(FOUO 8/79)

1 MARCH 1979 EFFECTS OF NONIONIZING ELECTROMAGNETIC RADIATION 1 OF 2

FOR OFFICIAL USE ONLY

JPRS L/8301

1 March 1979

USSR

TRANSLATIONS ON USSR SCIENCE AND TECHNOLOGY

BIOMEDICAL AND BEHAVIORAL SCIENCES

(FOUO 8/79)

EFFECTS OF NONIONIZING ELECTROMAGNETIC RADIATION

U. S. JOINT PUBLICATIONS RESEARCH SERVICE

FOR OFFICIAL USE ONLY

APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000100030004-3

NOTE

JPRS publications contain information primarily from foreign newspapers, periodicals and books, but also from news agency transmissions and broadcasts. Materials from foreign-language sources are translated; those from English-language sources are transcribed or reprinted, with the original phrasing and other characteristics retained.

Headlines, editorial reports, and material enclosed in brackets [] are supplied by JPRS. Processing indicators such as [Text] or [Excerpt] in the first line of each item, or following the last line of a brief, indicate how the original information was processed. Where no processing indicator is given, the information was summarized or extracted.

Unfamiliar names rendered phonetically or transliterated are enclosed in parentheses. Words or names preceded by a question mark and enclosed in parentheses were not clear in the original but have been supplied as appropriate in context. Other unattributed parenthetical notes within the body of an item originate with the source. Times within items are as given by source.

The contents of this publication in no way represent the policies, views or attitudes of the U.S. Government.

BIBLIOGRAPHIC DATA SHEET	1. Report No. JPRS L/8301	2.	3. Recipient's Accession No.
4. Title and Subtitle TRANSLATIONS ON USSR SCIENCE AND TECHNOLOGY BIOMEDICAL AND BEHAVIORAL SCIENCES, (FOUO 8/79) Effects of Nonionizing Electromagnetic Radiation			5. Report Date 1 March 1979
			6.
7. Author(s)			8. Performing Organization Rept. No.
9. Performing Organization Name and Address Joint Publications Research Service 1000 North Glebe Road Arlington, Virginia 22201			10. Project/Task/Work Unit No.
			11. Contract/Grant No.
12. Sponsoring Organization Name and Address As above			13. Type of Report & Period Covered
			14.

15. Supplementary Notes

16. Abstracts

The report contains information on aerospace medicine, agrotechnology, bionics and bioacoustics, biochemistry, biophysics, environmental and ecological problems, food technology, microbiology, epidemiology and immunology, marine biology, military medicine, physiology, public health, toxicology, radiobiology, veterinary medicine, behavioral science, human engineering, psychology, psychiatry and related fields, and scientists and scientific organizations in biomedical fields.

17. Key Words and Document Analysis. 17a. Descriptors

USSR	Medicine
Aerospace Medicine	Microbiology
Agrotechnology	Physiology
Biology	Psychology/Psychiatry
Botany	Public Health
Epidemiology/Immunology	Radiobiology
Human Engineering	Toxicology
Marine Biology	Veterinary Medicine

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group 2, 5E, 5J, 6, 8A

18. Availability Statement For Official Use Only. Limited Number of Copies Available From JPRS	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 121
	20. Security Class (This Page) UNCLASSIFIED	22. Price

FORM NTIS-35 (10-70) USCOMM-DC 40329-P71

JPRS L/8301

1 March 1979

TRANSLATIONS ON USSR SCIENCE AND TECHNOLOGY

BIOMEDICAL AND BEHAVIORAL SCIENCES

(FOUO 8/79)

EFFECTS OF NONIONIZING ELECTROMAGNETIC RADIATION

CONTENTS PAGE

CONTENTS (Continued) Page

ADVANCES IN MAGNETOBIOLOGY

Moscow REAKTSII BIOLOGICHESKIKH SISTEM NA MAGNITNYYE POLYA in Russian 1978 signed to press 24 Feb 78 pp 3-5

[Article by Yu. A. Kholodov, Institute of Higher Nervous Activity and Neurophysiology, USSR Academy of Sciences, Moscow, from book edited by Yu. A. Kholodov, Izdatel'stvo Nauka, 2250 copies, 213 pages]

[Text] Only 6 years have passed since the first collection of works dealing with magnetobiology [1] was published by the scientific council for the complex problem of "Cybernetics," USSR Academy of Sciences; but in this time many publications have appeared on this topic (especially in the USSR). There have been All-Union symposiums on different aspects of magnetobiology in Moscow (1971, 1972, 1974), Baku (1972), Belgorod (1973), Frunze (1974), Leningrad (1975), Kaliningard (1975) and Yalta (1975) [1-4, 7, 8, 13, 15]. Monographs [5, 6, 14, 16-18] and survey articles [9, 10] have been published. Tens of dissertations have been defended on different problems of biological effects of magnetic fields (MF), and this is indicative of the development of this branch of biophysics in our country.

As of today, there are at least 2000 literature sources dealing with the biological effects of MF. Magnetobiology is also discussed in textbooks [12, 20] and encyclopedias [11, 19].

At the present time, there are few who question the biological effects of MF, but there is still no satisfactory answer to the question of how these effects are expressed. For this reason, attention is focused on the mechanism of effects of MF on biological systems in the articles of this collection. In essence, each author devotes some of his attention to this basic problem of magnetobiology, but the works dealing solely with it are assembled in the first part of the collection. Here, authors with physicochemical specialization set the style. Each of them stresses the facet he considers the most important in the multifaceted process of interaction between MF and a biological object, outlines the different approaches to solving this important problem and lays the foundation of general theory of primary mechanisms (obviously, he is not alone) of biological effects of MF.

The second part of the collection was written by medical specialists and biologists who concentrate primarily on the properties of biological systems (be they mitochondria or a population of organisms). There, MF often emerges as a convenient tool for the study of biological systems, although the ecological role of this physical factor has already been reflected in some works. The complaint can be made that the effects of attenuated magnetic fields (AMF) on biological objects are still not being studied enough, while the role of biomagnetic fields in the function of biosystems and in magnetobiological reactions is still unclear.

It has been shown that an organism also presents a reflex reaction to MF, as it does to other stimuli, as well as a direct reaction, since MF have penetrating action and can directly influence the CNS [central nervous system]. The second route of influence was demonstrated in experiments with isolated mammalian CNS preparations and surviving nervous system of invertebrates. Interestingly enough, the isolated CNS reacted better to MF than the intact CNS [18].

We should also mention a third route of effects of MF on an organism, which is a mediated one. We refer to the fact that aqueous solutions of many substances, including drinking water and solutions of pharmacological agents, present a change in their biological properties after exposure to MF [6].

Thus, by altering the target, the researcher can vary the degreee of effects of the same MF on a biological object for control purposes. The magnitude of exposure also makes a contribution to the nature of reaction to MF, which is notable for a long latency period and considerable aftereffect. In the case of intermittent exposure, summation of effects is observed, and this is used in physiotherapy [12]; with increase in exposure one observes adaptation. However, the ultimate biological effect is determined not only by localization and duration of exposure, but the distinctions of the biological object.

On the level of the organism, the reaction to MF is determined by species-specific and genetic characteristics, age (young organisms, especially embryos, are sensitive to MF), sex (males are more sensitive than females), individual distinctions and functional state.

This information is indicative of the most vulnerable elements of a biological system to magnetism, but it does not define the degree of biotropism of different parameters of this factor.

The third part of the book deals with the characteristics of biological effectiveness of some parameters of MF. It was written by engineering specialists. It is to be hoped that consideration of information given in this section will raise the methodological standards of magnetobiological experiments, in which only the MF intensity had previously been indicated in most cases.

It is also necessary to indicate the gradient and vector of MF and for VMF [variable MF], the pulse frequency and shape. The duration of exposure to MF and its localization also determine the magnitude of the biological effect.

We discussed above the biological effects in the case of fixed MF parameters. It was demonstrated that the effectiveness increases when one or several parameters are altered during exposure [19]. Thus, intermittent exposure is stronger than continuous, exposure to a changing frequency is stronger than a fixed frequency, etc.

It should be concluded that by artificially altering the MF parameters researchers can control the behavior of an organism to some extent, affecting its regulatory systems by a contact-free method.

The ultimate goal of magnetobiological research--the possibility of controlling the function of biosystems--can be reached with the inclusion of feedback in the circuit of an automated controlled experiment. The means of reaching this goal are outlined in this collection. It is to be hoped that the friendly efforts of different specialists will help solve complex theoretical and practical problems of magnetobiology.

BIBLIOGRAPHY

1. "Effects of Artificial Magnetic Fields on Living Organisms," "Mater. Vsesoyuz. simp." [Proceedings of All-Union Symposium], Baku, 1972.

2. "Effects of Natural and Weak Artificial Magnetic Fields on Biological Objects," "Mater. Vsesoyuz. simp.," Belgorod, 1973.

3. "Effects of Magnetic Fields on Biological Objects," "Mater. III Vsesoyuz. simp. [Proceedings of 3d All-Union Symposium], Kaliningrad, 1975.

4. "Hygienic Evaluation of Magnetic Fields," "Mater. simp." [Symposium Proceedings], Moscow, 1972.

5. Dubrov, A. P. "Geomagnetic Field and Life," Leningrad, Gidrometeoizdat, 1974.

6. Klassen, V. I. "Water and Magnetism," Moscow, Nauka, 1973.

7. "Space and Evolution of Organisms," "Mater. soveshch. [Proceedings of Conference], Moscow, 1974.

8. "Magnetic Fields in Medicine," "Trudy Kirg. med. in-ta (Frunze)" [Works of Kirgiz Medical Institute (Frunze)], 100, 1974.

9. Maykelson, S. M. "Radio-Frequency Radiation. Magnetic and Electrical Fields," in "Osnovy kosmicheskoy biologii i meditsiny" [Fundamentals of Space Biology and Medicine], Moscow, Nauka, Vol 2, Bk 2, 1975, p 9.

10. Nakhil'nitskaya, Z. N. "Biological Effects of Magnetic Fields," KOSM. BIOL. I AVIAKOSM. MED. [Space Biology and Aerospace Medicine], No 6, 1974, p 3.

11. Novitskiy, Yu. I. "Magnetobiology. Children's Encyclopedia," Moscow, Pedagogika, 1973, p 62.

12. Pasynkov, Ye. I. "Physiotherapy," Moscow, Meditsina, 1975.

13. "Reactions of Biological Systems to Weak Magnetic Fields," "Mater. simp.," Moscow, 1971.

14. Travkin, M. P. "Life and Magnetic Fields," Belgorod, 1971.

15. "Physicomathematical and Biological Problems of Effects of Electromagnetic Fields and Air Ionization," "Mater. Vsesoyuz. nauch.-tekhn. simp." [Proceedings of All-Union Scientific and Technical Symposium], Moscow, Nauka, 197[illegible].

16. Kholodov, Yu. A. "Magnetism in Biology," Moscow, Nauka, 1970.

17. Idem, "Man in the Magnetic Web," Moscow, Znaniye, 1972.

18. Idem, "Reactions of the Nervous System to Electromagnetic Fields," Moscow, Nauka, 1975.

19. Idem, "Magnetobiology," BSE [Great Soviet Encyclopedia], Vol 15, 1974, p 167.

20. Beier, W. "Biophysic," VEB Gorg Thieme, Leipzig, 1975.

10,657
CSO: 8144

APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000100030004-3

MAGNETOHYDRODYNAMIC AND ELECTROHYDRODYNAMIC EFFECTS IN THE MECHANISMS OF ACTION OF MAGNETIC FIELDS ON BIOLOGICAL OBJECTS

Moscow REAKTSII BIOLOGICHESKIKH SISTEM NA MAGNITNYYE POLYA in Russian 1978 signed to press 24 Feb 78 pp 26-38

[Article by Ye. Z. Gak, G. P. Komarov and M. Z. Gak, Agrophysical Scientific Research Institute of the All-Union Academy of Agricultural Sciences imeni Lenin, Leningrad]

[Text] In spite of the great strides made by magnetobiology in the last few years, the basic possibility of biomagnetic effects (BME) under the influence of SMF [stationary magnetic fields] and VMF [variable magnetic fields] is still being denied [1-4]. The skeptical attitude toward magnetobiology is largely attributable to current thermodynamic conceptions, according to which the effects of MF [magnetic fields] on biological systems are smaller by a factor of 10^4-10^5 than the phenomena induced by the thermal energy of these systems.

However, an increasing number of experimental studies confirm the direct effects of MF on biological objects, and this prompted an extensive search for the primary physical mechanisms of action of MF, ranging from the quantum mechanical level to the level of the integral organism [5-18].

To date, a large cycle of theoretical and experimental studies on model systems, containing aqueous solutions of electrolytes, has been completed at the Agrophysical Scientific Research Institute, since all living organisms are referable expressly to such open systems, which cannot be described from the positions of modern thermodynamics of irreversible processes [19-21].

These investigations warrant the belief that the most diverse macroscopic phenomena can occur in such systems under the influence of MF, and they overlap by several orders of magnitude any effects of a thermal nature. In particular, it was possible to demonstrate that a change in kinetics and rate of heterogeneous reactions are a typical property of such systems, when they interaction of SMF or VMF, in spite of the fact that there is virtually no change in total energy of such systems in the above-mentioned MF.

This article deals with the nature of occurrence of such phenomena in living systems.

It can be demonstrated that electric currents with density $j \neq 0$ and space charges with density $\rho_{sc} \neq 0$ appear in an aqueous medium usually containing different ions and characterized by electric conductivity σ, specific magnetic susceptibility χ, constituting an open nonequilibrated system, a property of which is retention of a stationary or quasistationary concentration gradient $\nabla C \neq 0$ [22]. Thus, in particular, there are always endogenous electric currents with density $j_{end} \neq 0$, space charges with density $\rho_{sc,\ end} \neq 0$, while the presence of hemoglobin and other paramagnetic ions and molecules, including free radicals, enables us to describe the unit of live tissue volume and magnetic susceptibility as χ_{end}.

In general, one can describe the intensity of a magnetic field acting on a living system as follows:

$$H_{\Sigma} = \sum_{n=1}^{n=3} H_{=,n} [1 + k_n f_n (t)], \quad (1)$$

and the intensity of an electrical field as:

$$E_{\Sigma} = \sum_{n=1}^{n} E_n, \quad (2)$$

where $H_{=,n}$ is the intensity of SMF, $H_{0,n}$ is the amplitude of VMF, $f_n(t)$ is a time function, $n = 1$ corresponds to EMF [electromagnetic field] of natural origin, $n = 2$ are background EMF due to human activity and $n = 3$ are experimental MF. The values of E_n and H_n can vary over a very wide range. Thus, an electrical field of natural origin E can vary from 1-2 to 10^4 W/cm, for example during magnetic storms or thunder [23, 24]; $k_n = H_{0,n}/H_{=,n}$.

The presence of $E_{\Sigma} \neq 0$ causes generation of currents of an exogenous nature in biological tissue, with density of:

$$j_{ex} \cong \sigma_{\delta} \sum_{n=1}^{n} E_n.$$

We should like to note that the considerable space devoted in this article to the effects of electrical fields on living systems is due to the fact that one cannot realistically consider the effects on living systems of endogenous electric and magnetic fields separately without taking special shielding measures.

Consequently, the overall current density per unit volume of biological tissue under actual conditions is:

$$j_{\Sigma} = j_{end} + \sigma_{\delta} \sum_{n=1}^{n} E_n. \quad (3)$$

Magnetohydrodynamic (MHD) and electrohydrodynamic (EHD) forces are generated in biological tissue under the influence of H_Σ and E_Σ, and this can be described in the most general form per unit tissue volume as:

$$\vec{F}_\Sigma = \mu_0 [\vec{j}_\Sigma \times \vec{H}_\Sigma] + \rho_{sc,end} \vec{E}_\Sigma + \chi_\delta \vec{H}_\Sigma \, \mathrm{grad}\, H_\Sigma, \quad (4)$$

where μ_0 is magnetic permeability of vacuum, $\rho_{sc,end}$ is density of endogenous space charges and grad H describes the intensity gradient of MF. Taking (1), (3) and (4) into consideration, we can write down for F_Σ:

$$F_\Sigma = \mu_0 [(j_{end} + \sigma_\delta \sum_{n=1}^{n} E_n) \times (\sum_{n=1}^{n} H_{=,n}(1 + k_n f_n(t))] + \rho_{sc,end} \sum E_n + \chi_\delta H_\Sigma \mathrm{grad}\, H_\Sigma. \quad (5)$$

In the case of a single biological cell with consideration of the region of diffuse layer with volume ΔV:

$$F_{v+\Delta v} = \int_0^{v+\Delta v} F_\Sigma dv. \quad (6)$$

We see from (5) and (6) that the magnitude of forces is determined not only by the physical parameters of MF and electric fields, such as amplitude, time, gradients, but to an equal extent by the electric, metabolic and morphological parameters of the living organism. Evidently, the chief difficulties involved in this problem are related more to underestimation by physicists of the specifics of function of living matter than to the inadequacy of a purely physical approach to it. Thus, it is only in a very few works that it has been noted that it is imperative to take into consideration, when discussing the nature of BME [biomagnetic effects], one of its most typical properties, electric ones.

In our model experiments with aqueous solutions of electrolytes, with current densities close to biological levels (j_{end}), i.e., of the order of 1-10 mA/cm^2, we obtained flux rates of the order of cm/s with SMF of about 0.1-5 kOe [25-26], and when using alternating current and VMF they constituted 1-10 Oe [27].

Convective flows varying in geometry appear when MF heterogeneity $\nabla H \neq 0$ or nonuniform current density in space $\nabla j \neq 0$ is present in the electrolyte. Thus, with the use of magnetophores as sources of polygradient static magnetic fields, which are presently used in medicine [28-29], we observed a large class of flows varying in geometry in thin layers of electrolyte situated directly above the magnetophore. As an example, Figure 1a illsutrates a photograph of convective flows of aqueous solution 1 and $CuSO_4$ (magnetophore No 5), which were visualized with particles of lycopodium powder. Figure 1b illustrates the distribution of MF intensity on the surface, visualized by means of a corresponding ferromagnetic suspension.

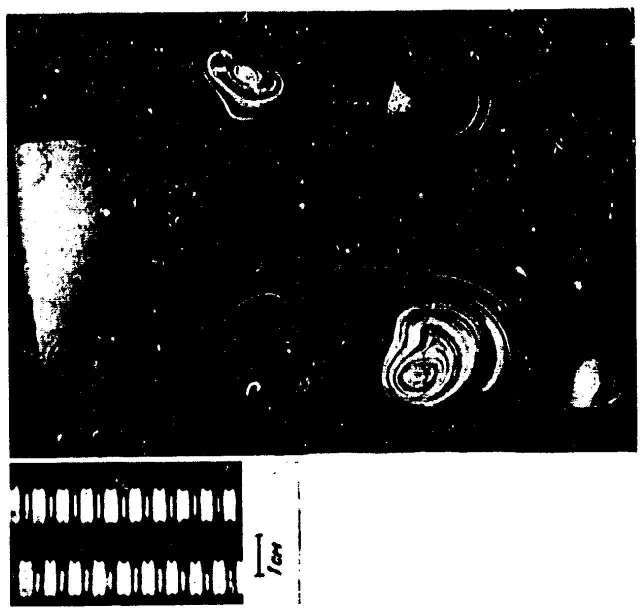


Figure 1. Shape of hydrodynamic flows in thin layer of electrolyte situated above magnetophore 5 surface (a), structure of MF visualized by means of ferromagnetic suspension (b).

With the use of nonstationary electric current and SMF under specific boundary conditions, we observed effects of generation of stationary and traveling waves in thin layers of aqueous media [30-31].

All these effects enabled us to experimentally observe a change in kinetics of various heterogeneous reactions in aqueous media of 10 or more times, and to discuss the reality, from the physical point of view, of any magneto-hydrodynamic and electrohydrodynamic phenomena in aqueous media.

However, living systems consist, to a significant extent, of gel-like structures with special rheological characteristics. For this reason, it should be noted that the same levels of forces, i.e., according to (5), can arise not only in aqueous media, in macrospaces, but in gels. This distinction of MHD and EHG effects is attributable to the fact that the motility of low molecular ions in gels is of the same order as in macroscopic spaces, in spite of the significant change in rheological characteristics.

In a study of the microscopic mechanism of MF effects on the kinetics of heterogeneous reactions in open systems, we discovered an interesting feature thereof which, in our opinion, is of special interest for living systems. In view of the fact that this phenomenon has not been sufficiently investigated, we shall discuss it in greater detail.

It was found that when the heterogeneous reactions occurs in the area of mixed or diffusion kinetics there is formation, beyond the area of double layers, of macroscopic diffuse electric space charges of relatively low density, as compared to diffuse charges of double electric layers, but tens and hundres of times longer. These charges are attributable to the presence of thermal movement in fluid and a difference in diffusion coefficients of anions and cations. The maximum length of such charges is attributable to the thickness of the diffusion layer, which reaches 10^{-2} cm in free spaces in the presence of natural convection.

Such space charges appear when a dispersion system in aqueous media is exposed to low-frequency electric fields [32-33]. This phenomenon explains the anomalously high dielectric permeability of such systems, including a number of biological suspensions (suspensions of cells, viruses, etc.). However, these charges are resorbed when the electric field is removed.

In the case of heterogeneous reactions in a concentration of $C<0.1$ N in aqueous media, for open systems, such a space charge is an inseparable property of such systems, which is due expressly to the reaction and its selectivity. Let us mention that such concentrations of electrolyte are typical for living biological systems. Such a space charge plays the role of an electric "barrier," inhibiting the reaction to some extent or other. There may be "resorption" of the charge under the influence of various physicochemical factors. However, after removal thereof the space charge is completely relaxed. We have discussed some of these properties elsewhere [34-36]. We then conducted additional experimental studies, in which the space charge was formed near a small electrode immersed in 0.1 N or less electrolyte. Figure 2 illustrates one of the techniques used to study its properties. In the absence of forced convection, when there is only spontaneous convection between electrode A and B ($S_A \ll S_B$, where S_A and S_B refer to electrode area), potential difference AB appears due to the difference in areas of electrodes that are made of the same material. As we have already noted [34, 35], probing methods are unsuitable for the study of properties of such charges in aqueous media. In this case, we used the fact that the space density of a macroscopic space charge (MSC) ρ_{MSC} and length δ_{MSC} are exceptionally sensitive to exogenous hydrodynamic factors, for example turbulization of flow. Convection arising near one of the electrodes can "tear off" this layer entirely, which causes generation of an electric pulse between the electrodes, which is recorded by means of an amplifier and oscillograph.

