Journal of Human Physiology
https://ojs.bilpublishing.com/index.php/jhp

ARTICLE

Low-intensity Microwave Radiation of Natural Substances for Physiotherapy

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ARTICLE INFO

Article history
Received: 13 May 2020
Accepted: 13 August 2020
Published Online: 31 December 2020

Keywords:
Physiotherapy
Ozokerite
Paraffin
Microwave radiation
Radiometer
Measurement
Negative currents

ABSTRACT

The mechanisms of influence of physiotherapy procedures in ozokerite-paraffin therapy are considered in this paper. It is shown that microwave electromagnetic radiation formed by heated ozokerite-paraffin mixture is an important component of physiotherapy procedures. Using the experimental setup developed by the authors, the radiative abilities of ozokerite, paraffin and their mixtures in the microwave range were investigated. It was found that in the process of cooling the ozokerite-paraffin mixture, during the procedure, negative microwave fluxes occur, affecting the inflammatory processes in the patient's body. The dependences of the microwave radiation level on the composition of the ozokerite-paraffin mixture are investigated. The results of experimental studies allowed us to evaluate the interaction of electromagnetic radiation of ozokerite-paraffin mixtures with human own electromagnetic radiation and to approach the choice of modes of therapeutic interaction more carefully.

1. Introduction

The most common materials of the organic and mineral origin used in physiotherapeutic treatment are ozokerite, paraffin and healing mood (peloids). These dielectric substances are used in physiotherapy for treatment by the method of thermal impact on the stricken area of the patient's body [1-3]. The most commonly used of them is ozokerite, which belongs to the group of petroleum substances, has the highest heat capacity and heat retention capacity and the lowest thermal conductivity. It consists of ceresin (60-85%), paraffin (3-7%), petroleum oils (5-10%) and a small amount of asphaltenes, bituminous substances, methane, ethylene and some others additional substances [1]. Such composition and physical characteristics determine its therapeutic effects. The therapeutic effects of ozokerite include, first of all, anti-inflammatory action. Beside this, it has mechanisms of chemical - acetylholin-like and aestrogen-like and physical - compression (in 1,5 times more than paraffin) action [3].

Pure paraffin is used in physiotherapy technology less

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 DOI: https://doi.org/10.30564/jhp.v2i2.1885

commonly. Pure paraffin is a white anhydrous substance, which is also characterized by low thermal conductivity, high heat-retaining ability, but lack of chemical activity and is more plastic.

Usually, for physiotherapy procedures, combinations of these materials (ozokerite-paraffin mixtures) are used. In addition to the thermal action, such mixture has a mechanical effect, since cooling reduces it volume and thus way realize compression effect on the treatment site.

In addition, during these procedures the permeability of the skin increases, this leads to increased protein breakdown. As a consequence, the regeneration processes accelerate due to the effect of "irritation" [4].

There are three main factors which act in the treatment with ozokerite and paraffin on the patient's body both locally and at the level of the whole organism: thermal, mechanical and chemical; they act through the direct influence on the area of the body surface according to specialized literature [1-4].

So, the specified influence during thermal treatment is realized by contact method. At the same time, it is known that when heating any dielectric material (physical body) weak noise electromagnetic signals of a wide frequency spectrum arise. Low-intensity electromagnetic radiation (EMR) of the radio and optical bands are used in various types of therapy: microwave (millimeter), low-level light therapy (LLLT) and others [5-7], for influence on the biologically active points and individual skin areas of patients in order to regulate (change) the condition of the human body. The main frequency range of the medical equipment of the microwave band is in the range of 30-120 GHz, and the wavelength range of optical radiation is 280-760 nm [7-10].

Thus, it should be expected that the overall therapeutic effect will be due to both thermal and microwave factors, and therefore a more in-depth study of the spectral composition and other characteristics of EMR of the materials used in physiotherapy, particularly, in ozokerite-paraffin therapy, is relevant task.

