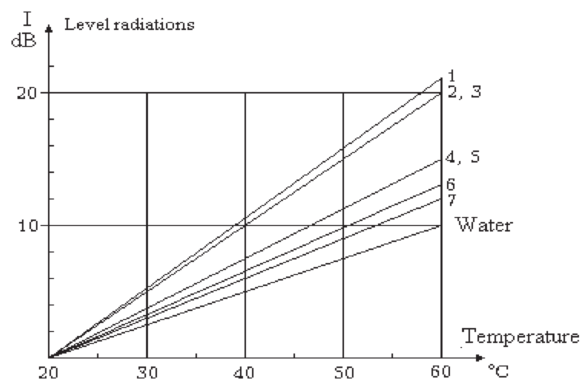

Figure 7. Dependence of radiation level of building materials on temperature

Designation on Figure 7: shell rock- 1, pine board - 2, granite - 3, gypsum - 4, red brick - 5, white marble - 6, sand - 7, water - 8.

Figure 7 shows that building materials have different emissivity. The maximum intensity of radiation is provided by shell rock ($>1\cdot10^{-20}$ W/Hz), which is much higher than human own radiation ($\sim0,5\times10^{-21}$ W/Hz). The dependence of the change in the radiation intensity of materials during heating is linear and is: shell rock ~0,52 dB/°C, granite and pine board ~0, 5 dB/°C, brick and gypsum ~0,4 dB/°C, marble ~0,35 dB/°C, sand ~0,3 dB/°C, water ~ 0,23 dB/°C.

In comparison with the ambient temperature, the emissivity of materials, when heated to indicated temperatures, increases, in the range from 10 dB (water) to 20 dB (shell rock), which must be taken into account when using them. Thus, the considered building materials have different radiation capacity in the mm range of waves, the level of which may be higher than the actual human radiation. It must be taken into account when using them and when human is in their environment with active temperature

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gradients.

3. Conclusions

1) The environment is filled with low-intensity microwave fields and natural radiation (primary and secondary), to which the human body has adapted well.

2) Recently, the filling of the air space with microwave signals of man-made nature, the intensity of which significantly exceeds the natural background and has the prospect of further growth. Studies by many authors reveal the negative impact of increasing microwave field intensity on sensitive biological objects (butterflies, bees and other insects). It fully applies to the human body, too.

3) The interaction of microwave fields and radiation with biological objects can manifest itself in the form of positive or negative energy flows. Such a manifestation is especially important for the cells of the human body when they come into contact with sources of EMR external or internal location.

4) Studies of the interaction of low-intensity microwave signals from objects in contact with the human body have confirmed the presence of positive and negative EMR flows in many medical technologies associated with the use of reconstructive biomaterials, which can have both positive and negative effects on surrounding biotissues. It is proposed to evaluate the electromagnetic compatibility of biomaterials with the human body by the level of their EMR, the criteria for the evaluation of new types of bio and nanomaterials is identified.

5) The method is offered and experimental researches of EMR of objects in contact with a human body (materials for clothes, precious and semiprecious minerals) are carried out. EMR evaluation reveals the correlations between indicated studied materials and allows to identify objects for their more comfortable contact use.

6) The study of materials and objects of the environment, which are sources of increased levels of EMR, allows us to realize the importance of microwave fields for the natural impact on the surrounding biological objects and the human body.

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