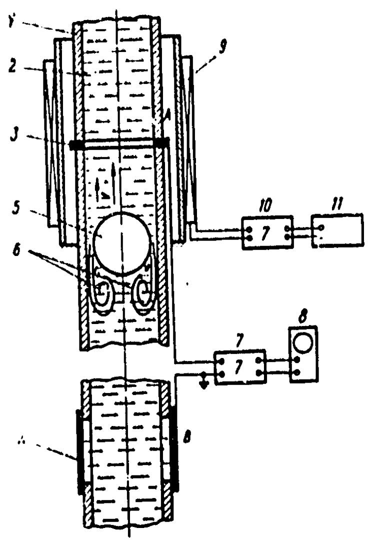


Figure 2.
Diagram of device for studying properties of space charge
1) polyvinyl chloride pipe
2) $CuSO_4$ solution
3) small electrode A
4) large electrode B
5) dielectric sphere
6) turbulized flow
7) direct current amplifier
8) oscillograph
9) solenoid
10) low-frequency amplifier
11) sound generator

The parameters of such a pulse are determined by the following conditions: amplitude U_0, by the density of the space charge ρ_{MSC}; duration of leading edge [anterior front] $\tau_{a.f}$ by flow rates near the small electrode and duration of trailing edge [posterior front] $\tau_{p.f}$, by the time of relaxation of the MSC generation system. Under specific conditions determined by the geometry of the system, concentration of electrolyte and cation and anion diffusion coefficients, a symmetrical pulse arises, i.e., $\tau_{p.f} \approx \tau_{a.f}$. For stability of results, flow turbulization was created by passing a dielectric sphere with diameter D_1 close to pipe diameter D_2 through the pipe, at any set velocity in the range of 1 to 50 cm/s. The diameters of pipe [tube] D_2 were varied from 0.1 to 2 cm in different experiments. In these experiments, aqueous solutions of $CuSO_4$ varying in concentration, copper and graphite electrodes were used.

Figure 3 illustrates a typical oscillogram of the observed pulses. Figure 4a illustrates pulse amplitude as a function of temperature $U_0 = f(t°C)$ and Figure 4b, pulse amplitude as a function of effects of sinusoidal VMF of different frequencies and intensities. According to Figure 4a, the MSC resorption effect appears at temperatures in excess of 40-50°C and it decreases somewhat in the low temperature range. Figure 4b shows that, with increase in frequency and amplitude there is resorption of MSC. In our opinion, such a model is also of independent interest for the study of electricphenomena that occur when an erythrocyte passes through a blood capillary.

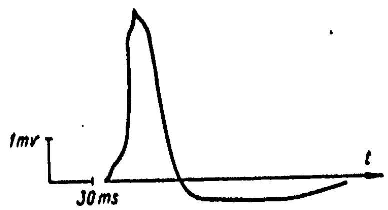


Figure 3. Shape of electric pulse arising with resorption of space charge near small electrode

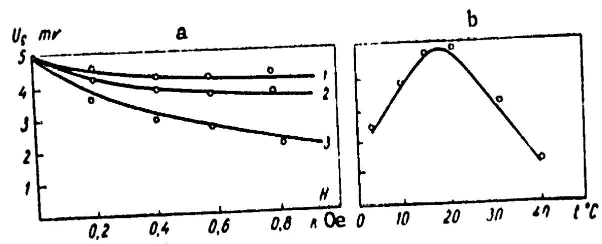


Figure 4. Amplitude (y-axis) of electric pulse as a function of frequency and intensity of VMF (a) and electrolyte temperature (b)

The appearing space charge causes diffusion potential U_{dif}, the magnitude of which is determined by the equation:

$$U_g = \frac{RT}{F} \sum_{i=1}^{i} \frac{D_{k,i} - D_{a,i}}{Z_{k,i} D_{k,i} + Z_{a,i} D_{a,i}} \cdot \ln \frac{C_{i,1}}{C_{i,2}}, \qquad (7)$$

where R is the constant of Mendeleyev-Clapeyron, T is absolute temperature, F is the Faraday number, $D_{a,i}$ and $D_{k,i}$ are the diffusion coefficients for cations and anions, $Z_{a,i}$ and $Z_{k,i}$ are their charges, i is the kind of ion, $C_{i,1}$ and $C_{i,2}$ are the ion concentrations on the phase interfaces and in the space.

The conceptions expounded above concerning the nature of formation and role of space charges also enriched our conceptions about the role of endogenous electric properties of a living system in the mechanism of action of MF. The presence of diffusion transport of matter to the cell surface from the ambient medium, their efflux via a diffusion route and selective transfer of ions through membranes--all this enables us to agree that in such systems not only are there diffusion layers outside the cell and near its actively functioning organelles, for example, mitochondria (Figure 5), but also MSC with their inherent properties in these layers. The presence in such systems of both low molecular and high molecular ions, for example, of a protein nature, warrants the belief that this charge serves not only as an electric barrier, but has special structurization in this region, which we also observed in our physicochemical studies [34, 35]; in addition to this, with resorption of part due, for example, to the presence of low molecular Cl^-, OH^-, etc., anions, and a slowly resorbing part due to protein ions.

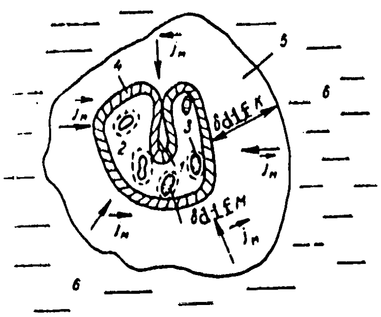


Figure 5.
Diagram of formation of macroscopic space charge near membranes of isolated intact cell
1) nucleus
2) intracellular medium
3) mitochondria
4) surface membrane of cell
5) region of diffusion layer
6) extracellular medium

No doubt, resorption of such a charge, partial or complete, does not require considerable energy since, according to our theoretical and experimental estimates for MSC and estimates for MSC in disperse systems [32, 33], it is of the following order:

$$E_{MSC} \simeq \frac{U_{\varepsilon}}{\delta_{MSC}} \approx 10^2 - 10^3 \text{ V/cm}, \quad (8)$$

whereas in the regions near membranes, where there is a concentration of space charges of enormous density, the electric fields are of the order of 10^5 W/cm.

This conclusion warrants the belief that the superposition of electric fields of the order of hundreds of W/cm can have a direct influence on metabolism of living cells.

In our model experiments, resorption of such a space charge by different techniques enabled us to alter substantially the rates of various heterogeneous reactions in aqueous media with electrolyte concentrations of $C<0.1$ N.

We also believe that there may be effects leading to resorption of MSC, as illustrated in Figure 4b, in any living organisms exposed to VMF of relatively high frequency and intensity. Blood capillaries, where hydrodynamic conditions on both sides of endothelial cells are basically different, can serve as a typical example of areas of localization of such space charges. Under such conditions, we could expect that VMF would have a direct effect on transendothelial transfer and, consequently, on capillary permeability.

The EHD and MHD phenomena occurring in living systems are attributable primarily to the energy of the living systems themselves. Under the influence of SMF and VMF, there is a change in electric energy accumulated by the living system and energy of both types of space charges into mechanical energy, which is capable of performing work, altering barrier thickness and rate of delivery of reagents to membranes and reaction zones.

With reference to the possibility of direct MDH and EHD effects on metabolism of living cells leading to microvibrations, microconvection and "barrier resorption" effects, it should be noted that the following applies when there is additional appearance in living tissue of pressure P_Σ, induced by MDH and EHD forces:

$$P_\Sigma = \frac{F_\Sigma}{\rho_\delta} > \tau_0, \tag{9}$$

where ρ_δ is the cross section of the cell or diffusion layer and τ_0 is maximum intensity of change in protoplasm, which may become diluted or even split, especially in the case of brief exposure to electromagnetic fields of an impact nature, as comprehensively discussed by Yu. V. Berlin et al. [37].

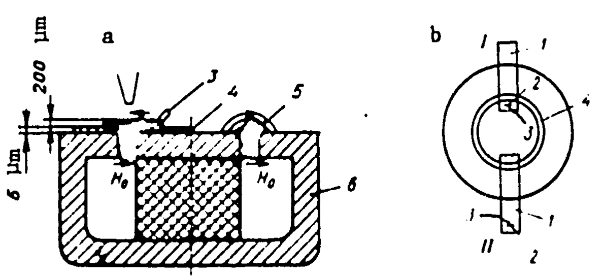
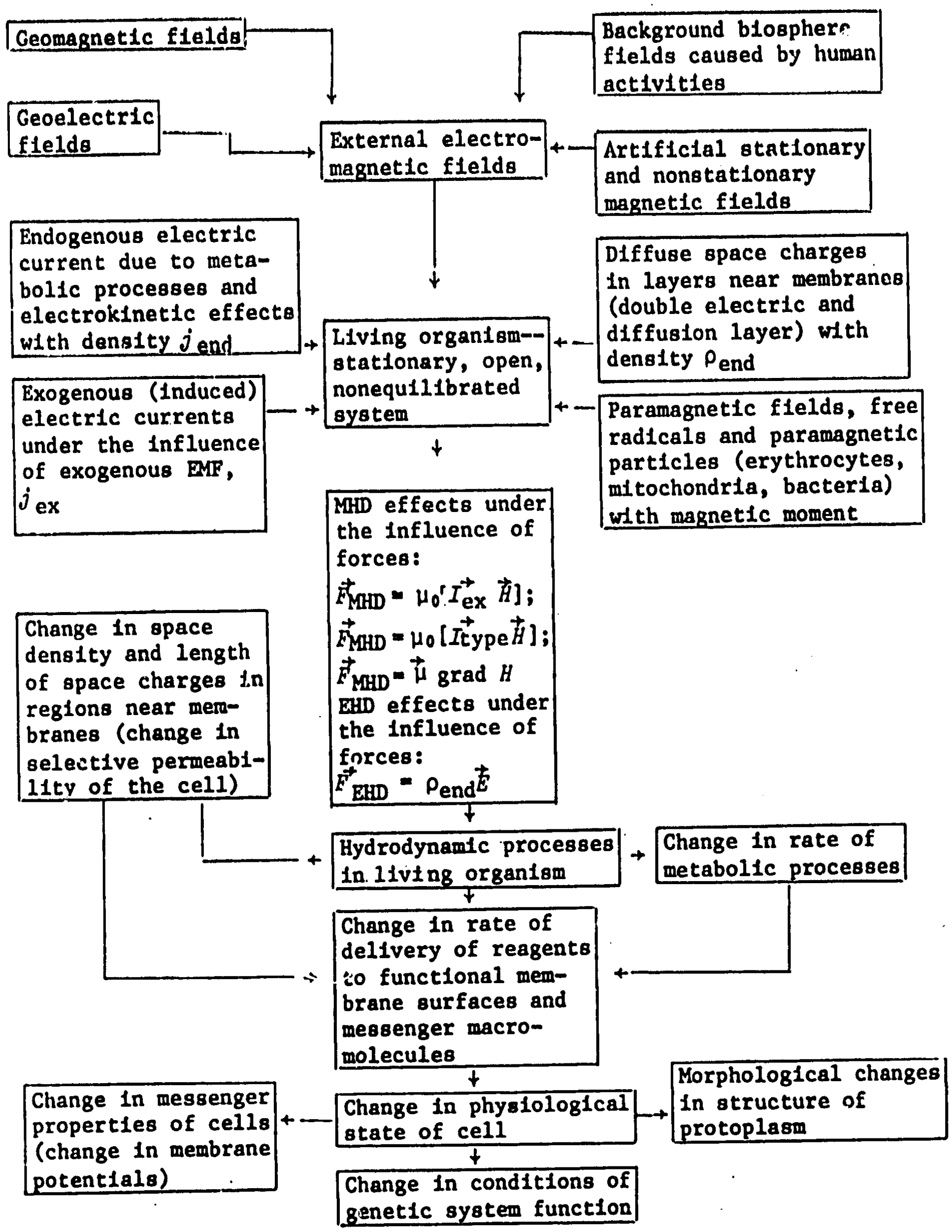


Figure 6. Diagram of experiment dealing with blocking of AP by heterogeneous MF (a) and set-up for stimulation of AP (b)

1) muscle preparation
2) nerve segment
3) salt crystal
4) nonmagnetic layer (film)
5) circular magnetic space
6) magnetic system with circular space

With preparation in position (I) there is no block, whereas in position (II) it does occur.

Chart


Geomagnetic fields
Background biosphere fields caused by human activities
Geoelectric fields
External electromagnetic fields
Artificial stationary and nonstationary magnetic fields
Endogenous electric current due to metabolic processes and electrokinetic effects with density $\vec{j}_{end}$
Diffuse space charges in layers near membranes (double electric and diffusion layer) with density ρ_{end}
Living organism--stationary, open, nonequilibrated system
Exogenous (induced) electric currents under the influence of exogenous EMF, $\vec{j}_{ex}$
Paramagnetic fields, free radicals and paramagnetic particles (erythrocytes, mitochondria, bacteria) with magnetic moment
MHD effects under the influence of forces:
$\vec{F}_{MHD} = \mu_0[\vec{I}_{ex}\vec{H}]$;
$\vec{F}_{MHD} = \mu_0[\vec{I}_{type}\vec{H}]$;
$\vec{F}_{MHD} = \vec{\mu}$ grad H
EHD effects under the influence of forces:
$\vec{F}_{EHD} = \rho_{end}\vec{E}$
Change in space density and length of space charges in regions near membranes (change in selective permeability of the cell)
Hydrodynamic processes in living organism
Change in rate of metabolic processes
Change in rate of delivery of reagents to functional membrane surfaces and messenger macromolecules
Change in messenger properties of cells (change in membrane potentials)
Change in physiological state of cell
Morphological changes in structure of protoplasm
Change in conditions of genetic system function

Numerous data in the literature and, apparently, our own experimental findings with regard to the effects of SMF and VMF on living systems can serve as experimental confirmation of the above conceptions.[11, 13-18, 38-40].

For example, as shown by calculations, one can induce a direct SMF effect on living systems, even with the use of shields, by means of using MF gradients of the order of 10^5-10^7 Oe/cm and intensities of the order of kilooersteds. We generated such fields under laboratory conditions, and in these experiments we observed changes in concentration and vital functions of iron-depositing bacteria [15], as well as total blocking of action potential (AP) conduction in neuromuscular fibers. The techniques for this experiment were described by A. V. Kibyakov et al. [39, 40], while Figure 6 illustrates the experimental set-up.

Let us indicate that experimental results analogous to those reported by A. V. Kibyakov [39, 40] were subsequently obtained by P. G. Bogach et al. [41]. However, since the authors used lower Hgrad H, they succeeded in inducing a partial block of AP conduction, characterized by a decrease in amplitude and rate of conduction. All of the foregoing enabled us to formulate the primary mechanism of interaction between MF and living systems (see Chart) as follows: exogenous SMF and VMF, as well as spontaneous and artificial concomitant electric fields, which interact with electric currents and space charges of an endogenous nature that are determined by metabolic processes in the course of function of a living organism, induce generation of MHD and EHD pressures capable of altering the rate of metabolic processes, cell permeability, rate of delivery of reagents to functioning membrane surfaces and messenger macromolecules.

Equation (5) reflects only the general nature of MF effects on living systems. A comparative quantitative analysis of the effects on living systems of different types of MF would be of special interest to practice. In most cases, such estimates are feasible. Thus, we consider the case where VMF is involved against the background of SMF of considerable intensity, which occurs, for example, by insufficient rectification of current in the electromagnetic which, in turn, causes a radical increase in all SMF effects.

The analysis revealed that analogous effects can be obtained by exposing living systems to VMF with an intensity of $H_{1,2} \gg H_{2,0}$ but provided that $\omega_2 \gg \omega_1$, which we also observed [16-18].

The mechanism we have discussed reflects only the primary effects of MF on living systems. The reaction of an integral organism is a more complex phenomenon that requires further special investigation with due consideration of the role of the central nervous system.

BIBLIOGRAPHY

1. Akkerman, Yu. "Biofizika" [Biophysics], Moscow, 1964, p 554.

2. Abashin, V. M., and Yevtushenko, G. I. "Effects of Stationary Magnetic Fields on Biological Systems," BIOFIZIKA [Biophysics], 20, 2, 1975, pp 281-282.

3. Idem, "Stationary Magnetic Fields and Impulse Conduction in Nerves," Ibid, 20, 2, 1975, pp 276-281.

4. Idem, "Comments on Article Entitled 'Effects of Magnetic Fields on Blood Flow' by V. A. Vardanyan," Ibid, 18, 3, 1973, p 491; 19, 6, 1973, pp 1117-118.

5. Dorfman, Ya. G. "Physical Phenomena in Living Objects Under the Influence of Stationary Magnetic Fields," in "Vliyaniye magnitnykh poley na biologicheskiye ob"yekty" [Effects of Magnetic Fields on Biological Objects], Moscow, Nauka, 1971, pp 17-31.

6. Shishlo, M. A. "Effects of Magnetic Fields on Enzymes, Tissular Respiration and Some Aspects of Metabolism in the Intact Organism," Ibid, pp 32-58.

7. Presman, A. S. "Electromagnetic Fields and Living Nature," Moscow, Nauka, 1968.

8. Travkin, M. P. "Possible Mechanisms of Biological Effects of Magnetic Fields," in "Mater. nauch.-metod. konf. Belgorod" [Proceedings of Scientific and Methodological Conference in Belgorod], 1969, pp 23-26.

9. Piruzyan, L. A.; Glezer, V. M.; Dement'yev, V. A.; et al. "Mechanism of Biological Action of Stationary Magnetic Fields," IZV. AN SSSR. SER. BIOL. [News of the USSR Academy of Sciences. Biology Series], No 4, 1970, pp 535-539.

10. Aristarkhov, V. M.; Piruzyan, V. P.; and Tsybyshev, V. P. "Physicochemical Bases of Primary Mechanisms of Biological Effects of Magnetic Fields" (in this collection, p 6), 1977.

11. Komarov, G. P., and Gak, Ye. Z. "Primary Mechanism of Physicochemical Action of Stationary and Low-Frequency Magnetic Fields on Biological Objects," in "Mater. III Vsesoyuz. simp. Kalningrad" [Proceedings of 3d All-Union Symposium in Kaliningrad], 1975, pp 31-32.

12. Arber, S. L., and Faytel'berg-Blank, V. R. "Mechanism of Biological Effects of Electromagnetic Fields on the Cell," in "Elektronnaya obrabotka materialov" [Electronic Processing of Materials], Vyp 6, 1974, pp 67-70.

13. Gak, Ye. Z. "Some Questions of Biological Effects of Stationary Magnetic Fields," in "Morfologicheskiye i khimicheskiye izmeneniya v protsesse razvitiya kletki" [Morphological and Chemical Changes During Cell Development], Riga, Zinatne, 1967, pp 125-132.

14. Gak, Ye. Z. "On the Question of Primary Mechanisms of Physicochemical Processes With Exposure of Biological Objects to Stationary Magnetic Field," in "Tezisy I soveshch. po izucheniyu vliyaniya magnitnykh poley na biol. ob"yekty" [Summaries of Papers Delivered at the First Conference Dealing With the Study of the Effects of Magnetic Fields on Biological Objects], Moscow, Nauka, 1969, pp 18-20.

15. Idem, "On the Question of Effects of External and Local Magnetic Fields on Biological Objects," TRUDY LENINGR. OB-VA YESTESTVOISPYTATELEY (LGU) [Works of the Leningrad Society of Naturalists (Leningrad State University)], Vol 76, Vyp 1, 1971, pp 57-59.

16. Gak, Ye. Z.; Komarov, G. P.; and Zhgenti, T. G. "The Mechanism of Biological Action of Low-Frequency Magnetic Fields," in "Elektronnaya obrabotka materialov," Vyp 1, 1971, pp 63-66.

17. Zhgenti, T. G.; Gak, Ye. Z.; Komarov, G. P.; and Nishnianidze, K. A. "Biological Activity of Sonic Range of Magnetic Fields," Ibid, pp 82-84.

18. Gak, Ye. Z., and Komarov, G. P. "Some Distinctions of Effects of Low-Frequency Magnetic Fields on Biological Objects," Ibid, pp 71-73.

19. Romanovskiy, Yu. M.; Stepanova, N. V.; and Chernavskiy, D. S. "Mathematical Modeling in Biophysics," Moscow, Nauka, 1975, pp 320-321.

20. Bauer, E. S. "Theoretical Biology," Leningrad--Moscow, Izd-vo VIEM [All-Union Institute of Experimental Medicine], 1935.

21. Tokin, B. P. "Theoretical Biology and the Creativity of E. S. Bauer," 2d edition, Izd-vo LGU [Leningrad State University], 1968.

22. Emanuel', N. M., and Knorre, D. G. "Course of Chemical Kinetics," 3d edition, Moscow, Vysshaya shkola, 1974.

23. Pudovkin, P. P. "Distribution of Electric Fields in the Ionosphere," in "Subburi i vozmushcheniya v magnitosfere" [Substorms [?] and Perturbances in the Magnetosphere], Moscow, Nauka, 1978, pp 38-66.

24. Voychishin, K. S.; Brachan, Ya. P.; Kuksenko, V. I.; and Mihaylovskiy, V. N. "Informative Correlations Between Bio-Helio-Geophysical Phenomena, and Elements of Forecasting Them," Kiev, Naukova dumka, 1974.

25. Gak, Ye. Z., and Rik, G. R. "Effects of Stationary Magnetic Field on Kinetic Movement of Ions in Aqueous Solutions of Potent Electrolytes," DAN SSSR [Reports of the USSR Academy of Sciences], 175, No 4, 1967, pp 856-858.

26. Gak, Ye. Z.; Rokhinson, E. Kh.; and Bondarenko, N. F. "Distinctions of Changes in Kinetics of Electrode Processes in Electrolytes in Stationary Magnetic Fields," ELEKTROKHIMIYA [Electrochemistry], 11, 4, 1975, pp 528-534.

27. Gak, Ye. Z., and Komarov, G. P. "Stationary Flows in Electrolytes in Low-Frequency Magnetic Fields," ZHTF [Journal of Technical Physics], 41, 9, 1971, pp 1996-1998.

28. Fefer, A. S. "A Means of Exposing Biological Objects to Magnetic Fields (Author Certificate 445 438)," BYUL. IZOBRET., OTKRYTIY I PROM. ZNAKOV [Bulletin of Inventions, Discoveries and Trademarks], No 37, 1974, p 15.

29. Idem, "Magnetophores and Magnetophore Devices," (in this collection, p 209), 1978.

30. Gak, Ye. Z.; Gak, M. Z.; and Komarov, G. P. "A Method of Direct Generation of Mechanical Oscillations in Electrolyte Space (Author Certificate 410 821)," BYUL. IZOBRET., OTKRYTIY I PROM. ZNAKOV, 2, 1974, p 22.

31. Bondarenko, N. F., and Gak, M. Z. "Investigation of Nonlinear Properties of Capillary Gravitation Waves in Electrolytes," INFORM. BYUL. AFI [Information Bulletin of the Institute of Agricultural Physics], No 17-18, 1973, pp 102-108.

32. Dukhin, S. S., and Shilov, V. N. "Electrical Phenomena and Double Layer in Disperse Systems and Polyelectrolytes," Kiev, Naukova dumka, 1975.