The purpose of this work was to conduct an experimental study of the characteristics of microwave radiation of ozokerite and paraffin, as well as their mixture, which is a concomitant factor in performing appropriate physiotherapy procedures. This factor, as a rule, is not taken into account, but can significantly affect the functional state of the body (see, for example [5,9]). Therefore, it is advisable to determine the level of own EMR of the indicated materials, first of all, in the millimeter wavelength range, to take into account its influence during physiotherapy procedures.

2. Theoretical Information and Basics of the Study

The exchange of thermal energy between the surfaces of the applicator of the ozokerite-paraffin mixture and the patient's skin is performed due to the thermal conductivity process described by the Fourier law

$$P_T = \lambda \,\mathrm{grad}\, T \cdot \sigma_0 \quad (1)$$

where λ- coefficient of thermal conductivity of a substance or biotissue; grad$T$- temperature gradient between the ozokerite paraffin applicator and the skin, a σ_0- the square of the applicator surface contacting with the skin.

It is known that any heated physical body emits electromagnetic waves over a wide frequency range. According to Planck's law, the distribution of the density of electromagnetic energy emitting by an element with a single body volume is described by the formula

$$S(f,T) = \beta hf\left[\frac{1}{\exp(hf/kT)-1}+\frac{1}{2}\right] \quad (2)$$

where k=1,38·10^{-23} J/K - Boltzmann constant; h=6,63·10^{-34} J·s - Planck constant; T- body temperature; f- radiation frequency; β - the emissivity of the object coefficient (for a completely black body β =1).

Since the radiation of the millimeter part of the microwave range [7,9,10], in relation to which the ratio is performed $h\nu \ll kT$, has a significant effect on the state of a living organism, then formula (2) turns into the Nyquist formula

$$s(f,T)=\beta kT \quad (3)$$

Thus, taking into account (3), the radiometric receiver with the analysis band Δf is able to capture (measure) the integral power of the EMR

$$P=S(f,T)\,\Delta f=\beta kT\,\Delta f \quad (4)$$

However, the coefficients of the emissivity of the applicator β_A and the bio-tissues β_H differ, and thus, there may be flows of the electromagnetic energy exchange between them, which can be defined as

$$\Delta P=(\beta_H-\beta_A)kT\,\Delta f \quad (5)$$

With respect to the human body, realized flows can be positive (plus-energy) - when the applicator emits more than the skin of the patient, and negative (minus-energy), when on the contrary. These flows may cause additional therapeutic effects. Thus, negative EMR flows are able to attenuate the inflammatory process [11-13], due to rob of excess energy which is intrinsic for inflamation.

It should be noted that the radiative ability of the ozokerite-paraffin applicator β_A is determined by the tangent of the dielectric loss angle tg δ_A and the dielectric permeability ε_A of the temperature-dependent components

DOI: https://doi.org/10.30564/jhp.v2i2.1885

of the mixture of ozokerite and paraffin. Thus, according to [14], with increasing temperature from 35°C to 50°C, the dielectric permeability of paraffin decreases from 2.2 to 1.9. At the same time, tangent of the dielectric loss angle increases from 0.0017 to 0.0040. The same dynamics is observed for ceresin (the main part of ozokerite): its dielectric constant reduce from 2.55 to 2.45 and tangent of the dielectric loss angle increase from 0.0008 to 0.0017. However, decrease of the dielectric permeability of paraffin is sharper, especially near + 50°C. In addition, it's necessary to take into account the frequency dependence of these characteristics, especially for the millimeter range EMR, both for physical materials and for biotissues (see, for example, [15]). Thus, it is necessary to assume that the coefficient of radiative ability of the applicator is a function of two variables $\beta_A(f,T)$, and for the surface of the patient's skin - one variable $\beta_H(T)$ Moreover, their temperature dependences differ. All this significantly complicates the theoretical analysis of the process under study. Thus, the radiative ability coefficient of the applicator in the microwave range is advisable to determine relatively to the skin surface of the patient by formula

$$\beta_A(f,T)=P_A(f,T)/P_H(f) \quad (6)$$

where: P_A, P_H - the integral radiation power, respectively, of the applicator and the surface of the human skin in the operating frequency band of the radiometer receiver.