33. Dukhin, S. S. "Electric Conduction of Disperse Systems," Kiev, Naukova Dumka, 1975.

34. Gak, Ye. Z.; Rokhinson, E. Kh.; and Bondarenko, N. F. "Possibility of Electrodynamic Effects in Electrolytes," ZHTF, 44, 5, 1974, pp 1066-1069.

35. Idem, "The Role of Space Charges in Kinetics of Electrode Processes," in "Elektronnaya obrabotka materialov," Vyp 6, 1973, pp 23-28.

36. Idem, "Influence of Magnetohydrodynamic Effects on Voltampere Characteristics of Flow-Type Electrochemical Cells,: ELEKTROKHIMIYA, 11, No 4, 1975, pp 535-539.

37. Berlin, Yu. V.; Buvin, G. M.; Bel'kevich, V. I.; and Gak, Ye. Z. "Distinctions of Effects of Pulsed Magnetic Fields on Biological Systems," (this collection, p 39), 1978.

38. Il'in, V. S.; Yemel'yantsev, A. M.; Komarov, G. P.; et al. "Biochemical Bases of Neural Trophics and Impairment Thereof in Skeletal Muscles," ZHURN. EVOLYUTS. BIOKHIM. I FIZIOL. [Journal of Evolutionary Biochemistry and Physiology], 8, 3, 1972, pp 240-251.

39. Kibyakov, A. V.; Komarov, G. P.; and Gak, Ye. Z. "The Role of Hydrodynamic Factors in Synaptic Transmission," FIZIOL. ZHURN. SSSR [Physiological Journal of the USSR], 57, No 11, 1971, pp 1641-1646.

40. Komarov, G. P., and Gak, Ye. Z. "Action Potential Blocking by Magnetic Fields," in "Mater. III Vsesoyuz. simp. Kaliningrad." 1975, pp 16-17.

41. Bogach, P. G.; Mirutenko, V. I.; and Kondrat'yeva, I. D. "Effects of Stationary Magnetic Fields and Ultrahigh-Frequency Electromagnetic Fields on Membrane Potential of Nerve and Muscle Cells," in "Mater. IV Mezhdunar. biofiz. kongr." [Proceedings of 4th International Biophysics Congress], 1973, p 245.

10,657
CSO: 8144

SOME DISTINCTIONS OF EFFECTS OF PULSED MAGNETIC FIELDS ON CONDUCTIVE FLUIDS AND BIOLOGICAL SYSTEMS

Moscow REAKTSII BIOLOGICHESKIKH SISTEM NA MAGNITNYYE POLYA in Russian 1978 signed to press 24 Feb 78, pp 39-48

[Article by Yu. V. Berlin, G. M. Buvin, V. I. Bel'kevich and Ye. Z. Gak, All-Union Scientific Research Institute of Medical Instrument Making, Moscow; Agrophysical Scientific Research Institute of the All-Union Academy of Agricultural Sciences imeni Lenin, Leningrad]

[Text] Of all the diversity of MF [magnetic fields] of spontaneous and artificial nature that influence biological systems [6], PMF [pulsed magnetic fields] are biologically the most active and the least studied. Yet PMF are encountered under the most diverse industrial conditions (when servicing radio-relay communication lines, radar stations, in a number of technological industries, etc.).

Thus, artificial PMF have become one of the environmental factors that affects man constantly. And if we consider that significant PMF are formed in the living organism with generation of action current [1, 5, 10, 11], the importance of studying the effects of PMF on models of biological processes becomes understandable.

There has been discussion of PMF that are active in a limited space, for example, when an animal is placed completely or partially in a solenoid [7-9]. Yet instances of traveling MF (or sliding in space) are encountered, when different parts of the body of a living object are successfully exposed to them.

An analogous phenomenon can be observed in living systems. Evidently, the MF accompanying propagation of action potential along an axon can be conceived of as a sliding PMF [1, 10, 11].

Consideration of such a problem is of interest, not only to define the mechanism of action of a moving PMF on biological systems, but as related to a number of technological tasks involving continuous exposure of flowing liquid to MF. There have been virtually no studies of the mechanism of action of PMF on various processes in aqueous media, and still unclear is the role of such important factors as transconductance ["steepness"] of edges, on-off time ratio and duration of MF pulses. All this prompted us to conduct this investigation.

The inadequate knowledge of primary physicochemical mechanisms of action of MF on man, animals and plants retarded development of research, both on the use of MF for treatment purposes and effects of this factor on the biosphere, physiological and regulatory mechanisms in man. It must be noted that such research is only making its first cautious steps in several branches of technology. This applies, in particular, to comprehension of the mechanism of effects of PMF on transfer processes in aqueous media.

We shall dwell on the distinctions of effects of PMF with a shape that is close to the ideally square-wave, since other pulse shapes are much closer to the known types of effects of nonstationary fields. For the sake of convenience in our further discussion of phenomena occurring in aqueous media, we shall successively consider the effect of a single pulse, train of pulses and PMF moving in space.

As we know, any pulsed signal lasting for a short period of time in relation to an interval considered can be described in the form of a Fourier series and written as follows:

$$\varphi(t) = \sum_{0}^{\infty} A_n \sin(2\pi f_n t + \gamma_n), \qquad (1)$$

where A_n is the amplitude of pulse components, f_n is the pulse frequency and γ_n is the phase.

In our further study of physicochemical mechanisms of phenomena that then arise, we shall confine ourselves to the simplified form of function $h(t)$ for a single pulse.

Figure 1a illustrates a typical single MF pulse $h = f(t)$, where τ_{af} is the duration of the leading edge [anterior front], τ_{pf} is the duration of the trailing edge [posterior front] of the pulse and τ_p is the duration of the central part of the pulse with amplitude H. Let us designate $\tau_{pf}/\tau_{af} = m$, and $m \geq 1 \div 5$. For value $h(t)$ with $0 \leq t \leq \tau_{af}$, i.e., to describe the leading edge of the pulse, let us assume the following condition:

$$h(t)\Big|_0^{\tau_{af}} = K_{af} t, \qquad (2)$$

where with $t = \tau_{af} \rightarrow K_{af} = \dfrac{H}{\tau_{af}}$.

At the same time with $\tau_{af} \leqslant t \leqslant \tau_p + \tau_{af}$ for $h(t)$ we should assume

$$h(t)\Big|_{\tau_{af}}^{\tau_p + \tau_{af}} = H, \qquad (3)$$

and with $\tau_{af} + \tau_p \leqslant t \leqslant \tau_p + \tau_{pf} + \tau_{af}$ $h(t)$ we can write down

$$h(t)\Big|_{\tau_{af}+\tau_p}^{\tau_{af}+\tau_p+\tau_{pf}} = H - K_{pf} t, \text{ where } K_{pf} = \frac{H}{\tau_{pf}}, \qquad (4)$$

so that

$$h(t) = K_{af}t\Big|_0^{\tau_{af}} + H\Big|_{\tau_{af}}^{\tau_{af}+\tau_p} + (H - K_{pf}t)\Big|_{\tau_p+\tau_{af}}^{\tau_{af}+\tau_p+\tau_{pf}}. \quad (5)$$

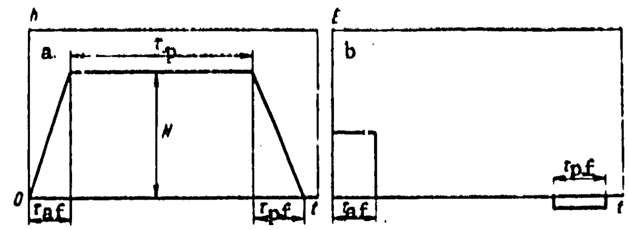


Figure 1. Diagram of magnetic field pulse (a) and induced electric pulse in conductive medium (b)

As it has been noted [4], one can obtain considerable MF effects on aqueous media and, first of all, changes in kinetics of heterogeneous reactions, mainly when such systems have electric currents due to nonequilibrium processes, i.e., when condition $j_{H\neq 0} \neq 0$ is met and when there are various space charges in the systems, i.e., $\rho_{sc,H\neq 0} \neq 0$. In addition, there may also be different ions in aqueous media, particles with $\mu \neq 0$, where $\vec{\mu}$ is the magnetic moment. The presence of some conductivity of aqueous media due to presence of low molecular ions determines, in turn, generation of induced electric currents in the aqueous media under the influence of induced EF [electric field] in space $j_{ind} \neq 0$, so that total current density in the medium can be written down as:

$$j_{H\neq 0} \cong j_{(H=0)} + j_{ind}\,. \quad (6)$$

Let us determine function $E(t)$ with consideration of $h(t)$ (Figure 1). Since $E \approx \frac{\partial h}{\partial t} f(r)$, where $f(r)$ is determined by f as a function of coordinates, by making a graphic differentiation of $h(t)$ with consideration of (2)-(4), we can describe $E(t)$ as in Figure 1b, which shows that with $\tau_{af} \leqslant t \leqslant \tau_{pf} + \tau_p$ $E(t) = 0$, with $0 \leqslant t \leqslant \tau_{af}$:

$$E(t) = \frac{H}{\tau_{af}} = \text{const}, \quad (7)$$

and with $\tau_p + \tau_{af} \leqslant t \leqslant \tau_{pf} + \tau_{af} + \tau_p$

$$E(t) = -\frac{H}{\tau_{pf}} = \text{const}. \quad (8)$$

Thus, at moment $\tau_{af} \leqslant t \leqslant \tau_{af}+\tau_p$, the MF effect on transfer processes in aqueous media is determined only by force:

$$f_{MHD} = \mu_0 [j_{H \neq 0} \times H] + \chi H_{grad} H, \tag{9}$$

where grad H characterizes the degree of MF heterogeneity, χ is magnetic susceptibility and MHD is magnetohydrodynamic.

As noted in (4), under the influence of these forces phenomena of convection and diverse hydrodynamic phenomena may arise in the aqueous medium, but the specifics of PMF action is not manifested here, especially under condition that $\tau_p/\tau_{af} \gg 1$. In modern equipment, such a correlation constitutes up to $10^6 \div 10^7$ or more. Figure 1b shows that the amplitude of generated EF pulses is inversely proportional to their duration.

In this case, the most interesting effects should be expected expressly at time $0 \leqslant t \leqslant \tau_{af}$ and $\tau_p+\tau_{af} \leqslant t \leqslant \tau_p+\tau_{af}+\tau_{pf}$. In this interval, in the space of the electrolyte with conductivity σ electric currents arise with density:

$$j_{ind\ \tau af} \approx \sigma \frac{H}{\tau_{af}} \psi(r, y, \theta), \tag{10}$$

$$j_{ind\ \tau pf} \approx -\sigma \frac{H}{\tau_{pf}} \psi(r, y, \theta). \tag{11}$$

Then, in the volume of the aqueous medium, with $0 \leqslant t \leqslant \tau_{af}$, forces are generated that are defined by the following values:

$$f_{\tau_{af}}(t) = \mu_0 [(j_{n \neq 0} + h(t)] + \rho_{SC} \frac{H}{\tau_{af}} \psi(r, y, \theta) + \chi h(t) \operatorname{grad} h(t). \tag{12}$$

Analysis of the above equations enables us to demonstrate several distinctions of PMF effects in the case of $\tau_{af} \leqslant 10^{-5} \div 10^{-7}$, τ_p = 0.01 1 s or more, which can be briefly formulated as follows:

1. Under the influence of PMF with high transconductance $10^{-5} \div 10^{-6}$ s and duration of the order of $10^{-2} \div 1$ s, high density pulsed electric currents arise, $j_{p,ind}$, the amplitude of which is determined by the conductivity of the fluid, pulse amplitude and duration are comparable in order of magnitude to currents generated under the influence on aqueous media of sinusoidal j_{sin} VMF [variable magnetic fields] at a frequency of $10^5 \div 10^7$ Hz with the same amplitude H.

Since, other conditions being equal:

$$\frac{j_{\text{sin.ind}}}{j_{\text{p.ind.}}} = \frac{2\pi\tau_{af}}{T} \qquad (13)$$

with $T \ll \tau_{af}$ $j_{\text{sin.ind}} \leqslant j_{\text{p.ind.}}$, where $T = 1/f$, $j_{\text{ind.sin.}}$

is the density of induced current under the influence of $H = H_0$ sine ωt.

2. The magnetohydrodynamic forces arising in period $0 \leqslant t \leqslant \tau_{af}$ and $\tau_p + \tau_{af} < t \leqslant \tau_p + \tau_{af} + \tau_{pf}$ are equal in mean value and opposite in sign, i.e., sign-variable pressures appear in the medium, but with interval τ_p between them. Herein lies the difference of occurring pressures from those introduced by ultrasound, which is usually obtained from generators of sinusoidal oscillations. Consequently in the case of a low value of τ_p, i.e., with $\tau_p \simeq \tau_{af}$, $\tau_p \simeq \tau_{pf}$, when the value of H is relatively low, the pressures may be:

$$\begin{aligned} P_{afMHD} &< \tau_{0,st}, \\ P_{pfMHD} &< \tau_{0,st}, \end{aligned} \qquad (14)$$

where $\tau_{0,st}$ is maximum shear stress of the liquid.

The rheological properties of the liquid medium do not necessarily change; macroscopic effects can occur only in the time interval $\tau_{af} \leqslant t \leqslant \tau_p + \tau_{pf}$, as we have noted above.

3. With significant values of $\tau_p = 10^{-2} \div 1$ s or more, hydrodynamic effects are manifested due to the fluidity effect of the liquid, i.e., there could be generation of hydrodynamic oscillations in aqueous media or convection due to heterogeneous distribution of forces in the volume. Thus, in our opinion, long pulses with liquid $\tau_p \gg \tau_{rel}$ time and with transconductance [steepness] of edges and time of the order of 10^{-6} s or less.

4. In the case of a periodic sequence of unipolar pulses with period T (Figure 3), of particular importance are the pauses between pulses, because if $\tau_{pauses} \ll \tau_{rel}$ the relaxation effect disappears and we can refer to a continuous spectrum of effects.

5. In the case of treating an aqueous medium with a single MF pulse that moves in space at a relatively slow rate, one should also expect generation of "running" magnetohydrodynamic and electrohydrodynamic forces in the liquid, at the same rate. Generation of such spatially heterogeneous forces should be associated with an increase in all types of convection effects.

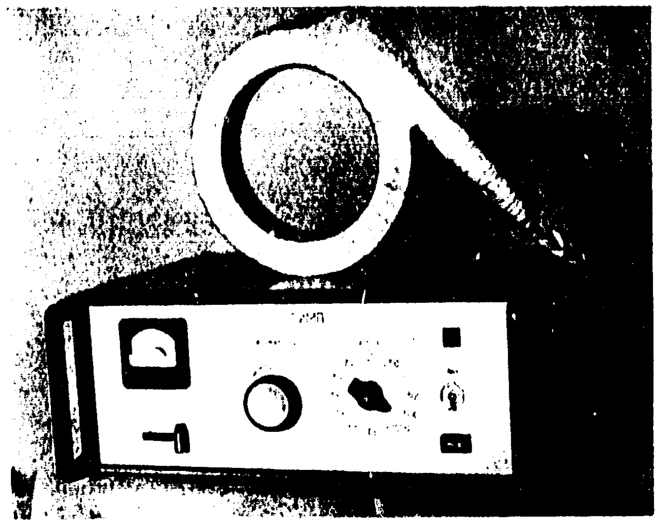


Figure 2. Generator of sliding pulsed magnetic field

6. All of the foregoing, with consideration of [6], causes intensification of all heterogeneous reactions in the nonequilibrated aqueous system.

The effects of PMF on aqueous media can be demonstrated by physicochemical experiments. As an example, we made an experimental study of the effect of turning the electrolyte in a circular electrochemical cell by the method described in [3].

A device was designed for experimental purposes to generate a moving PMF [4] (GPMF), which provided for the successful formation of magnetic pulses.

Let us mention that, as demonstrated by our experiments, the generated pulses fully met the above stipulation, i.e., $\tau_{af} \approx 10^{-6}$, $\tau_{pf} \approx 10^{-6}$ and τ_p = 0.01 1 s. Moreover, with spatial separation of coils we could obtain the effect of an MF sliding in space [1].

The GPMF device consists of a pulse generator, distributor, oscillator [shaper] keys, electrodes and switch. The pulse generator is assembled as a multivibrator, yielding approximately square-wave voltage with varying pulse recurrence frequencies. The distributor is a circular n-digit counter with presetting of the initial state. The oscillator key is executed as an inverter, and the coils of the circular electrode are connected to it. The device delivered sliding PMF of 0.5-25 Oe, and the multivibrator made it possible to select pulse recurrence frequencies of 1 to 1000 Hz with 1 to 400 mA current in the electrode coils.

The effects of PMF on a colloid 2% suspension of analogous ferromagnetic particles flocculating in MF are of independent interest. Such a suspension is a model of relaxing medium liquid with $\tau_{rel} \approx 0.1 \div 0.2$ s. Depending on the intensity of MF, ranging from 1 to several dozen oersted, there is a change in number of particles oriented in the field and a corresponding change in optical coefficient of passage of light in such a medium. We observed the action of PMF according to modulation of intensity of a laser beam traversing the suspension. The beam of light from an LG-75 laser, reflected from a mirror, passes through the bottom of the glass with the suspension and hits a photodetector (photodiode). The glass is situated in an inductor fed by the pulse generator. As can be seen on the oscillogram (Figure 3), if $\tau_p > \tau_{rel}$ the medium has time to alter light absorption after MF changes, and if $\tau_p \approx \tau_{rel}$ we observe distortion of the leading edge of the light pulse.

The above-described phenomena can also exist in living systems exposed to PMF, since all of the above properties of aqueous systems are present in biological systems, i.e., induced and endogenous electric currents, diverse space charges, paramagnetic ions and particles.

A special property of square-wave MF pulses is the possibility of obtaining in biological tissues, under isothermal conditions, high pulse pressures with relatively low expenditure of average power, which is analogous to impact [shock] factors that impair biological structures.

At the same time, exposure of biological objects to spatially sliding MF makes it possible to radically intensify the effect of heterogeneity of forces appearing in space.

As an example of the direct effect of MF on biological objects, we shall submit the results obtained with exposure of a skeletomuscular system to a field [1, 2].

We tested the effect of a sliding wave field with intensity of 0.5 to 25 Oe on the human skeletomuscular system on the basis of changes in the main informative parameters of electrical activity of muscles: mean frequency and degree of coherence [synphasing] of electrical processes in two leads.

We recorded 2 electromyograms for 1 min before exposure, immediately after exposure and 5 min after exposure during isometric contraction of the brachial biceps with a constant load. Analysis of electrical activity of the muscle was made on a specialized MIAN-1 device.

The mean frequency of the electric myosignal was estimated as the mean number of intersections (number of zeroes per unit time) of the electromyosignal isoline. To assess synphasing of two myosignals, we determined the coefficient of the intercorrelation function with a zero shift between these signals ($\tau = 0$).

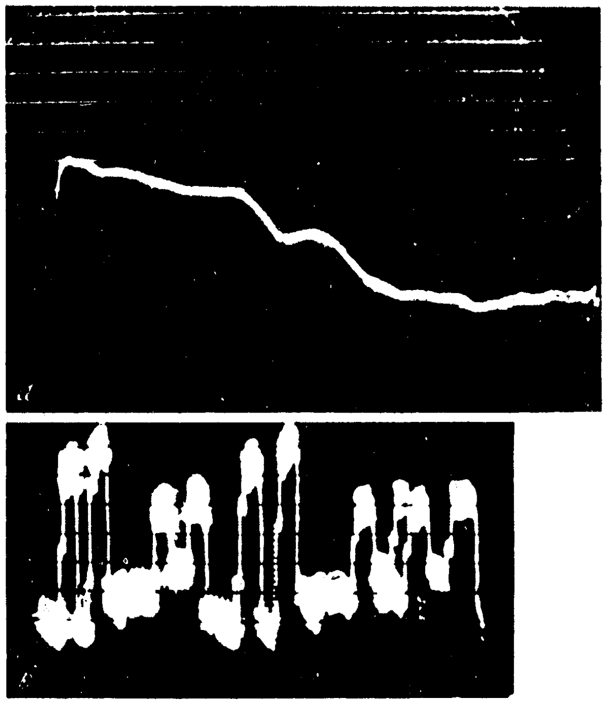


Figure 3. Oscillogram of intensity of modulated light from quantum generator (LG-75). A single MF pulse of 1800 Oe (a) and sliding MF Pulses of 20 Oe, 10 Hz (b)

As shown by analysis, the change in frequency of electrical oscillations and degree of synphasing in two leads characterize the change to an alleviated asyncrhonous mode of stimulation of motor units, which is reflected by an increase in frequency and decrease in synphasing. Figure 4 illustrates the relative changes in these parameters averaged for a period of 20 s. The indices for the first 20-s interval prior to exposure were taken as 100%. We observed virtual smoothing of the effects in the next 5 min. No changes in electromyosignals were observed with exposure to stationary MF of the same intensity.

In conclusion, we should like to mention some areas of practical application of PMF with a high transconductance [steepness] of edges [fronts].

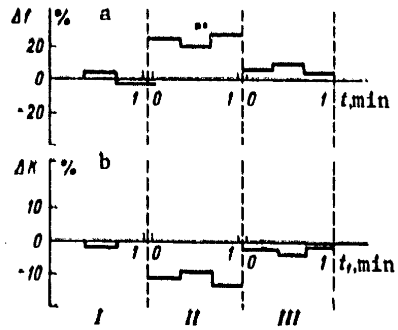


Figure 4.
Diagram of distribution of mean frequency of electromyosignals (a) and degree of synchronization (b) of electrical activity of muscles

I) before exposure
II) after exposure
III) 5 min after exposure

1. The use of PMF with $\tau_{af} \approx 10^{-6}$ s permits experimental investigation of their effects on aqueous media, various models of biological tissues and, finally, directly on animals and man.

2. There is continuous generation of endogenous electric currents, due to metabolic energy, in living biological tissues. Electrical charges are generated near the surfaces of membranes, and there is also continuous flow of blood and other biological fluids at rates ranging from m/s to mm/s or less, which determines continuous generation of flow currents.

This makes it possible for intensive magnetohydrodynamic and electrohydrodynamic phenomena to be generated in biological tissues, even under the influence of low-amplitude PMF which, in turn, could have a substantial influence on these processes in the organism.

3. There are also several possible applications of PMF in solving a number of technical problems in various branches of the national economy. This thesis is based on prior experience with MF to intensify various heterogeneous processes in liquids [4] and experiments described here. In our opinion, of special interest are our experiments dealing with the effects of PMF from different sources, including GPMF, on the kinetics of behavior of a suspension of analogous ferromagnetic particles.

The great time and spatial heterogeneity effect makes it possible to control the distribution of particles in a volume of liquid, even with MF intensities of the order of a few oersted, which could be used to develop various types of instruments and devices.

BIBLIOGRAPHY

1. Berlin, Yu. V. "A Device for Exciting a Sliding Magnetic Field," NOVOSTI MEDITSINSKOY TEKHNIKI [News in Medical Technology], Vyp 1, 1974, p 123.

2. Berlin, Yu. V.; Krotov, A. V.; Bel'kevich, V. I.; et al. "Biophysical Prerequisites for Developing a New Method of Using Moving Magnetic Fields. Magnetic Fields in Medicine," TRUDY KIRG. MED. IN-TA (Frunze) [Works of Kirgiz Medical Institute], 100, 1974, p 20.

3. Gak, Ye. Z. "The Question of Magnetohydrodynamic Effect in Aqueous Solutions of Strong Electrolytes," ELEKTROKHIMIYA [Electrochemistry], 3, 1967, p 89.

4. Gak, Ye. Z.; Komarov, G. P.; and Gak, M. Z. "Magnetohydrodynamic and Electrohydrodynamic Effects in the Mechanisms of Action of Magnetic Fields on Biological Objects," (this collection, p 32), 1977.

5. Kibyakov, A. V.; Komarov, G. P.; and Gak, Ye. Z. "The Role of Hydrodynamic Factors in Synaptic Transmission," FIZIOL. ZHURN. SSSR [Physiological Journal of the USSR], 57, No 11, 1971, p 1641.

6. Manoylov, V. Ye. "Electricity and Man," Leningrad, Energiya, 1975.

7. Maryutin, V. I., and Dvorovenko, V. K. "Effects of Pulsed Magnetic Fields on Some Characteristics of Blood. Magnetic Fields in Medicine," TRUDY KRIG. MED. IN-TA (Frunze), 100, 1974, p 89.

8. Oliger, T. I. "Effect of Pulsed Magnetic Field on Cholinergic Nerves of the Heart. Magnetic Fields in Medicine," Ibid, p 61.

9. Toroptsev, I. V., and Garganeyev, G. P. "Comparative Characteristics of Biological Effects of Pulsed Magnetic Fields. Magnetic Fields in Medicine," Ibid, p 8.

10. Kolin, A. "Magnetic Fields in Biology," PHYSICS TODAY, 5, 1968, p 39.

11. Seipel, J. H., and Morrow, R. D. "The Magnetic Field Accompanying Neuronal Activity," J. WASH. ACAD. SCI., 50, 1960, p 1.

10,657
CSO: 8144

DESTABILIZATION OF NONEQUILIBRATED PROCESSES AS THE BASIS OF THE GENERAL MECHANISM OF BIOLOGICAL EFFECTS OF MAGNETIC FIELDS

Moscow REAKTSII BIOLOGICHESKIKH SISTEM NA MAGNITNYYE POLYA in Russian 1978 signed to press 24 Feb 78 pp 59-80

[Article by G. V. Plekhanov, Siberian Physico-Technical Institute, Tomsk]

[Text] Introduction

There are three scientific directions which have much in common, in spite of apparent differences. We refer to electromagnetic biology (EMB), investigation of solar and terrestrial relations (STR) and magnetic treatment of water and aqueous systems (MTW). If we consider them from the standpoint of the classical stimulus--object--reaction system of investigation, it is not difficult to see that electromagnetic fields (EMF) are used as the stimulus in all three directions. This stimulus is artificially created for EMB and MTW, whereas in the study of STR EMF of spontaneous origin constitute the direct active factor, as indicated by an analysis of the literature [6, 10-12, 39]. With the obvious difference in specific characteristics, the objects of investigation in these three directions also have at least one property in common, since they are all referable to nonequilibrium systems. One can alter substantially the course of processes in such systems by means of rather weak exogenous factors. The work performed by the system when it changes from one nonequilibrated state to another can be greater by several orders of magnitude, due to its endogenous energy, than the work of the acting stimulus. In view of the foregoing, the topics of these three sections can be combined under the general title of "Effects of EMF on Nonequilibrated Processes." But the basic similarity of the directions in question is also demonstrable in the general nature of reactions. Here, one observes a phenomenon that is quite familiar to researchers who have worked in this field for a long time, but quite shocking at first to novices, a phenomenon that we could call incomparability of the results of investigations. "Incomparability" refers to the fact that the results of studies may differ even when they are conducted under the very same conditions. This is encountered in the works of different authors, occasionally in the works of the same author and occasionally in the course of the same experiment.

Dozens of authors have studied the effects of magnetic fields (MF) on ESR [erythrocyte sedimentation rate] and more than a hundred works on this topic have been published; however, the opinions of different authors are quite varied as to the nature of ESR changes in MF. Some authors deny the fact that MF have an influence on ESR, even if they are of high intensity [32, 8]; others find that there is an increase in the rate [15, 13]; others yet find inhibition [1, 33] and, finally, there are some who state frankly that it proceeds in different directions [5, 24, 28-30, 34].

The reaction time in an individual exposed to MF may increase, decrease or undergo no change [2, 51, 69, 74, 75]. Nonspecific reactivity of animals in a magnetic field increases, decreases or does not change [9, 56, 24]. There are also changes in different directions in enzyme activity [20, 29], behavioral reactions [4, 65, 59, 27], growth and developmental processes [52, 54], etc., in a field, as compared to the control. Analogous findings are reported in studies of STR. As shown by biomedical investigations, onset of endemics [60-63, 66, 67, 71, 75], morbidity [67, 50, 60, 62], epizootic outbreaks [18, 19, 58, 44], changes in harvest [52], rate of wood growth [31], etc., are related to changes in level of solar activity. There is a 20-50% increase in mortality due to myocardial infarction [37, 38], an increase in accidents involving vehicles [16, 68] and an increase in suicides [16, 17] on the 2d day after a solar flare (with appearance of geomagnetic perturbations). But all this is demonstrable only by submitting large blocks of cases to statistical processing, and it may virtually fail to be reflected in the vast majority of biological systems. Changes in solar activity cause atmospheric perturbations [35, 36, 64], impairment of hydrological conditions [48, 49, 53] and increase the probability of earthquakes and eruptions of volcanoes [7], but they do not yet enable us to unequivocally predict a change in geophysical processes in each specific instance, i.e., in studying STR the phenomenon of ambiguity of reactions is even more apparent. It is encountered just as often in studies dealing with MTW. Magnetic treatment can clear drinking water, diminishes scum formation in boilers and improves flotation [26, 22, 23]. However, other instances are also encountered, when magnetic treatment alters the process in the opposite direction or does not affect it [25, 26]. Thus, the phenomenon of ambiguity of reactions may be considered a general typical feature that is encountered quite often in studies dealing with EMB, STR and MTW. At the same time, magnetic treatment of water is practiced widely in industry and yields millions of rubles of savings [26, 55]. In medicine, magnetic fields elicit a distinct therapeutic response [14, 57]. Each magnetic storm takes hundreds of human lives [37, 38]. This contradiction--the presence of clearcut relationships in mass experiments not always corroborated in different tests--is the most typical element of research on the effects of EMF on nonequilibrium processes. Repeated efforts have been made to determine the causes of ambiguity of results of studies involving EMF. Most often, this phenomenon is interpreted from the standpoint of inadequately sophisticated experimental set-up. The authors of such studies attribute the incomparability of their results to the fact that either the fields used were not the same or that the influence of some incidental stimulus could not be ruled out. In some cases, it is assumed that the experimenter worked with heterogeneous material, used the recording methods incorrectly or did not process the results properly. Probably some of the contradictory works could be attributed to methodological flaws, as is the case in any other branch of biological research. However, it is incomprehensible why many individuals who previously worked in other directions without mistakes would starting making them here. In this case, the contradictory data of the same author, encountered moreover in the course of the same experiment, are also incomprehensible. Evidently, we cannot attribute the incomparability phenomenon to investigative flaws alone. A. P. Dubrov offers another interpretation; he believes that life is based on dyssymetry due to the presence of dextrorotatory and levorotatory isomers of molecules that are not in equal proportion in each living object.[21]. It is difficult to reject this thesis, since it apparently is valid. However, we still do not know the extent and distribution thereof.

Efforts have also been made to attribute incomparability of results to the presences of exogenous artificial and spontaneous electromagnetic background, that is usually not taken into consideration in the studies. Indeed, in a number of investigations, a correlation between some functions of a living system and the electromagnetic background can be tracked rather well; occasionally the series phenomenon is clearly demonstrable and inherent patterns are observed in the incomparability itself. But the reference to "background" is also an inadequate explanation, since the "background" itself consists of the same EMF that are the stimulus considered and studied in the experiment. Moreover, various "malfunctions" and incomparability are also observed with different background levels and fluctuations. Thus, this brief analysis of the literature and our considerations enable us to formulate the topic of this investigation as follows: experimental and theoretical determination of the causes of ambiguity of results of studies of effects of EMF on diverse nonequilibrated processes.

Destabilizing Effects of Electromagnetic Fields on an Elementary Nonequilibrated Reaction Chosen as a Model of a Living System

One of the fortuitous models for the study of STR is the reaction of bismuth hydroxychloride precipitation in water, proposed by G. Piccardi [45, 72, 73]. In essence it consists of the fact that when certain amounts of hydrochloric solution of bismuth chloride are blended with water a milk-white colloid solution is formed, the solid particles of which settle relatively rapidly to the bottom. After reproducing this reaction many times and in different variants, G. Piccardi established that the rate of sedimentation of the solid particles in different glasses fluctuates quite markedly, both in the case of running the reaction in several identical containers at the same time and when conducting the experiment at different times. All of his attempts to stabilize the reaction failed, since even substantial changes in concentration of solution, purity of water, temperature, light and amount of shaking the containers had a rather mild influence on the rate of precipitation of colloid particles and did not diminish fluctuation. Using various experimental methods (F, D, P tests) and comparing their general results to indices of solar activity, G. Piccardi found a rather distinct correlation between these two processes.

The comprehensive studies of this phenomenon, conducted for many years by G. Piccardi and his proponents made it possible to demonstrate a correlation between the nature of fluctuation of different tests and time of day, season, place, level of solar activity, etc. In view of the overt instability of the Piccardi reaction, its simplicity, minimal dependence on purity of reagents and experimental conditions, as well as distinct relation to solar activity, it was decided to use it as a model, on which one could try to investigate the patterns of effects of spontaneous and weak artificial EMF on nonequilibrated systems. The specific methods used in this experiment, which were chosen after conducting a series of trials, consisted of the following:

Several thick-walled chemical beakers were filled with 5 mm sesquinormal hydrochloric solution of bismuth chloride and 25 mℓ distilled water, passed once through MF of 3200 A/m at the rate of 2 cm/s, was added to each at the same time. Such pretreatment of the water was undertaken on the basis of Piccardi's indications that it was desirable to "activate" the water, as well as because a reaction run simultnaeously in several beakers proceeds more stably with "magnetized" water, as shown by the preoiminary trials [40]. The beakers with reagents were placed in a predetermined area and the solid particles of colloid solution began to settle, forming a distinct interface with cleared liquid. The reaction was considered completed at the time of total precipitation, which was determined when he phase interface matched a mark on the beaker that had been made in advance on the basis of the preliminary tests. The accuracy of determination of the time of total precipitation constitutes ±10÷15 s, with a mean precipitation time of 7 10 min, i.e., the measurement error factor constitutes 1÷2%. We used a stopwatch to time total precipitation in each beaker, and it fluctuated from 2 to 33 min in different tests.

A. M. Opalinskaya used this method to conduct experiments for 7 years, and they consisted of 8 series of special investigations.

a. In the first series, a study was made of the relation between average rate of precipitation of bismuth hydroxychloride in water and various heliophysical and geophysical indices: For this purpose, the reaction rate in 3-5 beakers was measured daily for several years, and the arithmetic mean thereof was selected as the index of precipitation rate on a given day. Experiments were conducted at the same time in a building of the Physico-Tehcnical Institute. In all, 690 tests were conducted, including 2629 specific measurements. The smoothed distribution thereof is illustrated in Figure 1. Calculation of the coefficient of correlation between 24-h reaction times and local 3-h K index revealed a positive relationship between these series, with $r = 0.57$ and significance level of $P<0.01$.

A link between the reaction under study and magnetic storms was also demonstrated according to the criterion of Wilcoxson-Mann-Whitney, with

P<0.01 [40, 42]. Upon subsequent analysis of overall data, seasonal, daily and multiyear variations were demonstrated in the relationship between the reaction under study and geophysical processes [42]. The presence of a correlation between the test in question and the geomagnetic field made it necessary to investigate this phenomenon under model conditions, by means of using shields against spontaneous and artificial MF, as well as additional use of artificially generated MF in the test.

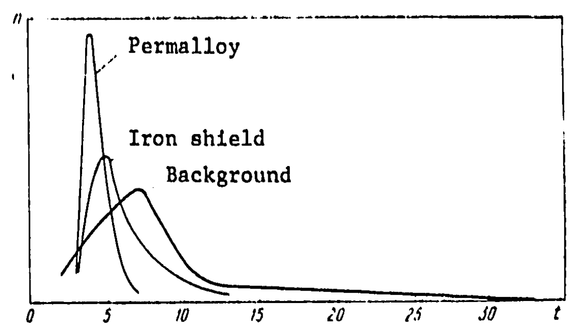


Figure 1. Effect of shielding from magnetic field on rate of precipitation of bismuth hydroxychloride in water.
X-axis, time in minutes; y-axis incidence of readings in a series.

b. Effect of shielding from EMF on course of Piccardi reaction: We used three methods to shield the reaction from exogenous MF: 1) distance, 2) welded iron shield (coefficient of attenuation ~10^2), 3) four-layer permalloy shield* with a coefficient of attenuation of ~10^6.

1. In order to attenuate the effects of industrial MF, a special series of experiments was conducted far from industrial installations in the building for geomagnetic measurements. The results of this series, which are illustrated in Figure 2, indicate that the mere reduction of industrial sources stabilizes the reaction somewhat, lowering the range of variation to 2-24 min, with a mean value of a = 9.2 min. A comparison of these data to the results of background experiments conducted in the institute building revealed a substantial difference between them, with a significance level of P<0.001 according to the criterion of Student.

2. The summary results of experiments conducted with the iron and permalloy shields are illustrated in Figures 1 and 2. A comparison thereof to one another and to the background distribution curve

*We wish to express our sincere appreciation to V. A. Troitskaya, head of EMF sector of the Institute of Physics of the Earth, USSR Academy of Sciences, and the staff of this sector for their assistance in making the shield and estimating degree of shielding with it.

shows rather distinct stabilization of the course of the reaction as a function of quality of screening. The most important and basic fact is that the reaction in a permalloy shield is virtually stable, with a range of variation of only 3 to 7 min, i.e., the coefficient of stabilization, according to extreme values, expressed as the ratio of background range of variations to the analogous index in the shield, constitutes 33-2/7-3 = 7.7. There are more marked fluctuations of the reaction in the iron shield, and here the coefficient of stabilization constitutes only K = 3. Accordingly, when distance is used as protection, this coefficient decreases to K_s = 1.4, i.e., there is only 40% reduction of fluctuation.

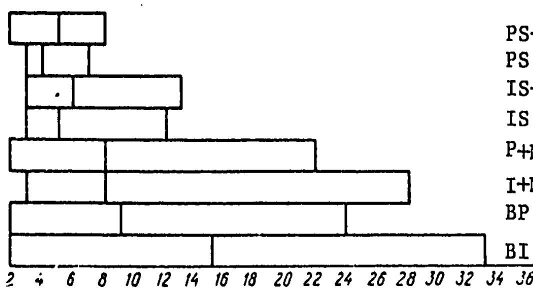


Figure 2. Mean and extreme values of time of complete precipitation of bismuth chloride in water in each experimental series

Key:

B) background
P) proving ground
I) institute
IS) iron shield
PS) permalloy shield
MF) magnetic field

c. Effect of artificial infralow-frequency field on course of Piccardi reaction: However, shielding is only one of the two possible means of determining the role of EMF in fluctuation of the reaction of precipitation of bismuth hydroxychloride in water. For this reason, another series of studies was conducted on the effect of artificial MF on the course of the reaction run under different conditions.

A magnetic field was generated within a solenoid with passage through its coils of current from an infralow-frequency generator. The amplitude intensity of the field corresponded to the maximum levels of spontaneous geomagnetic perturbations, and it ranged in different variants from 50 to 1000 γ with frequency changing from 0 to 100 Hz. The beakers with the reagents on special, nonmagnetic trays, were placed in the middle of the solenoid, where heterogeneity of the field did not exceed 30%. The background reaction was run in a similar solenoid with a time shift of 30 min, without current. As demonstrated by the study of the daily course of the background reaction, such a time shift does not lead to appreciable changes in the results. We then calculated the differences between them according to daily paired values. In all, we conducted 24 variants of studies, with different values of H and f, the results of which are illustrated in Figure 3. Analysis of these data indicates that starting with $H = 50\gamma$ we already observe some influence of the artificial MF on the Piccardi test, consisting of a change in mean reaction time. For a more comprehensive investigation of the effect of MF on the course of the reaction, we selected the most typical of the entire amplitude and frequency set of variants ($H = 500\ \gamma$, $f = 0.1$ Hz) and used it in all subsequent experiments. In all, we took 410 readings with these field parameters. The smoothed distribution of results is illustrated in Figure 2. A comparison of background and experimental curves shows that variation decreased to 3-22 min, with $\bar{a} = 8$, under the influence of MF, which corresponds to a stabilization coefficient of $K_s = 1.63$. The reliability of difference between the background and experiment constituted $P<0.001$ according to the criterion of Student and $P<0.0001$ according to the criterion of Wilcoxson. This warrants the statement that one observes stabilization of the reaction of precipitation of bismuth hydroxychloride in water under the influence of artificial MF with regular parameters $H = 500\ \gamma$ and $f = 0.1$ Hz.

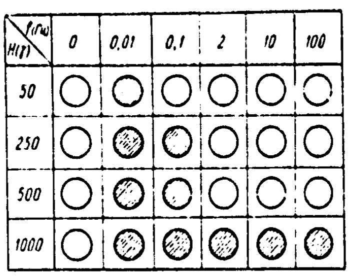


Figure 3.
Rate of precipitation of bismuth chloride as a function of intensity and frequency of VMF [variable magnetic field].

Striped circles--reliable acceleration, white circles--unreliable acceleration.

However, a comparison of experimental data on the effects of artificial sinusoidal MF on the test under study to data pertaining to the effect on it of spontaneous magnetic storms shows that the mean reaction time in these cases shifts in different directions, as compared to a nonperturbed background. The magnetic storm increases reaction time due to a higher incidence of cases of slow precipitation, whereas sinusoidal MF leads to a decrease in number of such cases.

The findings are analogous, but less marked, when the Piccardi reaction is exposed to a low-voltage electric field (EF) (Figure 4). This series of experiments was conducted in a condenser following the same method.

In summing up the obtained data, it can be concluded that sinusoidal infralow-frequency EMF lead to some stabilization of bismuth hydroxychloride precipitation time in water, as compared to the background.

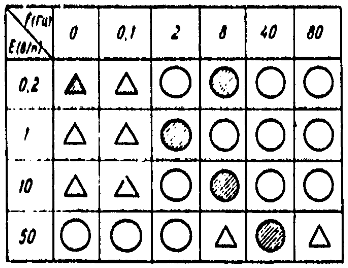


Figure 4.
Rate of precipitation of bismuth chloride in water as a function of intensity and frequency of EF.

Triangles--slower precipitation. Other designations are the same as in Figure 3.

Two additional series of investigations of the effects of artificial MF on the course of shielded reactions were conducted in order to determine the causes of difference in direction of effects of EMF on the Piccardi test during magnetic storms (slowing) and with exposure to artificial MF (acceleration). The results of these studies, illustrated in Figure 2, warrant the belief that MF affecting the shielded reaction lead to its destabilization, whereas MF stabilizes it somewhat under background conditions.

Analysis of summary data (see Figure 2) enables us to voice several considerations: a) maximum fluctuations of rate of precipitation of bismuth hydroxychloride in water are observed when the reaction is run under background conditions in the building of the Physico-Technical Institute, which contains a considerable amount of various electrical and electronic equipment; b) there is a consistent increase in background fluctuations during periods of geomagnetic perturbations; c) fluctuations can be reduced by using shields against external artificial and natural MF, and the stability of the reaction depends on the extent of shielding; d) additional use of artificial sinusoidal infralow-frequency MF on the Piccardi reaction leads to a reduction of fluctuations if they were originally high (background--institute, background--proving ground) and appreciable increase in fluctuations if the level thereof had been substantially reduced by shielding.

All of the foregoing enables us to formulate the general pattern observed in this investigation as follows: Weak, chaotic MF increase fluctuation of the reaction of precipitation of bismuth hydroxychloride in water, which can be reduced either by means of shielding from exogenous interference or use of additional MF with specific amplitude and frequency parameters known to be of greater intensity.

Destabilizing Effects of Electromagnetic Fields on Biological Processes

a. Effect of MF on the course of the agglutination reaction: In the preceding section it was demonstrated that weak MF can alter appreciably the course of a process in a nonequilibrated physicochemical system. Since living systems are also referable to the nonequilibrated ones, it may be assumed that, in this case, weak MF should constitute a factor that causes an increase in fluctuations of different biological processes. The immunological agglutination reaction, which involves the use of typhoid serum and special [ON] diagnosticum, was chosen as a model reaction on the borderline between physicochemical and biological processes. The experimental part of this study was also performed by A. M. Opalinskaya.

Trial experiments demonstrated fluctuations in the course of the reaction and changes in the former as a function of fluctuations of the spontaneous geomagnetic background. It was established that when the reaction was run many times using the standard method and with logarithmic dilution of serum (1/1, 1/2, 1/4, 1/8, ..., 1/160, 1/320), using diagnosticums from the same batch, the result of the reaction, interpreted by the usual method and expressed in plus signs, would be ambiguous. A change from four to three pluses is observed with dilutions of 1/16 to 1/24; there is an analogous change in boundary at which there is a change from three to two pluses, etc. Fluctuations are observed when several standard reactions are run at the same time, as well as when they are run at different times. The fluctuating nature of agglutination is even more graphic when smaller dilutions of serum are used and the logarithmic scale is replaced by a linear one, i.e., 1/2, 1/3, 1/4, etc. The main series of experiments was conducted with these nonstandard dilutions. In this case, the shift in boundary between adjacent changes in results, expressed as plus signs, could constituted 3-5 test tubes. In view of the fact that the contribution of each estimated change to the overall reaction should be about the same for each series of dilutions, we calculated the averaged index of agglutination using the following formula:

$$T = \frac{4n_4 + 3n_3 + 2n_2 + n_1}{n_4 + n_3 + n_2 + n_1},$$

where n_i is the number of test tubes in which the reaction constitute a number of pluses corresponding to i. The series of daily values of T was then compared to the indices of geomagnetic perturbation, and the coefficient of correlation between them was calculated. The estimates revealed that, with $n = 143$, $r = 0.235$ with a significance level of $P<0.01$, i.e., the course of fluctuations of this reaction is related to changes in the geomagnetic field.