Considering given the above, as well as the lack of literature data on the presence and level of the microwave component of the indicated materials, which has a significant impact on biological objects, the authors conducted experimental study of the radiative ability of ozokerite-paraffin mixture, taking into account the technological features of the treatment process.

3. Apparatus and Methods of Conducting the Research

The materials most commonly used in physiotherapy - ozokerite from the field of Borislav, Lviv region, Ukraine, producted by OJSC TD Ecomed. To study microwave parameters we used indicated specimens, as well as purified paraffin, from pharmacy packaging with the date of manufacturing January 2019.

The study of microwave parameters of the selected materials, taking into account the observed features of physical bodies during heating, was carried out according to the following method of their heating. The test material was placed in a cylindrical metal container with a base radius of 10 mm (which coincided with the radius of the aperture of the horn receiving antenna) and a height of 12 mm. Initially, the container with tested material was heated in the TC-80M-2 thermostat to the required temperature in the range of 36-50°C, the value of which was automatically controlled to within ± 0.25°C. The heating temperature within these limits was also monitored by an alcohol thermometer. The samples were heated for 30 minutes after reaching the temperature of the experiment. The measurement of electromagnetic microwave radiation power of the indicated samples of materials was carried out by means of an experimental stand, the structural scheme of which is presented in Figure 1.

The experimental stand includes a highly sensitive radiometric system (MS) of the millimeter wavelength range and a heater with automatic temperature maintenance, consisting of: 1 power supply; 2 - thermostat; 3 - attenuator; 4 - microwave signal conversion channels; 5 - measuring device (indicator); 6 - test material in the container; 7 - conical receiving antenna; 8 - metal plate of the thermostat; 9 - temperature control device on the plate of the thermostat 8.

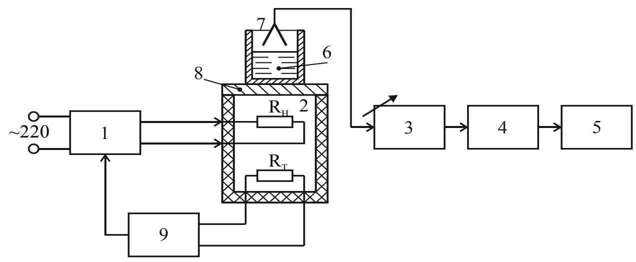

Figure 1. Structural scheme of the experimental studies of the microwave radiative abilities of the ozokerite and paraffin

The temperature on the plate of the thermostat heater 8, using the temperature regulator 9, was pre-set at the test temperature level of the thermostat (TS). Measurement of the temperature of the plate was performed using a contact thermometer of the digital voltmeter B7-27A. During measurements, the receiving antenna was placed directly next to the container.

4. The Results of the Experimental Study

During the study of microwave parameters of the materials were measured and evaluated:

(1) average level of radiation of the skin surface of the person (palms of the hands of two respondents);

(2) changes in the level of radiation during the reuse of ozokerite during the course of treatment with the addition of fresh material;

(3) radiation level of pure ozokerite and paraffin

at maximum therapeutic temperature of the materials (+50°C);

(4) changes of the power level of EMR of the materials during their cooling;

(5) the power level of EMR of ozokerite depending on the percentage of paraffin impurities;

(6) comparison of the radiation level of materials with the average level of radiation of the human body.

Considering that ozokerite and paraffin are the components of natural oil deposits, the authors additionally carried out measurements of the level of radiation of the oil sample from the Oil field "Shpak Academician" of NJSC "Naftogaz" of Ukraine, which amounted to $2.3 \cdot 10^{-13}$ W.

The average level of radiation power of the human palm surface (limited with antenna aperture area of 2cm^2) of two respondents, measured by RS, was P_H=(4,5±0,5)$\cdot 10^{-13}$ W in the analysis band frequency of 52±0,1 GHz or, taking into account the aperture area of the measuring antenna, was $2,25 \cdot 10^{-13}$ W/cm^2.

Typically, the recommended course of treatment is up to 10 procedures with adding of 25% fresh material before each session. Measurements of the selected samples during the treatment cycle did not reveal any significant changes in the parameters of EMR with the addition of fresh portions of ozokerite.