To study the effect of MF on the course of agglutination, we used a field with the same parameters as in the studies using the physicochemical test ($H = 500\ \gamma$, $\overline{f} = 0.1$ Hz), exposing the series of tubes to it for 2 h, while they were in the incubator. In view of the fluctuating nature of the reaction itself, we selected only one serum dilution, 1/24,000, for both the background and experiment, with which estimation of a three and four plus reaction was found to be equally probable in the preceding tests. To increase the reliability, the test was run in 20 tubes at a time, and half of them were put in the MF. The tests were conducted daily, and the difference between the experiment and control was evaluated according to the paired criterion of Wilcoxson. The results of this series, which are listed in Table 1, warrant the belief that agglutination is more intensive in the field, i.e., the pattern demonstrated in the physicochemical test is also confirmed here.

Table 1. Agglutination reaction as a function of MF

Index	Number of test tubes							
	3	4	5	6	7	8	9	10
Background	—	2	6	6	20	10	—	—
Field	—	—	6	6	5	17	10	2
Shield	5	8	1	3	—	—	—	—

b. Effect of MF on fermentation process: Demonstration of the stabilizing or destabilizing effect of MF on the course of a nonequilibrated physicochemical and immunological reaction enabled us to turn to an attempt to extent this thesis to biological systems. We selected the anaerobic phase of glycolysis as the test, and we studied it on the model of fermentation of glucose by yeast. This process is at the basis of metabolism of any organism, and the patterns of effects on it of MF could be extended, without particular error, to other biological objects. For this purpose, 1.5 g standard dry yeast dissolved in 30 mℓ distilled water was added to 10 mℓ 15% glucose solution, and the mixture was put in a tube set vertically in an incubator at 30°C. The dynamics of the fermentation reaction was evaluated according to the number of carbon dioxide bubbles, and it was recorded automatically using electromechanical counters throughout the experiment. All of the test tubes were in solenoids, by means of which we could generate magnetic fields with specified parameters. For the purpose of pair-by-pair comparison, in each experiment we examined the same number of daily alternating experimental and control material. The results, in the form of hourly and overall number of carbon dioxide bubbles, for experimental and control material were submitted to processing using the paired criterion of Wilcoxson. Two series of studies were conducted by A. G. Kartashov using this method of recording. In the first, a study was made of the effect of a vertical SMF [stationary magnetic field], the intensity of which changed from +500 to -500 A/m in different experimental variants.

The positive direction of the field corresponded to the direction of the vertical component of GMF [geomagnetic field]. The results of this series, which are listed in Table 2, show that on the average the amount of carbon dioxide discharged during fermentation changes consistently with change in magnitude and direction of the additional SMF. At the same time, specific readings taken in the course of each experimental variant were not always comparable. Thus, in the experiments with an intensity of +500 A/m, the

the mean number of bubles discharged during the experiment constituted 2193 in control tubes. With exposure to the field, this figure dropped by a mean of 66 bubbles. At the same time, paired comparison of different experiments showed the figure to range from -240 to +100. However, increased gas production was encountered only twice in this experimental variant (+100 and +40) and decreased, in 17. Analogous findings were made in the series with intensity of 500 A/m, where inhibition of the reaction was encountered 5 times out of 28 tests, the absolute figures being rather low (-40, -30, -10, -10, -10). There was more marked acceleration (+260, +230, +180, etc.), and it was observed in 22 experiments. If we compare these data to the results of the preceding studies, it is easy to see that, here too, some experiments yield opposite results, in the presence of a rather distinct mean statistical function. In the second series of studies, the same method was used to test the effect of VMF [variable magnetic fields] on the fermentation process. The summary data of these experiments, processed in a similar manner, are listed in Table 3. Analysis shows that we have here a very unequivocal dependence of the fermentation process on amplitude and frequency characteristics of the field, and it is demonstrable upon statistical processing. However, the distribution of specific readings in each individual variant is quite heterogeneous, and we always encountered some readings with the opposite sign against the general background of slowing or acceleration of the reaction.

Table 2. Fermentation process as a function of intensity and direction of SMF vector

HA/м	n	ΔM	Change in field	P	HA/м	n	ΔM	Change in field	P
+500	20	−66	Inhibition	0,01	−125	30	+6,3	Scatter	0,05
+375	10	−40	"	0,01	−250	51	+22	Acceler.	0,01
+250	51	+3,5	Scatter	0,05	−500	25	+41	"	0,01
+125	18	−26	Inhibition	0,05					

Key: HA/m) intensity of artificial SMF
n) number of experiments
ΔM) mean difference between number of bubbles discharged in 6 h in experiment and control
P) level of significance according to Wilcoxson's paired criterion

c. Stabilizing effect of SMF on motor activity of white mice: The existence of a rather distinct mean statistical dependence of the fermentation process on intensity and direction of SMF vector enabled us to turn to analogous experiments on mammals; they were performed by A. G. Kartashov. In view of the static nature of the effect of the field on nonequilibrium systems, it was decided to conduct the chronic variant of experiment, which made it possible to operate with similar accumulated data. For this purpose, male white mice of the same age were placed in special solenoid cages, one in each, where they were kept for 4-9 months. In all, we used four such set-ups in the experiments, two of which alternately served as controls. A 24 A/m field, directed from West to East, was generated in the experimental solenoid cages by turning on direct current from a battery. When added to the GMF, the total field vector increased by 17% and its horizontal component, which is 13.6 A/m in Tomsk, doubled and deviated 65° to the East. Alternation of periods of exposure of experimental animals to the field and with no field ranged from 1 to 4 weeks, constituting a mean of 20 days. Such a variable mode was set in order to track the field aftereffect. Motor activity of the mice was recorded continuously with a series of photodiodes illuminated with a lamp, the intersection of light from which was recorded on an automatic recorder when the animal moved. The overall results of these studies are summarized in Tables 4 and 5, which clearly show a decrease in activity of mice when they are in the field. A more comprehensive analysis of the data revealed that there was no field aftereffect in these tests. A comparison of these data to the results of studies involving physicochemical and elementary biological tests shows that the general nature of the reaction is the same in all cases: Under the influence of a regular MF there is some stabilization of the process, although some values of the measured parameter may vary over a rather wide range. Thus, a pair-by-pair comparison of mean daily activity of the same animals showed it to be distinctly diminished in the field. But if the comparison is made for the entire series as a whole, we see that some mice moved more in the field than in the control (Table 5). Thus, a weak MF present for a long time inhibits mouse activity, causing some stabilization thereof.

Table 3. Fermentation process as a function of VMF intensity and frequency

HA/m	Frequency, Hz	n	ΔM	P
9,5	0,01	15	−5,7	—
19,1	0,01	28	+41	0,01
4,7	0,1	10	−1	—
9,5	0,1	34	−4	—
19,1	0,1	34	+30	0,05
38,1	0,1	14	+68	0,01
2,3	1	15	+12	—
4,7	1	30	−41,3	0,05
9,5	1	16	−42,5	0,05
19,1	1	23	−51,4	0,01
2,3	10	12	+2	—
4,7	10	10	−3	—
9,5	10	17	−7,6	—
19,1	10	54	+35	0,01

Key:
HA/m) amplitude intensity of artificial VMF
n) number of experiments
ΔM) mean difference between experiment and control, relative units
P) level of significance according to Wilcoxson's paired criterion

Table 4. Change in hourly activity of white mice in SMF

Index	Number of mice	Number of series	Median	Scatter	p	Change in field
Control	5	6	15	1—30	0,01	Decrease
Field	5	6	11	1—21		

Table 4. Pair-by-pair comparison of mean daily activity of mice in SMF

Mouse No	Number of series	Total mean daily activity		p	Change in field
		Control	Field		
1	3	457	402	0,05	Decrease
2	1	220	200		
3	2	236	124		
4	1	134	76		
5	1	180	111		

d. Destabilizing effect of variable electric and magnetic fields on human reaction time: In order to verify the phenomena of stabilization and destabilization on the psychophysiological level, L. P. Agulova conducted a special series of studies of the effects of VMF and VEF [variable electric fields] on reaction time (RT). The subject was put in a soundproof and shielded chamber, in which one could create horizontal (back--chest) EF or MF. Heterogeneity of the field in the working space did not exceed 20%. In the first experimental variant, MF with amplitude intensity of 320 A/m and frequency of 0.033 Hz was used. Exposure time constituted 3 min. The simple reaction time to a sonic signal was recorded for 3 min before and after exposure to the field, as well as during exposure. At unequal intervals, 9-11 signals were delivered per 3-min segment of time. Some experiments were conducted similarly without the field, for the purpose of comparison to spontaneous dynamics of RT changes, and the results of experiments with the field were calculated in relation to the background readings. The summary results of this experimental variant, calculated on the basis of Wilcoxson's criterion, are listed in Table 6. Analysis thereof shows that the field accelerated the reaction unreliably in 3 cases and slowed it down in 2, with a significance level of $P<0.01\div0.02$, i.e., we see here the same difference in reaction direction as in all preceding studies. In the second variant of this series, a study was made of the effect of EF of 100 V/m intensity and 50 Hz frequency on the same reaction. The results, processed analogously, are listed in Table 7. Here the destabilization phenomenon is even more apparent. In 1 out of 9 subjects, the RT diminished in the field ($P<0.001$), it did not change in 3 cases ($P<0.05$) and increased appreciably in 5 ($P<0.01\div0.001$). But when we averaged all the data for the group of subjects, slowing of RT in the field was found at a significance level of $P<0.0001$. Thus, in this series of studies we could track rather distinctly the presence of the destabilizing phenomenon in the field, when the results were analyzed element-by-element, and a unidirectional shift on the average for the entire group.

Table 6. Effect of magnetic field of 4 Oe, 0.033 Hz on human simple reaction time to sonic 1000 Hz stimulus

Subject No	Number of tests		Number of readings		Median, ms		P	Trend of change in RT in the field
1	7	4	76	40	170	162	0,05	No change
2	9	5	93	51	191	207	0,01	Increase
3	8	8	80	78	205	197	0,05	No change
4	9	7	91	76	182	199	0,02	Increase
5	10	8	101	81	195	182	0,05	No change

Table 7. Effect of electric field of 1000 V/m, 50 Hz on time of human simple motor reaction to 1000 Hz sonic stimulus

Subject No	Number of tests		Number of RT measur.		Median, ms		P	Trend of RT change in field
	BG	F	BG	F	BG	F		
1	3	4	242	320	347	357	0,05	Increase
2	3	3	240	210	264	270	0,05	"
3	3	3	240	242	292	307	0,01	"
4	3	4	240	320	244	254	0,001	"
5	2	4	162	290	212	233	0,001	"
6	3	2	242	130	306	265	0,001	Decrease
7	2	4	160	290	313	328	0,01	Increase
8	3	3	242	242	285	311	0,01	"
9	3	4	210	289	444	475	0,05	"

To conclude this experimental section, we should like to stress that, regardless of the nature of the nonequilibrium system, specific field parameters, experimenter's personality, etc., in all cases one observes a difference in reactions with similar mean statistical direction of changes of the nonequilibrated process proper.

Discussion

A brief analysis of the literature and our own experimental data shows that the course of nonequilibrium processes in living systems and models thereof changes can be described by three tendencies, encountered concurrently in most studies. In the first place, under the influence of the fields there is destabilization of nonequilibrium processes, as a result of which the measured parameters of the living system deviate from their base state in different directions. By virtue of asymmetry of most nonequilibrium processes, these deviations are ambiguous and there is prevalence of a unidirectional change in the overall reaction. This is illustrated the most graphically by the experiments involving precipitation of bismuth chloride in water, where the mean reaction time increases consistently under the influence of spontaneous or artificial fields used with a shield. The same tendency is observed in other experiments: Unidirectional changes in agglutination, fermentation and motor activity of mice are combined with the mandatory presence of some tests yielding the opposite results. This trend is also quite demonstrable in the psychophysiological test, when some subjects presented a distinct opposite change, as compared to the mean group result. A comparison of the obtained data to those in the literature shows them to be totally similar. And, while there is no direct indication of assymetrical change in different directions of the reaction under study with exposure to weak fields in some of the sources, this is most likely attributable to the author's desire to submit more graphic, averaged results. For this reason, it would not be very wrong to maintain that the phenomenon of destabilization of processes under study is always observed in all studies of EMB. The second tendency, which ensues from the first, consists of the fact that nonequilibrated processes, on the average, change consistently under the influence of the fields, in the direction of slowing or accelerating. Although there may be other causes for this pattern, it is opportune to consider it here as the consequence of destabilization. As already indicated, nonequilibrium processes are usually asymmetrical. This is manifested by the fact that the range of fluctuation thereof extends dissimilarly in both directions from the mean value (median). The asymmetry is obvious for biological processes. Indeed, spontaneous variations of any biological process are rather rigidly confined, and this limitation is usually more rigid on one side. Thus, maximum arterial pressure of man constitutes 120 mm Hg under normal conditions. Double this figure is encountered in hypertensive individuals quite often. But with zero pressure life is impossible, and the minimum cannot constitute less than 50-60 mm Hg, i.e., if we were to consider a random group of individuals, their distribution would be asymmetrical for this parameter, and it would be rather rigidly limited on the side of minimum values. An analogous phenomenon is observed in toxicology, where a homeopathic dose is lower by several orders of magnitude than the mean therapeutic dose, while the lethal dose is less than one order of magnitude higher than the therapeutic. The same applies to respiration rate and pulse, blood coagulation and sedimentation rate, renal and endocrine gland function. After analyzing similarly most biological processes, it can be stated that they are all asymmetrical. Incidentally, this means that the use of statistical criteria, which work well with normal distribution (criterion of Student), are not valid always by far when analyzing nonequilibrated processes. But in the case of asummetrical distribtuion, even uniform destabilization would lead to a shift of mean value in the direction of the less rigid boundary. If we consider that destabilization itself and a living system in its original state may be asymmetrical for any of the self-regulation parameters, the existence of some differences in reaction direction under the influence of a field becomes understandable. Also understandable is the consistent shift of reactions studied on mass scale material, since shifting of the median as a result of averaging would be observed mainly in the direction of the less rigid boundary. Accordingly, in order to obtain a consistent functional change under the influence of weak fields, one must standardize the objects under study as much as possible and conduct the study either on a large number of identical objects or for a long time on one object. These initial theses were used as the basis for the experimental part of this work. Many repetitions of the reaction of bismuth hydroxychloride precipitation under different conditions made it possible to demonstrate distinct patterns in the course of the reaction as related to presence and parameters of EMF. A multimillion colony of standard yeast automatically led to averaging of individual reactions and made it possible to detect a clearcut relationship between fermentation reaction and field parameters. An experiment lasting many months on white mice made it possible to gather sufficient statistical data for one object. Although an animal underwent certain changes in the course of several months, they were still less significant that the differences between different animals, and this was well corroborated by experimental data. The same phenomenon can be tracked in the experiments involving human reaction time. Many readings taken on the same object demonstrated a consistent change therein under the influence of fields, while averaging for a group of individuals led to demonstration of a general species-specific tendency. Thus, the destabilization of an asymmetrically distributed biological process can be considered one of the causes of consistent change in any function of a living system under the influence of weak EMF. The third trend, that is encountered quite frequently in studies of EMB, can be called stabilization of a non-equilibrated process by EMF with specific parameters. The meaning of stabilization consists of the fact that the wide scatter of variation of a feature under study, which is observed under background conditions, diminishes appreciably under the influence of regular EMF. This phenomenon is the most distinctly demonstrable in the model experiments with bismuth chloride also, where the reaction in fields of a specific frequency and intensity is more stable than in the control and, conversely, when an increase in the industrial EM background leads to some destabilization of the process. The fact that the random [chaotic] field destabilizes the reaction much more than a field with regular parameters may be considered the cause of this oppoiste effect. Stabilization is observed to a lesser extent, but quite apparently, in the experiments on biological objects as well. There is decrease in fluctuation of motor activity of mice and the fermentation process in SMF; there is some stabilization of background variations of reaction time of an individual in regular variable fields. Evidently, this is related to the fact that, with significant standardization of the objects under study, regular fields alter an unequilibrated process more unidirectionally, thereby causing grouping of fluctuating values within a certain range.

To sum up all the foregoing, the main conclusion derived from the work that has been done can be formulated as follows: Weak EMF induce destabilization of nonequilibrated processes, which can be attenuated either with the use of an additional field with regular parameters and higher intensity or by means of even more shielding from all exogenous natural and artificial fields. Extending this thesis to living systems, it can be stated that the mechanism of biological effects of EMF is based on the destabilization phenomenon which, by virtue of asymmetry of biological processes, leads to a consistent unidirectional change therein.

BIBLIOGRAPHY

1. Alimova, V. G.; Brebenyuk, A. V.; and Lakomkin, A. I. "Effects of VMF and SMF on some Hematological Indices," in "Mater. II Vsesoyuz. soveshch. po izucheniyu vliyaniya magnitnogo polya na biol. ob"yekty (24-26 sentyabrya)" [Proceedings of 2d All-Union Conference on the Study of the Effects of Magnetic Fields on Biological Objects (24-26 September)], Moscow, 1969.

2. Anan'yev, L. M., and Ryabchuk, Yu. A. "Comparative Characteristics of Effects of MF with Different Parameters on the Central Nervous System of Operators," in "Vliyaniye yestestvennykh i slabykh iskusstvennykh magnitnykh poley na biol. ob"yekty" [Effects of Spontaneous and Weak Artificial Magnetic Fields on Biological Objects], Belgorod, 1973.

3. Achkasova, Yu. N., and Monostyrskikh, L. V. "Effects of Extra-Low Frequency EMF on White Mice," TRUDY KRYM. MED. IN-TA (Khar'kov) [Works of Crimean Medical Institute], 53, 1973.

4. Afonina, V. M., and Chernyshev, V. B. "Effect of Weak Low-Frequency Magnetic Fields on Some Insects," in "Mater. II Vsesoyuz. simp. 'Reaktsii biol. sistem na slabyye magnitnyye polya'" [Proceedings of 2d All-Union Symposium on "Reactions of Biological Systems to Weak Magnetic Fields], Moscow, 1971.

5. Akhutin, V. M., and Muzalevskaya, N. I. "Effects of Weak VMF in the Infralow-Frequency Range on Sedimentation Rate in in Vivo and in Vitro Experiments," in "Vliyaniye yestestvennykh i slabykh iskusstvennykh magnitnykh poley na biol. ob"yekty," Belgorod, 1973.

6. Ben'kova, N. P. "Solar Activity, Perturbation of Earth's EMF and Possible Effects Thereof on the Human Body," "Tezisy dokladov II nauch. konf. po voprosam klimatol. serdechno-sosudistykh zabolevaniy (22-24 noyabrya)" [Summaries of Papers Delivered at the 2d Scientific Conference on Problems of Climatology of Cardiovascular Diseases (22-24 November)], Moscow, 1962.

7. Brusevtsov, G. V., and Brusevtsova, N. Ye. "Link Between Earthquakes and Solar Activity," in "Solntse, elektrichestvo, zhizn'" [Sun, Electricity and Life], Moscow, 1972.

8. Vasilenko, F. D., and Puchkov, V. V. "Effects of SMF on Some Physiological Functions in the Organism," TRUDY TSENTR. NII KURORTOLOGII I FIZIOTERAPII [Works of the Central Scientific Research Institute of Balneology and Physiotherapy], 14, 1969.

9. Vasil'yev, N. V., and Boginich, L. F. "Effects of MF on Infection and Immunity Processes," Tomsk, 1973.

10. Vladimirskiy, B. M. "Possible Factors of Solar Activity Affecting Processes in the Biosphere," in "Vliyaniye solnechnoy aktivnosti na atmosferu i biosferu Zemli" [Effect of Solar Activity on Earth's Atmosphere and Biosphere], Moscow, Nauka, 1971.

11. Vladimirskiy, B. M.; Achkasova, Yu. N.; and Monostyrskikh, A. V. "Perturbation of Earth's EMF and the Problem of Heliobiological Relations," in "Problemy kosmicheskoy biologii" [Problems of Space Biology], Moscow, Nauka, Vol 18, 1973.

12. Gnevyshev, M. N. "Solar Radiation and Its Effects on the Biosphere of Earth," in "Adaptatsiya organizma pri fizicheskikh vozdeystviyakh" [Adaptation of the Organism to Physical Factors], Vil'nyus, 1969.

13. Golovatskaya, O. L., and Gobovatskiy, A. S. "Clinical Prognostic Significance of Sedimentation Rate Changes in Magnetic Fields, in Patients With Tuberculosis of the Lungs," in "Tezisy dokladov soveshch. po vliyaniyu magnitnykh poley na biol. ob"yekty (20-22 sentyabrya)" [Summaries of Papers Delivered at a Conference on the Effects of Magnetic Fields on Biological Objects (20-22 September)], Moscow, 1966.

14. Degen, I. L., and Chumakova, L. G. "Treatment of Thrombophlebitis With Magnetophores," "Mater. III Vsesoyuz. simp." [Proceedings of 3d All-Union Symposium], Kalinigrad, 1975.

15. Dernov, A. I.; Senkevich, O. I.; and Lemesh, G. A. "Biological Effects of MF," VOYENNO-MEDITSINSKIY ZHURN. [Military Medical Journal], No 3, 1969, pp 43-48.

16. Desyatov, V. P. "Activity of the Sun and the Human Body," SOLNECHNYYE DATA [Solar Data], No 2, 1962.

17. Desyatov, V. P.; Osipov, A. I.; and Suzdal'skaya, O. V. "Solar Activity and Mortality Statistics," in "Solntse, elektrichestvo, zhizn',' Moscow, 1972.

18. Dorofeyev, K. A. "Solar Activity and Epizootic Outbreaks," SOLNECHNYYE DANNYYE, No 8, 1974.

19. Dorofeyev, K. A. "Long-Term Forecasting of Epizootic Tularemia," SOLNECHNYYE DANNYYE, No 9, 1966.

20. Dubova, V. M. "Investigation of Blood Serum Fructose Diphosphate Aldolase Activity as a Function of SMF Effects," in "Solntse, elektrichestvo, zhizn'," Moscow, 1972, p 68.

21. Dubrov, A. P. "The Geomagnetic Field and Life," Leningrad, Gidrometeoizdat, 1974.

22. Yeliseyev, N. I.; Kirbitova, N. V.; and Klassen, V. I. "Effect of Magnetic Treatment of Reagent Solutions on Flotation," DAN SSSR [Reports of the USSR Academy of Sciences], 209, No 2, 1973.

23. Zinov'yev, Yu. Z., et al. "Magnetic Treatment of Flotation Tailings to Improve Thickening Thereof," UGOL' [Coal], No 3, 1968.

24. Kazanin, V. I.; Konyshev, V. V.; and Plyashkevich, V. P. "Possible Role of Serum Proteins in Expression of Magnetiobiological Information," "Mater. II Vseosyuz. soveshch. po izucheniyu vliyaniya magnitnogo polya na biol. ob"yekty (24-26 sentyabrya)," Moscow, 1969.

25. Klassen, V. I., and Zinov'yev, Yu. Z. "Effect of Magnetic Treatment of Water on Aggregative Stability of Suspensions," COLLOIDNYY ZHURN. [Colloid Journal], 29, 5, 1967.

26. Klassen, V. I. "Water and Magnetism," Moscow, Nauka, 1973.

27. Kogan, A. B., and Tikhonova, N. A. "Effects of SMF on Movement of Paramecia," BIOFIZIKA [Biophysics], No 2, 1965, p 292.

28. Kozlova, L. N., and Kozlova, M. M. "The Question of Effects of SMF on Sedimentation Rate in Man," "Mater. Vsesoyuz. simp. 'Reaktsii biol. sistem na slabyye magnitnyye polya," Moscow, 1971.

29. Kozlova, L. N.; Nazarenko, L. D.; and Marsakova, N. V. "The Question of Effects of SMF on Activity of Some Enzymes," "Mater. III Vsesoyuz. simp. 'Vliyaniye magnitnogo polya na biol. ob"yekty'" [Proceedings of 3d All-Union Symposium on "Effects of Magnetic Fields on Biological Objects"]. Kaliningrad, 1975.

30. Komar, V. V. "Investigation of Reactivity to Magnetic Fields of Peripheral Blood Erythrocytes of Women in the Case of Physiological and Pathophysiological Course of Pregnancy and Parturition, and the Prognostic Significance of These Studies in Cases of Uterine Bleeding During Labor," "Mater. II Vsesoyuz. soveshch. po izucheniyu vliyaniya magnitnogo polya na biol. ob"yekty (24-26 sentyabrya)," Moscow, 1969.

31. Kostin, S. I. "Effect of 11- and 100-Year Cycles of Solar Activity on Tree Growth," SOLNECHNYYE DANNYYE, No 4, 1968.

32. Liyepa, M. E.; Slutskiy, L. I.; Kikut, R. P.; et al. "Effects of SMF on Some Peripheral Blood Indices in Clinical Practice," in "Magnitnoye pole v meditsine" [Magnetic Fields in Medicine], Frunze, 1974.

33. Mogendovich, M. R., and Tishan'kin, V. F. "Mechanism of Effect of MF on Sedimentation Rate," BYUL. EKSPER. BIOL. I MED. [Bulletin of Experimental Biology and Medicine], 25, 1948, p 26.

34. Muzalevskaya, N. I., and Shushkov, T. D. "Effect of Weak, Homogeneous, Infra-Low Frequency MF on Sedimentation Rate in Vitro in Patients With Myocardial Infarction," in "Mater. Vsesoyuz. simp. 'Reaktsiya biologicheskikh sistem na slabyye magnitnyye polya'," Moscow, 1971.

35. Mustal', E. R. "The Sun and Earth's Atmosphere," Moscow, 1957.

36. Idem, "Effects of Solar Activity on Lower Layers of the Atmosphere," VESTNIK AN SSSR [Vestnik of the USSR Academy of Sciences], No 4, 1968, p 60.

37. Novikova, K. F.; Gnevyshev, M. N.; Tokareva; et al. "Effects of Solar Activity on Onset of Myocardial Infarction and Mortality From It," KARDIOLOGIYA [Cardiology], 8, No 4, 1968.

38. Novikova, K. F.; Tokareva, N. V.; et al. "Sudden Death Due to Cardiovascular Disease and Solar Activity," "II ukrainskaya respublikanskaya konferentsiya (11-14 iyunya)" [Second Ukrainian Republic Conference (11-14 June)], Kiev, 1968.

39. Ol', A. I. "Manifestation of Solar Activity in Earth's Magnetosphere and Ionosphere," in "Vliyaniye solnechnoy aktivnosti na atmosferu i biosferu Zemli," Moscow, Nauka, 1971.

40. Opalinskaya, A. M. "Attempted Use of Chemical Test to Forecast Solar Activity," "Mater. II Vsesoyuz. soveshch. po izucheniyu vliyaniya magnitnogo polya na biol. ob"yekty (24-26 sentyabrya)," Moscow, 1969.

41. Opalinskaya, A. M., and Plekhanov, G. F. "Change in Rate of Precipitation of Bismuth Hydroxychloride in Magnetic Fields of Different Frequencies," "Mater. Vsesoyuz. simp. 'Reaktsiya biol. sistem na slabyye magnitnyye polya'," Moscow, 1971.

42. Idem, "Change in Nature of Relationship Between Piccardi Reaction and Geomagnetic Field as a Function of Phase of Solar Activity, Season and Time of Day," in "Vliyaniye yestestvennykh i slabykh iskusstvennykh magnitnykh poley na biol. ob"yekty," Belgorod, 1973.

43. Idem, "Effect of Weak, Infralow-Frequency MF on Agglutination Reaction," "Mater. III Vsesoyuz. simp. 'Vliyaniye magnitnykh poley na biol. ob"yekty'," Kaliningrad, 1975.

44. Panteleyev, P. A. "Mass Reproduction of Water Vole and Relation Thereof to Cyclicity of Solar Activity," ZHURN. OBSHCH. BIOL. [Journal of General Biology], 28, 6, 1967.

45. Piccardi, G. "Chemical Bases of Medical Climatology," Moscow, Gidrometeoizdat, 1967.

46. Plekhanov, G. F., and Kartashov, A. G. "Effect of weak SMF on Rate of Glucose Fermentation by Yeast," TRUDY KIRG. MED. IN-TA (Frunze) [Works of Kirgiz Medical Institute], 100, 1974.

47. Plekhanov, G. F., and Opalinskaya, A. M. "Effect of Shielding From Geomagnetic Field and Artificial MF on Piccardi Fluctuation Reaction," in "Vliyaniye yestestvennykh i slabykh iskusstvennykh magnitnykh poley na biol. ob"yekty," Belgorod, 1973.

48. Pokrovskaya, T. V. "Solar Activity and Climate," in "Vliyaniye Solnechnoy aktivnosti na atmosferu i biosferu Zemli," Moscow, 1971.

49. Idem, "Long-Term Weather Forecasts, Atmospheric Circulation and Solar Activity," author abstract of doctoral dissertation, Leningrad, 1967.

50. Ryvkin, B. A. "Effects of Heliogeophysical and Meteorological Factors on the Course and Outcome of Cardiovascular Diseases in Leningrad," author abstract of candidatorial dissertation, Leningrad, 1966.

51. Ryabchuk, Yu. A. "Strength and Nature of Body Reactions as a Function of MF Magnitude," Frunze, 1974, p 38.

52. Sirotina, L. V.; Sirotin, A. A.; and Travkin, M. P. "Some Distinctive Features of Biological Effects of Weak MF," "Mater. II Vsesoyuz. simp. 'Reaktsiya biologicheskikh sistem na slabyye magnitnyye polya'," Moscow, 1971.

53. Sleptsov-Shalevich, B. A. "Multiyear Fluctuations of Atmospheric Pressure in the Northern Hemisphere Related to Changes in Solar Activity," SOLNECHNYYE DANNYYE, No 1, 1966.

54. Taranov, S. V. "Some Distinctions of Pulsed Magnetic Field Effects on Cell Cultures," "Mater. III Vsesoyuz. simp. 'Vliyaniye magnitnykh poley na biol. ob"yekty'," Kaliningrad, 1975.

55. Tebenkhin, Ye. F., and Gusev, B. G. "Treatment of Water with MF in Heat and Power Engineering," Moscow, Energiya, 1970.

56. Tkachenko, Ye. G.; Padalka, Ye. S.; Nikol'skaya, M. A.; et al. "Effect of SMF on Immunobiological Reactivity of the Body," "Mater. Vsesoyuz. simp. 'Vliyaniye iskusstvennykh magnitnykh poley na zhivyye organizmy'" [Proceedings of All-Union Symposium on "Effects of Artificial Magnetic Fields on Living Organisms"], Baku, 1972.

57. Ukolova, M. A. "The Question of Central and Peripheral Mechanisms of Action of MF on the Organism," Frunze, 1974.

58. Formozov, A. N. "Essay on Ecology of Tularemia-Carrier Muridae," Moscow, 1947, pp 1-93.

59. Chernyshev, V. B. "Solar Activity, Perturbation of Gemomagnetic Field and Insect Behavior," in "Solntse, elektrichestvo, zhizn'," Moscow, 1972.

60. Chizhevskiy, A. L. "Periodic Effects of the Sun on Earth's Biosphere," Moscow, 1915.

61. Idem, "We and the Sun," Moscow, 1963.

62. Chizhevskiy, A. L., and Shishina, Yu. G. "In the Sun's Rhythm," Moscow, Znaniye, 1969.

63. Chizhevskiy, A. L. "Echoes of Solar Storms," Moscow, 1973.

64. Ellison, M. A. "The Sun and Its Effects on Earth," Moscow, 1959.

65. El'darov, A. L., and Kholodov, Yu. A. "Effect of SMF on Motor Activity of Birds," ZHURN. OBSHCH. BIOL., 25, 3, 1964, p 224.

66. Yagodinskiy, V. N., and Aleksandrov, Yu. V. "Helioepidemiology of Tick-borne Encephalitis," SOLNECHNYYE DANNYYE, No 4, 1965.

67. Yagodinskiy, V. N. "Some Aspects of Relationship Between MF and Infectious Morbidity," "Mater. II Vseosyuz. simp. 'Reaktsiya biol. sistem na slabyye magnitnyye polya,'" Moscow, 1971.

68. Altman, G. "Effects of Physical Factors on Organusms," MATH. UND NATURWISS. UNTERR., 22, 7, 1969, p 385.

69. Konig, H. L. "Effects of Extra-Low Frequency Electric Phenomena in the Atmosphere on the Environment," Z. ANGENW. BADER UND KLIM., 9, 5, 1962, p 3.

70. Novak, J., and Vabn, L. "Attempt of Demonstrating Effect of Weak Magnetic Field on Taraxacum Officinale," BIOL. PLANTRUM, 7, 1965, p 6.

71. Martini, R. "Effect of Solar Activity on Incidence of Accidents," ZBL. ARBEITSMED. UND ARBEITSCHUTZ, 2, 1952, p 98.

72. Piccardi, G. "Cosmic Phenomena and Bioclimatology," WIENER MED. WOCHENSCHR., 106, 1966, p 6.

73. Idem, "Correlation Between Atmospheric and Space Phenomena, and Physico-Chemical Processes," ARCH. METEOROL. GEOPHYS. UND BIOKLIMATOL., SER. B, 4, 1955, p 49.

74. Reiter, R. "Relationship Between Solar Flares, Weather and Human Reactions as Manifested by the Effect of Infra-Long Wave Current on Birth and Traffic Accident Rates," ANGEW. METEOROL., 1, 1953, p 289.

75. Idem, "Relationship Between Human Reaction Time, Traffic Accident Rate and Meteorological Events," MUNCHENER MED. WOCHENSCHR., 93, 1951, p 27.

76. Fraemmsdruff, W. R. "Biological Effects of Atmospheric Radiation," MINERVA MED., 58, 1967, p 35.

10,657
CSO: 8144

APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000100030004-3

BIOENERGETICS AND REGULATORY SYSTEMS OF THE ORGANISM DURING EXPOSURE TO MAGNETIC FIELDS

Moscow REAKTSII BIOLOGICHESKIKH SISTEM NA MAGNITNYYE POLYA in Russian 1978 signed to press 24 Feb 78 pp 81-102

[Article by M. A. Shishlo, S. Kh. Kubli and V. P. Nuzhnyy, Central Scientific Research Institute of Balenology and Physiotherapy, Moscow]

[Text] Numerous and diverse evidence of the biological effects of stationary and low-frequency variable MF [magnetic fields] over a wide range of intensities (from fractions to thousands of oersted) is indicative of the high sensitivity of biological objects to mild factors.

It is known that the energy of interaction of SMF and VMF with biological macromolecules is lower by several orders of magnitude than the mean energy of thermal movement of molecules at ordinary temperatures. For this reason, interpretation of magnetobiological phenomena from the standpoint of thermodynamics leads to the conception of probabilistic fluctuating effects of MF, which initiates triggering processes in the organism that enhance significantly a mild exogenous perturbation [1, 2].

In addition, in the course of investigation of biological effects of EMF [electromagnetic fields], the conception was formed and recognized of a resonance or informative mechanism of interaction between an exogenous physical factor and a target, in which multiple amplification of the end result of interaction by the system is interpreted as the consequence of resonance, i.e., a certain consistency between physical and time and space characteristics of the exogenous factor and properties of the target [3, 4].

The works of A. L. Buchachenko, which which he formulated a conception of the mechanism of action of MF unrelated to a change in energy of reactions, but due to the effect of the field on probability of reactions occurring in the form of states at different spin multiplicity, made a basic contribution to the study of the molecular mechanism of biological effects of MF. The field induces intercombinative transitions or alters the probability of such transitions. Hence, the probability of occurrence of free radical reactions depends on the MF, and the greater the difference of g factors of reacting particles and field intensity, the stronger these reactions. In this respect, reactions involving iron ions, interaction of which with oxygen or diamagnetic macromolecules may depend appreciably on SMF intensity [5], are of special interest to biology.

The proposed mechanism ensues from studies dealing with interpretation of nonequilibrated density of Zeeman levels occurring in free radical reactions. It can thus be expected that chemical polarization of nuclei and electrons, like the effects of MF, may have the most direct bearing on formation of nonequilibrated living biological systems.

Instability of Conformation of Polyatomic Systems and Its Role in Biological Processes. The Vibron Mechanism of Enhancement of Weak Low-Symmetry Perturbances

Basic research on instability of conformation of polyatomic systems due to electronic oscillatory interactions was pursued by I. B. Bersuker et al. [6, 7].

The prerequisite for formation of instability in polyatomic systems is interaction between atoms accompanied by marked (three-dimensional) delocalization of electrons in chemical bonds. The latter are called coordinated or donor-acceptor bonds. They are widesparead in biological systems and, in essence, an inherent feature thereof.

It is known from spectroscopy that the frequency of electron movement in molecules is about 10 times higher than the frequency of oscillation of nuclei. This permits the use, in describing polyatomic systems, the Born-Oppenheimer method of adiabatic approximation, in which it is assumed that movement of nuclei and electrons is independent. However, the applicability of adiabatic approximation is restricted by the condition of correlation between energy of oscillatory quantum of the nucleus $h\nu_{osc}$ and difference in energies of electron levels of the molecule:

$$h\nu_{osc} \ll \varepsilon_k - \varepsilon_j.$$

With decrease in $\varepsilon_k - \varepsilon_j$, the adiabatic approximation is less valid, and in the presence of electron degeneration $\varepsilon_k = \varepsilon_j$, it is inapplicable.

The conditions for occurrence of instability of nuclear configuration of a polyatmoc system were formulated by L. D. Landau and proven in the form of a theorem by Yan and Teller, according to whom the configuration of a nonlinear polyatomic system with electron degeneration is unstable in relation to a shifting of nuclei that eliminate this degeneration. Hence, the electron states of a degenerated therm lose physical meaning, since they are mixed with nuclear shifts and the states of the system become electron-nuclear, or vibronic.

A situation that is analogous in many respects occurs in polyatomic systems with rather close electron levels, which is called pseudodegeneration, as well in linear molecules with a strong electron oscillatory bond. It should be noted that appearance of instability of a polyatomic system can occur with both orbital and spin degeneration (with the exception of Kramers' degeneration).

Analysis of the form of adiabatic potential of Yan-Teller systems shows that, in all cases of electron degeneration, the multidimensional surface of the potential has several minimums that are equivalent in energy and symmetry, which correspond to the same number of equivalent, equiponderant configurations of nuclei with potential barriers between them. If there is sufficient depth of minimums, the configuration in each of them becomes quasistationary and the transitions between minimums are in the nature of tunneling, which causes cleavage of electron-oscillatory levels in each of them (inversion or tunnel cleavage [or segmentation]).

Let us discuss some of the consequences of tunnel segmentation of adiabatic potential [6] that are important to comprehension of a number of biological processes.

If there are two minimums of adiabatic potential situated close to one another and they are not deep enough, the system is nonstationary and it continuously undergoes tunnel transitions.

The typical property of Yan-Teller systems is their behavior in the presence of distoring perturbations. The latter can be conceived of in the form of differences in ligands proper or influences originating from the coordination sphers following the first one.

If the magnitude of low-symmetry perturbation is comparable or greater than vibron interaction, i.e., if the produced cleavage is greater than the Yan-Teller cleavage, the exogenous perturbation depresses the Yan-Teller effect completely, and all changes in the system are determined by the magnitude of the perturbing factor. In addition, in the case of minimal low-symmetry perturbatoons, the magnitude of distorion in the Yan-Teller system is virtually independent of the distorting perturbation and it is determined in essence by the Yan-Teller effect. Moreover, a minimal distorting perturbation is enhanced by vibron interaction, and this enhancement may be 20-40-fold. Expression of this effect at ordinary temperatures, including biological phenomena, is possible only if there is a cooperative Yan-Teller effect, i.e., correlated interaction between a large enough number of Yan-Teller centers.

The Yan-Teller system, being conjugated with a chemical reaction, may change from a symmetrical configuration to a quasistationary, distorted one.

The above properties of cooperative Yan-Teller systems make it possible to come closer to understanding a number of typical biological phenomena, such as high sensitivity to weak factors and "slipping away" from them, nonspecificity of vibron excitation with regard to the nature of perturbation and multi-optimum correlation between vibron excitation and magnitude and dyssymetry of perturbation.

The interaction between MF and cooperative Yan-Teller structure is determined both by its properties and characteristics of magnetic perturbations. In the latter, induction of EMF [electromotive force] plays a substantial role; it emerges in charge-conducting media as the main low-symmetry component forming nonadiabatic mechanisms. On this basis, one should expect maximum effectiveness of periodic magnetic perturbations with marked asymmetry thereof in time and space.

Such characteristics as energy of interaction of distortions between individual centers and symmetry of the process of interaction of perturbations with the anisotropic system acquire a special importance in the mechanism of action of MF. The maximum intrinsic frequencies of tunneling, rate of propagation and decrement of extinction of the vibron wave in an extended continuous medium depend directly on the magnitude of energy of interaction of correlated distortions.

With decrease in energy of interaction of correlated distortions, decrease in characteristic frequencies of tunnel transitions and approximation of the system to the coordinate of stationary instability, the effectiveness of MF effects will increase and, under certain conditions, one can expect that low-frequency MF will stimulate tunnel transitions in polyatomic systems.

Finally, in a nonstationary polyatomic system that continuously effects tunnel transitions between two closely situated minimums of adiabatic potential, the magnitude of magnetic segmentation may be insufficient to depress the Yan-Teller effect and tunnel transitions.

Thus, the MF effects at the usual temperatures should be expected in structures with low energy of interaction of distortions, low characteristic frequencies of tunnel transitions and high decrement of vibron wave extinction in an extended medium. One could expect both depression of tunnel transitions and an increase in their incidence, depending on the correlation between magnitude of Yan-Teller and magnetic splitting.

At the same time, with increase in energy of distortion interaction and characteristic tunneling frequencies, there will be a rise of thresholds of vibron excitation and radical decline in MF effects. In cooperative Yan-Teller systems, in the presence of a strong electron-oscillatory bond and marked correlation of distortions, the mechanism of vibron amplification should cause a change from local "excitation" to nondecremental, spreading excitation.

Thus, the property of vibron enhancement inherent in Yan-Teller systems makes it possible to approach the mechanisms of formation of such typical properties of biological systems as irritability and excitability on the same physical basis. In view of the foregoing, there is every reason to believe that some physiological patterns (threshold, optimum, pessimum of irritation, etc.) demonstrable during interaction of electric current with excitable structures is in essence a manifestation of characteristic properties of biological, cooperative Yan-Teller systems and nonadiabatic mechanisms of interaction between current and living tissue; the symmetry of interaction is expressed in the ambiguity of "anode" and "cathode" effects.

Let us further imagine that there is a certain set of cooperative structures with different energy of distortion interaction in living cells and various tissues of the integral organism. Then, by selecting the parameters of exogenous perturbation in such a way that the magnitude of introduced segmentation [splitting, cleavage] does not exceed the magnitude of Yan-Teller splitting, one can effect selective vibron excitation of various structures.

Such a multiphasic nature of interaction between exogenous perturbation and the integral organism has been experimentally demonstrated under the effect of MF (see Garkavi et al., in this collection).

The aggregate of the above data and analysis thereof very obviously shows that the model of cooperative Yan-Teller systems discloses the physical mechanism of interaction of perturbations, the energy of which is below kT, with living biological objects.

Conformation instability of macromolecules has been found in many proteins of the actomyosin complex, which are involved in energy transformation during muscular contraction and conjugation of redox reactions with processes of ion transport and ATP synthesis in membranes [8-10]. Moreover, the accumulated experimental data warrant the belief that actomyosin-like protein is a mandatory component of most biological membranes [11].

The surface of the protein macromolecule, which interacts with solvent, plays the leading role in formation of conformational instability. This is indicated by the data on the effects of various nonspecific agents (alcohol, salt, etc.) on the amplitude of conformational oscillations [8]. Protein macromolecules are characterized by the possibility of regulating donor-acceptor levels of their cooperative bonds by means of changing the concentration of hydrogen ions in the medium. Such regulation is based on the amphoteric properties of amino acids.

The fact that the PO_4 group has four minimums of adiabatic potental and KH_2PO_4 crystals present the behavioral patterns of Yan-Teller systems [7] could serve as ponderable proof of the Yan-Teller mechanism of formation of conformational instability of biological macromolecules. In biology, the phenomenon of activation of macromolecules by phosphorylation thereof is well known. In view of the foregoing, it becomes obvious that such activation can be interpreted as one of the means of vibronic excitation, in which phosphate groups are the centers of generation of vibronic oscillations of macromolecules,* while a solvent with thermal noise serves as the source of low-symmetry perturbations that activate this process nonlinearly. A temperature drop should lower the amplitude of vibron oscillations and radically alter the cooperative properties of such a system.

In accordance with the conceptions that are being developed, Mn, Co, Cr and certain other cations, with unfilled *d*-envelopes, should participate in formation of Yan-Teller centers of biological systems. In this regard, the role of the above cations in processes of energy transformation in mitochondria, chloroplasts and the plasma membrane merits special attention [12, 13, 14].

Analysis of the mechanisms of involvement of Yan-Teller systems in biological phenomena leads to the conclusion that they have universal significance in processes of deliberate transfer and separation of charges, the fundamental basis, forming active transport of ions and metabolites in biological membranes. This vector process occurs in heterogeneous systems [15] in the presence of hydrophil-hydrophobic gradients and functional conjugation of anisotropic media with different symmetry of their crystal lattice. The role of macromolecular complexes with Yan-Teller properties amounts to formation of symmetry properties of the medium, accumulation of dipole and deformational distortions, and use thereof in molecular transport phenomena. The effectiveness of transfer should be determined by the magnitude of intramolecular distortion (magnitude of gradient) and incidence of generation of vibron instability of the macromolecular complex; a correlation should be demonstrable between effectiveness of processes of molecular transfer and characteristic properties of the vibron generator, and there should be tightening of the characteristic functional mode.