The distribution of the relative radiative power of the ozokerite-paraffin mixture with different percentages of paraffin impurities and the dynamic changes in the level of radiation of the materials during their cooling are presented in Figure 2.

The figure shows that negative flows (β_A/β_H<1) for a typical mixture (ozokerite - 90%, paraffin - 10%) can be realized for a temperature below 45°C. In addition, there is a certain "saturation effect" of the curves in the temperature range of 45-50°C. This can be explained by the peculiarities of the temperature dependences of the tangent of the dielectric loss angle (absorption of EMR) and the dielectric permeability of paraffin and ozokerite (ceresin).

On the one hand, the radiative power of the applicator is proportional to its absorption capacity (Kirchhoff's law) and should increase with increasing temperature. On the other hand, by changing the dielectric permeability, electromagnetic matching between the receiving antenna and the emitting material is disturbed and RS fixes a smaller power value.

The absolute values of the EMR level at the maximum therapeutic temperature of 50°C are shown in Table 1. They can see that the level of radiation of pure ozokerite at the maximum therapeutic temperature of the materials (+50°C) is $5,1 \cdot 10^{-13}$W (or ≈ $2,55 \cdot 10^{-13}$W/cm^2) and is comparable with the EMR of the human body.

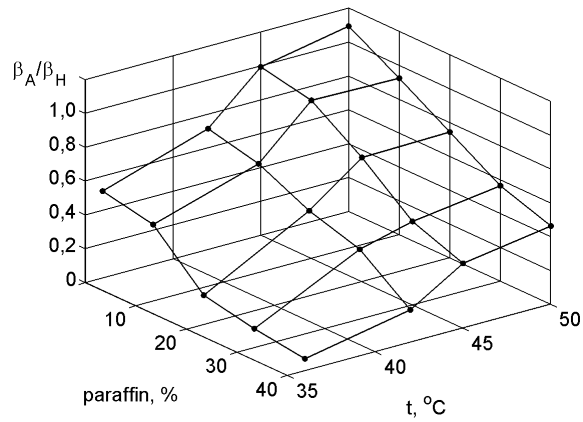

Figure 2. Dependence of relative radiative ability of ozokerite-paraffin mixture on temperature and paraffin content

Table 1. The level of radiation and relative radiation ability for therapeutic temperature +50°C

Material		P,10^{-13}W	$\frac{\beta_A}{\beta_H}$
Mixture (%):			
ozokerite	paraffin		
100	0	5,1	1,10
90	10	4,5	0,90
80	20	2,9	0,78
70	30	2,4	0,59
60	40	1,8	0,45
0	100	0,7	0,15
Oil		2,3	0,51
Human (palm)		4,5	1

The EMR level of pure paraffin at this temperature reaches only $0,71 \cdot 10^{-13}$W, which is much lower than in humans and can cause forming negative EMR flow. The intensity of such a stream increases with its percentage content grows in a mixture with ozokerite.

5. Conclusions

(1) Thus, as experimental studies show, the materials used in ozokerite-paraffin physiotherapy, form low-intensity electromagnetic radiation, which along with the thermal action affect the body of the patient.

(2) The pure ozokerite applicator at the maximum temperature of +50°C forms a low-intensity positive flow of EMR. Lowering the temperature of the applicator to

  DOI: https://doi.org/10.30564/jhp.v2i2.1885

+45°C leads to the formation of a negative flow of EMR, the intensity of which increases with the further cooling of the applicator.

The total power of the ozokerite applicator EMR, for example, 100cm^2 in size, can be $2,55 \cdot 10^{-11}$ W, which is comparable to the power used in millimeter therapy [5,7] .

(3) The use of ozokerite-paraffin mixture in the therapeutic temperature range leads to the formation of a negative flow of EMR, which increases as the percentage of paraffin in the mixture grows.

(4) Experimental studies of EMR of the materials for ozokerite-paraffin therapy have shown the complexity of electromagnetic microwave processes that have an effect and interact with the electromagnetic field of the human body and need to be taken into account when conducting physiotherapy.

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 DOI: https://doi.org/10.30564/jhp.v2i2.1885