The Role of Vibronic Instability and Symmetry of Heterogeneous Polyatomic Systems in Effects of MF on Processes of Energy Transformation in Mitochondria

Current conceptions of the mechanism of transformation of energy in the mitochondrial membrane are based on the principle of Mitchell, according to which the transmembrane transfer of electrons in the respiratory chain is associated with formation of electrochemical ion potential H [16]. The latter $\Delta\bar{\mu}_{H^+}$ is the moving force of the phosphorylation system, and it consists of electric component $\Delta\psi$ and an osmotic component represented by the difference between concentration of ions H^+ within and without the membrane:

$$\frac{\Delta\bar{\mu}_{H^+}}{F} = \Delta\psi - Z\Delta pH,$$

where F is the Faraday number, $\Delta\psi$ is the membrane potential in volts and Z is the coefficient of proportionality, which equals 0.06.

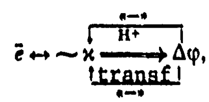
*A certain chemical interaction implementing the oscillatory-electron bond between phosphate and the macromolecule is a mandatory prerequisite for the activation mechanism under discussion.

The principle of chemiosmotic conjugation of respiration and phosphorylation is usually described in the following form:

$$\bar{e} \rightleftarrows \Delta\bar{\mu}_{H^+} \rightleftarrows \sim,$$

where $\bar{e}$ is electron transfer and ~ is a high-energy compound of the ATP type; $\Delta\bar{\mu}_{H^+}$ is used not only for ATP synthesis but for generation of heat, electric, osmotic, mechanical and other types of work.

According to the above-described mechanism of conjugation of the vibron with ion transfer,* the system of conjugation of electron transfer and generation of $\Delta\bar{\mu}_{H^+}$ can be described as follows:

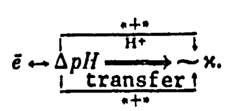


where $\bar{e}$ is transmembrane electron transfer, ~κ is the vibron, ⇛ is the hydrophilic-hydrophobic gradient, Δϕ is the electric difference in potentials that implements functional conjugation of transfer H^+, ~κ and $\bar{e}$.

An increase in transmembrane Δ pH leads to increase in dipole distortions, lowering of frequency and ultimately depression of vibron generation in the molecular system that implements proton transfer.

At the same time, an increase in Δϕ to a certain critical level opens up the possibility of intramolecular electron transfer over the Δϕ gradient in Yan-Teller structures with electron conductivity of the Fe-S protein type, inserted in the same anisotropic membrane layer. Such a mechanism may be responsible for reverse transport of electrons in mitochondria and certain other routes of energy transformation in the membrane.

At the same time, the process of ADP phosphorylation may be described as antisymmetrical to the mechanism of Δϕ formation:



*Involvement of the phonon (vibron) in mechanisms of energy transformation in mitochondria was theorized by C. McClare, D. Green and others [17].

Such a supramolecular bond of $\Delta\bar{\phi}$ and ΔpH with ~κ becomes possible in the presence of spatial charge asymmetry of the membrane due to the hydrophil-hydrophobic gradients generated by interaction of proteins with lipids, and the difference in pH on either side of the membrane. Transmembrane transfer of $\vec{e}$, $\overleftarrow{e}$ and $\vec{H}^+$ by the mitochondrial respiratory chain and presence of proton carriers in the lipid layer, the function of which is performed by ubiquinone is a mandatory condition for such a bond [18, 19].

There is accumulation of ΔpH on the internal hydrophobic barrier upon transfer of electron $\vec{e}$ in the respiratory chain to the external hydrophobic barrier of the mitochondrial membrane. Upon reaching a critical value of ΔpH H^+ are tunneled into ATP synthetase. There is transfer of $\overleftarrow{e}$ to the inside in the respiratory chain and increase of $\Delta\bar{\phi}$ in the external macromolecular block.

Consequently, the effectiveness of ATP accumulation, cation absorption and heat production in mitochondria are a function of the frequency of nonlinear oscillations in the system and integrity of hydrophobic "proton valves." The time of ΔpH accumulation is the limiting element of the phosphorylation process. Transport of Ca•• and several other cations capable of discharging [dropping] Δϕ and altering the time and space symmetry of processes in the mitochondrial membrane should depress the process of ADP phosphorylation.

The proposed mechanism of H^+ transfer through hydrophobic "valves" can occur in the case where protein macromolecules interacting with lipids are cooperative Yan-Teller structures with dipole distortion ($\Delta\bar{p}$). This provides for the bond of $\Delta\bar{p}_1$, $\Delta\bar{\phi}$ and ~κ, ΔpH, ~κ and $\Delta\bar{p}_2$ in the external and internal hydrophobic "valves," respectively.

It could then be expected that, with lowering of temperature and corresponding depression of active transfer, MF would induce in a conjugate mitochondrial preparation a decrease in spatial-charge asymmetry of the membrane and narrowing of the working range of the respiratory change, with decline of maximum values of characteristic frequencies of tunnel transitions in cooperative Yan-Teller structures of mitochondrial membranes.

Let us refer to the results of experiments dealing with the effect of MF on isolated mitochondria stored at 0–+4°C in a medium containing 0.3 mole saccharose and 0.02 mole tris-HCl, pH = 7.5. In this study, heterogeneous SMF were used, with intensity of 350-4500 Oe, and VMF of 50 Hz, with intensity of 30 and 180 Oe.

After exposure to heterogeneous SMF of 3500 Oe for 40-50 min, a decline is observed in the saccharose-magnesium incubation medium in rate of respiration on succinate as the oxidative substrate (V_0), with addition of 200 μmole ADP (V_3) and in the controlled state (V_4). There is negligible rise of ADP/O coefficient and increase in phosphorylation time (Δt). However, the rate of respiration on DNP [dinitrophenol] does not differ from the parallel control of preparation aging time.

Addition of 15 μmole KCl and reduction of $MgCl_2$ from 7.5 to 2.5 mmole in the incubation medium is associated with even more marked reduction of V_3 as compared to the control, even greater increase in phosphorylation time, negligible decrease of ADP/O coefficient and reliable decrease in respiratory rate on DNP in mitochondria exposed to SMF. The latter is unrelated to OAA [oxalacetic acid] inhibition of SDH [succinate dehydrogenase], since it is not eliminated by glutamate, and it depends on the presence of KCl in the incubation medium (Figure 1).

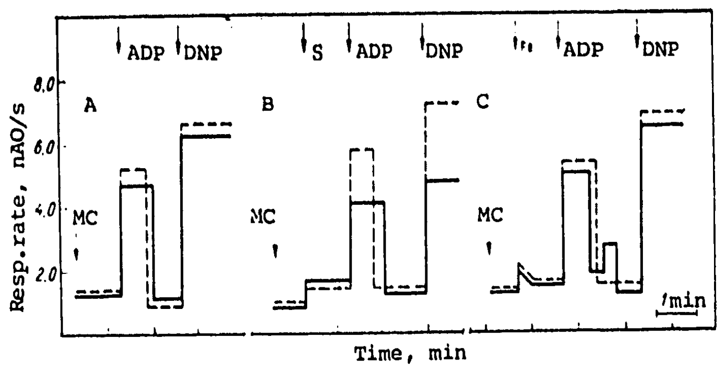


Figure 1. Rate of mitochondrial respiration in the presence of different metabolic states, in the control (dash line) and after 50-min exposure to SMF of 3500 Oe with a gradient of 380 Oe/cm (solid line)

A. C) incubation medium in mmoles: 230 saccharose, 7.5 $MgCl_2$, 10 KH_2PO_4, 5 succinate, pH 7.40

B) incubation medium in mmoles: 200 saccharose, 2.5 $MgCl_2$, 20 KH_2PO_4, 15 KCl, pH 7.40

The following were added: mitochondria (MC), 3-4 mg protein, 5 mmole succinate (S), 210 mmole ADP, 30 μmole DNP and 50 μmole $FeSO_4$

An increase in duration of exposure to 3500 Oe SMF to 75-100 min leads to elevation of V_0 and V_4 in the medium with KCl on succinate; the rate of phosphorylation is restored to control levels, while V_{DNP} remains low. This phase of the mitochondrial reaction is also observed in the aftereffect period following brief exposure to 3500 Oe SMF, and it is typical of the case of exposure for 30-40 min to VMF of 50 Hz and 180 Oe (Figure 2).

In the first and second stages of mitochondrial reactions to MF, one observes typical changes in their interaction with iron ions. In the first phase, with addition of Fe ions to the incubation medium there is a decrease in stimulation of respiration in state III, whereas in the controlled state there is appearance of a second respiratory wave ending with a change to marked energetic control, as demonstrable with subsequent addition of DNP. In the second phase, along with decline of V_3 Fe ions raise V_4 stationarily, which is indicative of irreversible impairment of mitochondrial membrane permeability and energetic regulation of the respiratory chain (Figures 1 and 2).

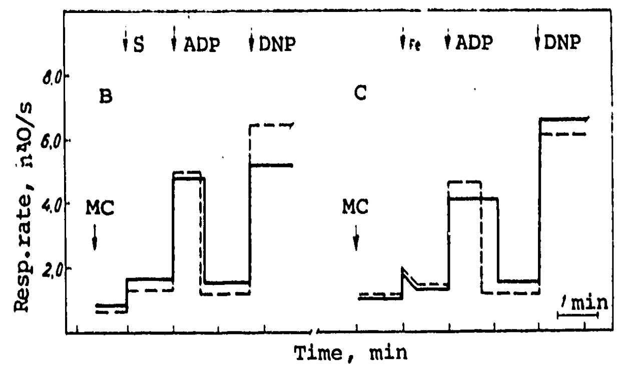


Figure 2. Rate of mitochondrial respiration in various metabolic states after exposure to VMF for 40 min, 50 Hz, 180 Oe. Designations are the same as in Figure 1.

The decline of respiratory rate in the third state and appearance of a second respiratory wave in the fourth state with addition of Fe to the mitochondrial incubation medium warranted the assumption that SMF inhibits reduction of $Fe^{\cdot\cdot\cdot}$ conjugated with function of the respiratory chain and leads to secondary mild activation of lipid peroxidation. The direct effect of MF on free radical processes of lipid peroxidation, which involve endogenous iron, could be the cause of these changes.

For this reason, experiments were conducted on the effects of SMF and VMF on high-amplitude mitochondrial swelling in a KNO_3 or NH_4NO_3 medium induced by $Fe^{\cdot\cdot}$ ($5\cdot10^{-4}$ mole) or $Fe^{\cdot\cdot}$ + ADP ($5\cdot10^{-4}$ and $5\cdot10^{-4}$ mole, respectively). The respiratory chain was blocked by antimycin A. Causing swelling at a temperature of 22°C directly in the MF showed that the rate of reduction of optic density did not differ reliably from the control with all of the intensities used.

Thus, the data indicated that MF induces primary depression of distortions in Yan-Teller structures of mitochondrial membranes containing Fe and involved in conjugation of electron transport along the respiratory chain with formation of membrane potential. Activation of lipid peroxidation induced by MF is secondary and limited in strength, due to decline of $\Delta\phi$ and charge asymmetry of the membrane, which disrupt regeneration of reduced iron by the respiratory chain.

The obtained data were consistent with the scheme, according to which ATP synthesis and cation transport are antisymmetrical processes (Figure 3). There is a decrease in spatial charge asymmetry of the mitochondrial membrane under the influence of MF tunnel effects, with retention of transmembrane pH. As a result, we observe vibron excitation of the system of cation transport, and in a medium with potassium chloride there is penetration and adsorption of the chlorine ion in the region of maximum jump of electrical potential on the membrane, which causes stationary decline of gradient $\Delta\phi$ and lowering of characteristic frequencies of tunnel transitions.

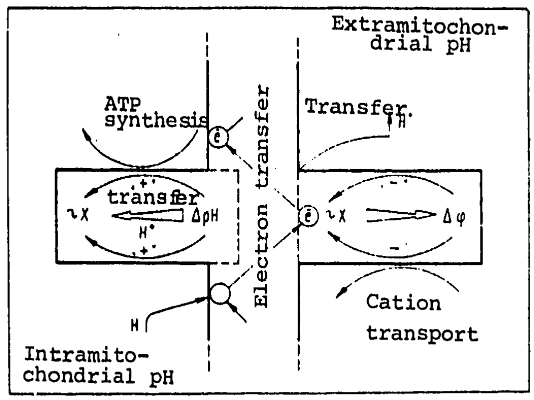


Figure 3. Diagram of conjugation of mitochondrial respiratory chain with cation transfer and ATP synthesis.

Circles: respiratory chain electron carriers; ~χ--vibron; pH--"spagen" [?] pH on the protein-lipid interface; $\Delta\phi$ --electric difference in potentials; white arrow--hydrophil-hydrophobic gradient. The diagram corresponds to the SDH-dependent segment of the respiratory chain (described in detail in the text)

Inhibition of oxidative phosphorylation (increase of Δt, decrease of ADP/0, as well as V_{DNP}), similar to the observed effect of MF, occurs upon alkalinization of the mitochondrial incubation medium [20], but in this case it is the result of equilibrated decrease in charge-spatial asymmetry due to a decline of transmembrane pH gradient.

Typically enough, after exposure to SMF, the mitochondria restore charge asymmetry of the membrane during ADP phosphorylation. The dependence of this restoration on specific functional activity of mitochondria is distinctly demonstrable with a mixture of malate and glutamate, when a decrease in added ADP from 200 to 100 μmole causes a 30% reduction of V_3 and 80% recution of V_{DNP}; DNP was added in the fourth state after ADP phosphorulation. In the control, the change in these indices was in the range of 5-10%.

These data are indicative of the high sensitivity of the NAD-FAD [nicotine adenine dinucleotide--flavine adenine dinucleotide] segment of the mitochondrial respiratory change to the state of the spatial-charge membrane asymmetry and demonstrate the possible role of tunnel electron transport over Fe-S proteins in the mechanism of MF action.

One can observe the first inhibitory phase under the influence of SMF not only in isolated mitochondria but with exposure of the integral organism (7 days, 30 min, 500 Oe daily).

In a saccharose-magnesium incubation medium, we observed a tendency toward lowering of V_3 and V_{DNP} on succinate, reduction of all rates, particularly ($P<0.01$) on a mixture of malate and glutamate, and dissociation of oxidation of α-ketoglutarate--a tendency toward elevation of V_0 and reduction of ADP/O ($P<0.05$). The latter most probably reflects activation of the nucleoside diphosphate kinase reaction, and it can be interpreted as the compensatory component of mitochondria with decline of $\Delta\mu_{H+}$ and production of ATP.

A comparison of these findings to in vitro experiments warrants expectation of an increase in monovalent cations in hepatic mitochondria of animals exposed to SMF many times.

The reduction of mitochondrial membrane potential and impairment of reduction of nonhemin iron by the respiratory change could inhibit processes of lipid peroxidation and alter resistance of the organism to the toxic effect of oxygen and ionizing radiation. Experiments conducted with Maksimova and Demurov confirmed this assumption: preliminary exposure to SMF (7 days, 500 Oe, 30 min daily) increases with statistical reliability rat resistance to the toxic effect of oxygen under pressure of 7 atm(abs.).

Let us now return to the second phase of the mitochondrial reaction to MF, when there is "slipping away" from the inhibitory response and a change to stimulation of V_0 and V_4 in a medium with KCl, and attenuation of energetic regulation of respiration. According to the functional scheme of the mitochondrial membrane, this "slipping away" is quite likely with depression of symmetry of the bond of ATP synthetase with structural protein, i.e., with decrease in capacity properties of the lipid layer and hydrophobic proton valves.

It is known that activation of lipid peroxidation leads to appearance of proton, potassium and certain other channels of permeability of model lipid membranes [21]. This effect is enough to weaken hydrophobic interactions between proteins and lipids [22, 23], depress the antisymmetrical bond between ATP synthetase and structural transfer protein, and lead to a change in function of ATP synthetase into ATP hydrolase.

Confirmation of the hypothetical mechanism of the second phase of reaction to MF was obtained in experiments with rat testicular mitochondria, where the animals were exposed once to VMF for 6.5 h, at 50 Hz and 200 Oe. The results of these expeirments, which were conducted together with S. M. Khlynin, revealed that 48 h after exposure testicular mitochondria in a saccharose-magnesium incubation medium with succinate as the oxidative substrate presented a 20% increase of V_0, 14% decline of V_3 and insignficant increase of V_4; there was also a reliable increase, to 26% versus 5% in the control, in the inhibitory effect of dicyclohexyldiimide (DCHD) added in the 4th state (50 μmole). Subsequent addition of DNP stimulates respiration, the absolute level of which was virtually the same in the experiment and control.

It is known that the oligomycin-like effect of DCHD is attributable to the reduction of proton conductivity of hydrophobic areas of mitochondrial membranes [24]. The obtained data indicated that the second phase of MF effect is manifested by activation of ATPase, appearance of excessive proton conductivity of the membrane and impairment of energetic regulation of respiration.

The mechanism of mitochondrial membrane function discussed here could be called chemivibron-electric. According to this mechanism, ATPase could be the source of infrared radiation, whereas structural protein could raise the "temperature" of tissue without transfer of heat in the form of infrared radiation. Excitation of electron nuclear oscillations, synchronized by means of $\Delta\phi$, in cooperative Yan-Teller systems of cell membranes with bond symmetry of $\sim\kappa$ and $\Delta\phi$ inherent in structural transfer protein (see Figure 3), is this specific biological heating mechanism. In such a system, cyclic discharge of $\Delta\phi$ by means of $Ca^{\cdot\cdot}$ or other mechanism (see above) should lead to excitation if vibron oscillations of actomyosin-like protein and elevation of its "structural" temperature. Without touching upon many aspects of this complex problem [14, 16] and, in particular, the possibility of raising the "structural" temperature of other specialized cell membranes, it should be noted that SMF and pulsed MF are capable of altering the rate of restoration of body temperature in hypothermic animals that had not been previously adapted to the cold. Under controlled experimental conditions, with and without administration of amytal, MF can both increase and decrease the rate of restoration of body temperature [25, 26].

These data indicate that there are alternative routes of thermogenesis in tissues of warm-blooded animals, with the opposite space and time symmetry of internal molecular mechanisms. It becomes obvious that ATPase and vibron mechanisms are these antisymmetrical routes of biological heating of tissues.

Thus, theoretical and experimental substantiation of molecular mechanisms of biological effect of MF indicates that it is based on probabilistic quantum processes, in which symmetry plays a decisive role, along with the law of minimum energy.

Instability and symmetry, which are the basic properties of life [27, 28], enable us to interpret many facts from new vantage points. It is assumed and there is much evidence of the fact that development of hypoxic and a number of other pathological processes is determined by the rate of occurrence of successive mutually determined states of mitochondria: impairment of oxidative phosphorylation, passage of K into mitochondria, absorption of Ca, etc. [29-32]. Most probably, this sequence reflects instability and symmetry of processes in the mitochondrial membrane, and it is in essence determined, since expression of various forms of regulation of the mitochondrial respiratory chain--by ADP, cations, substrates--is the form of manifestation of the law of minimum rate of increased entropy in a stationary nonequilibrium system as permitted by symmetry.

Effects of Magnetic Fields on Adrenergic and Cholinergic Mechanisms of Regulating Cardiac Function

When a conductive material moves in an MF, an electric difference of potentials occurs under the influence of Lorentz forces. For this reason, the heart and blood vessels can be viewed as stationary electrodes to which is directed EMF upon movement of blood in them in an MF, and both the vascular and cardiac walls, as well as the moving components of blood are exposed to the influence of polarization currents and conduction currents.

It was demonstrated above that interaction of weak electric perturbations with biological structures must be based on nonadiabatic mechanisms expressed in cooperative Yan-Teller systems.

Let us now discuss the results of experiments dealing with the effects of MF on rhythmic contractile function of the heart, reactivity of its adrenergic and cholinergic structures, as well as some concomitant metabolic reactions. Experiments were conducted on isolated rat hearts subjected to flow-through perfusion and frog hearts perfused according to Shtraub. The methodological aspects of the experiments have been published [33, 34]. Systolic pressure in the rat aorta was recorded on an Alvar polygraph, and the mechanogram of the frog heart, on a kymograph. In this study, flame photometry was used to assay Na and K ions in the perfusate and cardiac tissue; polarography was used to investigate oxygen uptake; fluorometric methods were used to assay catecholamines and the method of recording the intensity of spontaneous extraweak fluorescence of lipids extracted from cardiac tissues.

In different segments of the study, SMF were used with intensities of 1000 and 50 Oe, and VMF at a frequency of 50 Hz and intensity of 180 Oe. The studies were pursued after exposure of the isolated heart to MF for 50 min.

The specific activity of the frog heart, isolated according to Shtraub without additional aeration of the perfusate, i.e., in the case where an oxygen deficiency occurs, is associated with lowering of perfusate pH and impairment of ion balance in the form of passage of Na into the myocardium and exit of K into the perfusate. Under such conditions, 50-min exposure to 1000 Oe SMF potentiates the hypoxic effect. This is expressed by an additional decline of perfusate pH and increase in extra weak fluorescence of cardiac lipids (Figure 4), which is indicative of activation of processes of lipid peroxidation under the influence of MF with an intensity of 1000 Oe.

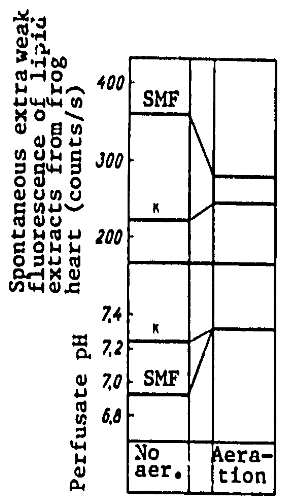


Figure 4.
Effect of 1000 Oe SMF on intensity of extra weak fluorescence of lipid extracts and pH of perfusate of isolated frog heart. Exposure time, 60 min

Left, without aeration; right, with aeration of perfusate.

K) control

Examination of processes of tissular respiration in pieces of ventricular myocardium from the frog revealed that their intensity is low and regulation of respiration by releasing protonophores is poor. For this reason, it may be assumed that the rates of aerobic oxidative processes, magnitude of pH gradients on membranes and maximum frequency of tunnel transitions in cooperative structures of the frog myocardium are minimal, as compared to most tissues of warm-blooded organisms, as can be judged from the comparative characteristics of tissular respiration under analogous conditions (Figure 5).

No substantial changes in respiration on succinate, as well as with addition of DNP, were demonstrable after exposure to SMF of 1000 Oe; there was merely a tendency toward decline of endogenous respiration. At the same time, 50 Oe SMF led to a reliable decrease of endogenous respiration of pieces of myocardium, in spite of the wide scatter of the obtained results; there was no substantial difference in rate of respiration on succinate and kinetics of activation of respiration with DNP, as compared to the control. It seems probable that addition of succinate stabilizes the indices of myocardial tissular respiration and eliminates variations thereof related to the effect of MF (Figure 5).

The obtained data warranted the assumption that inhibition of endogenous myocardial respiration is attributable to a decrease in spatial charge asymmetry of membranes responsible for aerobic processes of energy production, while activation of processes of free radical oxidation is the result of impairment of hydrophobic interactions and depression of cooperative properties of Fe-containing macromolecular membrane complexes.

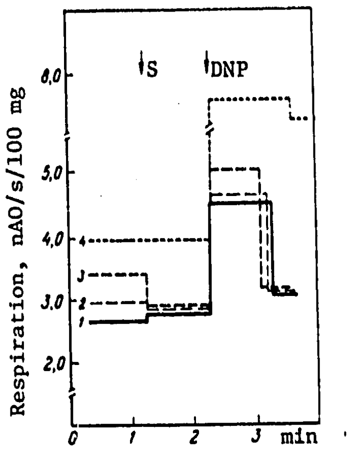


Figure 5.
Effects of 50 and 1000 Oe SMF on tissular respiration of frog heart ventricles (30-40 mg tissue)
Incubation medium (mmoles):
2[illegible]0 saccharose
7.5 $MgCl_2$
10 KH_2PO_4
10 S (succinate)
20 μmole DNP

1) 50 Oe
2) 1000 Oe
3) control
4) rat liver

Artificial aeration induced a decrease in changes in perfusate pH and negligible increase in extra weak fluorescence of lipid extracts in the control; there was complete elimination of perfusate pH difference between the control and experiment, with a marked tendency toward decreased extra weak fluorescence of lipids of hearts functioning in SMF (see Figure 4). The results of these experiments indicated that the mechanism of the Pasteur effect is due to the symmetry properties of cell membranes: 1000 Oe SMF depresses the spatial charge asymmetry of membranes involved in aerobic processes of energy transformation and dissociates intramembrane redox reactions from processes of active transport; attenuation of the Pasteur effect is observed also. Conversely, molecular oxygen increases the asymmetry of these membranes, due to its role as acceptor, not only in some chains of electron transfer but in free radical reactions leading to vibron perturbation of macromolecular complexes involved in ion transfer and energy transformation. Vibron perturbation of actomyosin-like protein is associated with activation of processes of lipid peroxidation in membranes [35].

Interaaction of nervous system mediators with receptors of plasma membranes is associated with cooperative conformational changes in membranes, in their permeability, electric potential and ion flux [36]. The cooperative conformational changes in cell membranes cause changes in bioenergetic processes, which form feedback between the end effects of mediators and their receptors in the plasma membrane [27].

These investigations revealed that SMF alters the correlation between bioenergetic processes: it decreases ATP production and causes compensatory activation of GTP [guanosine triphosphate] production; this is associated with intensification of glycolytic processes [25]. For this reason it was interesting to compare the reactivity of adrenergic and cholinergic structures of the isolated frog heart. After exposure to SMF for 50-60 min, we observed an appreciable decrease in reactivity to epinephrine over the entire range of tested concentrations thereof (see Table 1). In addition, interaction of the isolated heart with several concentrations of acetylcholine revealed increased cholinergic reactivity after exposure to 1000 Oe SMF. The degree of demonstrable changes in cholinergic reactivity was largely related to season and a number of other factors [34].

Table 1. Positive inotropic effect (%) of epinephrine on frog heart after 60-min exposure to 1000 Oe SMF*

Experimental series	Epinephrine, g/mℓ		
	$1 \cdot 10^{-9}$	$1 \cdot 10^{-8}$	$1 \cdot 10^{-7}$
SMF	14,5±4,3	12,8±3,2**	15,6±4,2**
Control	26,6±8,3	37,6±9,6	29,8±1,2

*Conditions: Ringer's solution for cold-blood organisms without glucose; perfusion according to Shtraub without aeration.

**$p<0.05$

The aggregate of findings referable to the effects of SMF indicated that there is a correlation between decrease in ATP-dependent bioenergetic processes and depression of β-adrenoreceptors, while compensatory activation of cholinergic mechanisms corresp nds to increased GTP production. The change in levels of cyclic cAMP and cGTP nucleotides probably plays an important mediatory role in the mechanism of SF effects on reactivity of different types of cells and tissues.

It was demonstrated that treatment of the isolated frog heart with chelate-forming compounds (8-hydroxyquinol, EDTA and certain others) attenuates the positive inotropic effect of catecholamines, which can be restored by ions of bivalent iron $Fe^{\cdot\cdot}$. Ions of other metals, including $Fe^{\cdot\cdot\cdot}$, do not elicit such restoration. This indicates that the adrenoreceptors are Fe-containing macromolecular complexes [38]. The demonstrated high sensitivity to weak electromagnetic perturbation warrants consideration of these complexes as cooperative Yan-Teller systems, in which there is conjugation of ion fluxes with the vibron. Then the incidence of tunnel transitions initiated by an agonist in receptor membrane complexes should determine the magnitude of inotropic effects of catecholamines, and it should depend on the spatial charge asymmetry of the plasma membrane, regulated under ordinary conditions by transmembrane ΔpH, $\Delta\bar{\mu}Na^{+}$ and electrochemical potentials of other ions, as well as intramembrane redox processes. The latter are linked with the main metabolic cycles of the cell through NADH and NADPH [11, 39].

In addition to the foregoing, the obtained data definitely describe the symmetry properties of cholinoreceptors and adrenoreceptors of the plasma membrane, which determine the direction of their conjugate changes under the influence of MF.

It is known that the level and correlation of different metabolic routes, as well as molecular organization of receptors of nervous system mediators, may differ in cold- and warm-blooded animals. In particular, it is known that complexons do not alter the effects of catecholamines on the rat heart [40]. There are also substantial differences in conjugate excitation and contraction in the myocardium [41].

In spite of these differences, the results of the experiments were indicative of a decrease in reactivity of adrenergic structures of the isolated rat heart after exposure to 1000 Oe SMF. The effects of VMF of 180 Oe were insignificant. The latter is apparently attributable to effective triggering of compensatory mechanisms and the fact that plasma membranes of the heart escape from the influence of VMF (Table 2).

Table 2. Positive inotropic effect of epinephrine (%) on isolated rat heart with exposure to 1000 Oe SMF and 180 Oe VMF (exposure time, 50 min; N 8÷9)*

Epinephrine, g/mℓ	SMF		VMF	
	Control	Experim.	Control	Experiment
$1 \cdot 10^{-9}$	18,0±5,0	12,0±2,0		
$1 \cdot 10^{-8}$	17,3±3,0	5,0±2,0**	12,4±2,8	6,6±2,0
$5 \cdot 10^{-8}$	10,0±4,0	5,0±2,0	16,8±2,9	12,8±3,1
$1 \cdot 10^{-7}$	9,0±3,0	9,0±2,0	12,6±2,9	16,6±3,0
$1 \cdot 10^{-6}$			13,4±2,7	13,0±3,0

*Flow-through refusion, Krebs' solution, 95% O_2+5% CO_2 aeration; solution temperature 37.5°C, moist chamber.

**$P<0.01$

Deposition of catecholamines in the myocardium is an important factor that characterizes the state of the sympathoadrenal system, and it is related to energy and electrolyte metabolism of tissue. It was demonstrated that DNP, but not fluoride or cyanide, effectively depresses absorption of catecholamines in specific granules of sympathetic nerve endings, as it increases proton conductivity of membranes [42, 43].

A comparison of the results obtained (Table 3) to the molecular mechanism of MF action warrants the belief that the influence of MF of the tested intensities on deposition and levels of catecholamines in the isolated heart is based on a decline of $\Delta\bar{\mu}_{H^+}$ on intracellular membrane structures of the myocardium.

Table 3. Catecholamine content of isolated rat heart with exposure to 1000 Oe SMF and 180 Oe VMF (exposure time, 50 min; N = 8÷9)*

Catecholamines, μg/g	SMF		VMF	
	Control	Experim.	Control	Experim.
Norepinephrine	0,62±0,10	0,56±0,04**	0,72±0,03	0,58±0,04*
Epinephrine	0,14±0,02	0,07±0,02	0,17±0,01	0,11±0,02*

*See Table 2 for experimental conditions. **P<0.05

* * *

The theoretical and experimental data submitted in this report lead to conceptions of the fundamental significance of the effect of vibron enhancement and symmetry properties of Yan-Teller systems in processes of self-regulation of flows of energy, matter and information in biological objects. Biological membranes play a substantial role in systemic organization of functions on the supramolecular and cellular levels of organization, and they form the symmetry of intramembrane separation of charges, thereby determining the vector nature of transmembrane transfer and separation of substance.

It becomes obvious that the mechanism of vibron intensification and separation of the proton and electron, expressed in Yan-Teller systems, is the specific biological phenomenon that enables the supramolecular system to utilize free energy of chemical reactions in processes of transfer and separation of substance and, on the other hand, the opposite: it determines utilization of endogenous energy of the system in energonic reactions.

MF, which are capable of affecting quantum physical processes when a system passes through an unstable state, play the role of a distinctive indicator and regulator of dyssymmetry and vibron instability, the main moving forces of information and energy conversions on the supramolecular level of organization of biological objects.

BIBLIOGRAPHY

1. Movshovich, I. M., and Shishlo, M. A. "Effects of MF on Biological Systems," in "Mater. Vsesoyuz. soveshch. po izucheniyu vliyaniya magnitnykh poley na biol. ob"yekty" [Proceedings of All-Union Conference on the Effects of Magnetic Fields on Biological Objects], Moscow, 1969, pp 155-158.

2. Shishlo, M. A. "Effects of Magnetic Fields on Enzymes, Tissular Respiration and Some Aspects of Metabolism in the Intact Organism," in "Vliyaniye magnitnykh poley na biologicheskiye ob"yekty" [Effects of Magnetic Fields on Biological Objects], Moscow, Nauka, 1971, pp 24-40.

3. Dorfman, Ya. G. "Physical Phenomena in Living Objects Occurring Under the Influence of Stationary Magnetic Fields," Ibid, pp 15-23.

4. Presman, A. S. "Electromagnetic Fields and Living Nature," Moscow, Nauka, 1968.

5. Buchachenko, A. L. "Chemical Polarization of Electrons and Nuclei," Moscow, Nauka, 1974.

6. Bersuker, I. B. "Electron Structure and Properties of Coordinating Compounds," Leningrad, Khimiya, 1976.

7. Bersuker, I. B.; Vekhter, B. G.; and Ogurtsov, I. Ya. "Tunnel Effects in Polyatomic Systems With Electron Degeneration and Pseudodegeneration," USP. FIZIOL. NAUK [Advances in Physiological Sciences], No 4, 1975, pp 605-641.

8. Shnol', S. E. "Synchronous Conformational Oscillations of Molecules of Actin, Myosin and Actomyosin in Solutions," in "Molekulyarnaya biofizika" [Molecular Biophysics], Moscow, Nauka, 1969, pp 56-82.

9. Idem, "Conformational Oscillations of Macromolecules," in "Kolebatel'nyye protsessy v biologicheskikh i khimicheskikh sistemakh" [Oscillatory Processes in Biological and Chemical Systems], Moscow, Nauka, 1967, pp 22-41.

10. Lehninger, A. "Mitochondria," Moscow, Mir, 1966.

11. Neyfakh, S. A. (editor) "Mechanisms of Integration of Cellular Metabolism," Leningrad, Nauka, 1967.

12. Shishlo, M. A.; Kotova, Ye. N.; and Yeliseyeva, S. V. "Possible Mechanism of Preventive Effect of Bivalent Mn, Co and Ni Ions Under the Toxic Effect of High Concentrations of Molecular Oxygen," in "Mater. konf. posvyashchennoy 100-letiyu so dnya otkrytiya D. I. Mendeleyevym periodicheskogo zakona khimicheskikh elementov" [Proceedings of Conference Commemorating the 100th Anniversary of the Discovery by D. I. Mendeleyev of the Periodic Law of Chemical Elements], Moscow [no year], pp 87-89.

13. Khodorov, B. I. "General Physiology of Excitable Membranes," Moscow, Nauka, 1975.

14. Skulachev, V. P. "Energy Buil-Up in the Cell," Moscow, Nauka, 1965.

15. Tarusov, B. N., and Kol's, O. R. (editors) "Biophysics," Moscow, Vysshaya shkola, 1968.

16. Skulachev, V. P. "Energy Conversion in Biomembranes," Moscow, Nauka, 1972.

17. McClare, C. W. F. "Resonance in Bioenergetics," ANN. N.Y. ACAD. SCI., 227, 1974, pp 75-98.

18. Yaguzhinskiy, L. S.; Khosni, F. M.; Kolesova, G. M.; and Smirnova, Ye. G. "Hydrophobic Areas and Electrophil Centers in the System of Oxidative Phosphorylation of Mitochondria," in "Mitokhondrii. Biokhimiya i ul'trastruktura" [Mitochondria. Biochemistry and Ultrastructure], Moscow, Nauka, 1973, pp 24-40.

19. Liberman, Ye. A.; Arzumanyan, A. M.; Vladimirova, M. A.; and Tsofina, L. M. "Potential Difference on the Membrane of Subcellular Particles. 1. Chemiosmotic and Chemielectric Mechanism of Generation," BIOFIZIKA [Biophysics], 21, 1976, pp 469-476.

20. Shishlo, M. A., and Kondrashova, M. N. "Substantiation of Pathogenetic Approach to Treatment by Means of Regulation of Bioenergetic Processes. 1. Effect of Physiotherapeutic Factors on State of Mitochondria. Choice of Normalizing Agent According to Pathogenesis," in "Regulyatsiya energeticheskogo obmena i ustoychivost' organizma" [Regulation of Energy Metabolism and Resistance of the Organism], Pushchino, 1975, pp 216-228.

21. Vladimirov, Yu. A.; Olenev, V. I.; Suslova, T. B.; and Potapenko, A. Ya. "Mechanism of Peroxidation of Lipids and Its Effect on Biological Membranes," in "Itogi nauki i tekhniki. Biofizika" [Advances in Science and Technology. Biophysics], Moscow, Vol 5, 1975, pp 56-117.

22. Kozlov, Yu. P. "Free Radical Oxidation of Lipids in Biomembranes Under Normal and Pathological Conditions," in "Bioantiokisliteli" [Bio-antioxidants], Moscow, Nauka, 1975, pp 5-14.

23. Sitkovskiy, M. V. "Investigation of Lipid Peroxidation as Related to Lipid--Protein Interactions in Biological Membranes," author abstract of candidatorial dissertation, Moscow, 1973.

24. Gudz', T. I.; Yaguzhinskiy, L. S.; and Skulachev, V. P. "Inhibitors of the System of Oxidative Phosphorylation of Mitochondria. Oligomycin-Like Effect of Alkylating Compounds," in "Mitokhondrii. Regulyatsiya protsessov okisleniya i sopryazheniya" [Mitochondria. Regulation of Oxidation and Conjugation Processes], Moscow, Nauka, 1974, pp 52-55.

25. Shishlo, M. A. "Effects of Magnetic Fields on Some Aspects of Biological Oxidation," candidatorial dissertation, Moscow, 1966.

26. Shishlo, M. A., and Maslov, S. P. "Effect of Stationary Magnetic Field on Restoration of Animal Body Temperature Following Acute Hypothermia," in "Nauchnyye trudy aspirantov i ordinatorov MMI" [Scientific Works of Graduate Students and Residents at Moscow Medical Institute], Moscow, Vyp 1, 1966, pp 97-100.

27. Romanovskiy, Yu. M.; Stepanova, N. V.; and Chernavskiy, D. S. "Mathematical Modeling in Biophysics," Moscow, Nauka, 1975.

28. Urmantsev, Yu. A. "Symmetry of Nature and Nature of Symmetry," Moscow, Mysl', 1974.

29. Kondrashova, M. N. "Regulation by Succinic Acid of Energy Supply and Functional State of Tissues," author abstract of doctoral dissertation, Pushchino, 1971.

30. Kondrashova, M. N. (editor) "Manual for the Study of Biological Oxidation by the Polarographic Method," Moscow, Nauka, 1973.

31. Idem, "Basic Concepts of Bioenergetics Applied in Functional Studies. Lability of Metabolic Reactions of Mitochondria," in "Regulyatsiya energeticheskogo obmena i ustoychivost' organizma," Pushchino, 1975, pp 67-82.

32. Sorokovoy, V. I., and Vladimirov, Yu. A. "Injury to Mitochondria in the Presence of Anoxia," in "Itogi nauki i tekhniki. Biofizika," Moscow, Vol 5, 1975, pp 11-55.

33. Nuzhnyy, V. P.; Zhdanova, N. F.; and Shishlo, M. A. "Effect of SMF on Functional State of Adrenergic Structures of the Isolated Heart," in "Magnitnoye pole v meditsine. Mater. k simp. 'Vliyaniye iskusstvennykh magnitnykh poley na biol. ob"yekty'" [Magnetic Fields in Medicine. Proceedings of Symposium on "Effects of Artificial Magnetic Fields on Biological Objects"], Frunze, 1974, pp 59-61.

34. Zhdanova, N. F.; Shishlo, M. A.; and Kudrin, A. N. "Change in Sensitivity and Reactivity of the Frog Heart to Acetylcholine After Exposure to Stationary Magnetic Field," VOPROSY KURORTOL. FIZIOTERAP. I LECHEBN. FIZKUL'TURY [Problems of Balneology, Physiotherapy and Therapeutic Physical Culture], 6, 1975, pp 545-551.

35. Shishlo, M. A.; Kudrin, A. N.; and Zhdanova, N. F. "Possible Role of Level of Free Radical Oxidation in Seasonal Fluctuations of Reactive Properties of the Frog Heart," in "Predbolezn'" [Premorbid States], Conference Proceedings, Moscow, Pt 2, 1969, pp 366-371.

36. Konev, S. V.; Aksentsev, S. L.; and Chernetskiy, Ye. A. "Cooperative Protein Changes in the Cell," Minsk, 1970.

37. Putintseva, T. G., and Turpayev, T. M. "Regulation of Cholinergic and Adrenergic Mediator Processes by the Feedback Mechanism," in "Sinapticheskiye protsessy" [Synaptic Processes], Kiev, Naukova Dumka, 1968, pp 46-61.

38. Komissarov, I. V., and Reutskaya, G. I. "Adrenoreceptors of the Frog Myocardium as Iron-Containing Complexes," BYUL. EKSPER. BIOL. I MED. [Bulletin of Experimental Biology and Medicine], 67, 6, 1969, pp 75-78.

39. Archakov, A. I. "Microsomal Oxidation," Moscow, Nauka, 1975.

40. Abramets, I. I.; Komissarov, I. V.; and Reutskaya, G. I. "Analysis of Adrenoreceptors of the Frog and Rat Myocardium at Different Temperatures," BYUL. EKSPER. BIOL. I MED., 70, 12, 1970, pp 48-50.

41. Orlov, R. S., and Izakov, V. Ya. "Basic Questions About the Mechanism of Conjugation of Excitation and Contraction in the Myocardium," USP. FIZIOL. NAUK, 2, 4, 1971, pp 3-23.

42. Chang, P.; von Euler, U. S.; and Lishajko, F. "Effects of 2,4-Dinitrophenol on Release and Uptake of Noradrenaline in Guinea Pig Heart," ACTA PHYSIOL. SCAND., 85, 4, 1972, pp 501-505.

43. Von Euler, U. S. "Adrenergic Nerve Particles in Relation to Uptake and Release of Neurotransmitter," J. ENDOCRINOL., 55, 2, 1972, pp 2-9.

10,657
CSO: 8144

MAGNETIC FIELDS, ADAPTATION REACTIONS AND RESISTANCE OF THE ORGANISM

Moscow REAKTSII BIOLOGICHESKIKH SISTEM NA MAGNITNYYE POLYA in Russian 1978 signed to press 24 Feb 78 pp 131-148

[Article by L. Kh. Garkavi, Ye. B. Kvakina and M. A. Ukolova, Rostov Scientific Research Oncological Institute, RSFSR Ministry of Health, Rostov-na-Donu]

[Text] Among the biologically active environmental factors, under the influence of which life evolved, recently an important role is being attributed to GMF [geomagnetic field], the mediator between solar activity and the biosphere [48, 32, 16]. Magnetobiology has accumulated a large amount of information about changes in vital functions of the organism with both attenuation of GMF and geomagnetic perturbances, as well as under the effects of all sorts of artificial MF [magnetic fields].

What then is the nature of the general reaction of an organism as a whole to MF? The reactions to artificially enhanced MF are considered nonspecific, i.e., they can also be induced by other biologically active factors [43-47, 32, 7, 8, 26]. Moreover, we believe that this reactions are adaptive, since the organism adjusts to existence in a given MF with their help.

An organism adjusts to numerous stimuli by means of reactions to these stimuli. It would be difficult to imagine that there are just as many absolutely different reactions in the integral organism as there are stimuli. This suggests that there are not so many standard reactions. In this regard, of special interest is the thesis expounded by H. Selye in 1936 concerning the general adaptation syndrome (GAS), a "stress" reaction appearing standardly in response to the qualitatively most diverse, but potent, stimuli, or stressors [52-54]. H. Selye makes a distinction between three successive stages of development of stress: 1) anxiety reaction; 2) stage of resistance; 3) stage of depletion [exhaustion]. Signs of the anxiety reaction are quite noticeable 6 h after exposure to the stressor: involution of the thymus, increased weight of adrenals, leukocytes, lymphopenia, eosinopenia and appearance of ulcers in the mucosa of the gastrointestinal tract. There is intensification of ACTH secretion, which leads to hyperactivation of adrenocortical glucocorticoid function, impairment of correlation between glucocorticoids and mineralocorticoids in favor of the former, with depression of the thymolymphatic system, connective tissue and immunogenesis. At the same time, there is a decline of thyroid and reproductive gland functions. In other words, there is depression, rather than activation, of defense systems of the organism, of its inflammatory potential. At first glance, this may appear undesirable. Yet a response commensurate to a potent stimulus could be devastating as a result of an excessive inflammatory reaction.

The move to the second stage is associated with reorganization of the hormonal background: diminished secretion of glucocorticoids, there may be more intensive secretion of hypophyseal thyrotropic hormone (HTH) and development of hyperplasia of the thyroid. Nonspecific resistance is distinct at this stage.

If the action of the stressor is prolonged, the stage of depletion occurs: decrease in resistance of the organism and even death. Again, there is activation of endocrine mechanisms that characterize the anxiety reaction.

From Selye's description of the anxiety reaction, it is apparent that there is close interweaving of defense and injury. Such a response is biologically desirable only with exposure to an excessive and potent stimulus. The changes associated with the anxiety reaction make it possible to rapidly mobilize energy, even at the cost of injury, since the former is vitally needed in extreme situations.

Severe excitation develops in the CNS [central nervous system] under the influence of strong, escessive stimuli, followed by supraliminal inhibition which is an extreme defense measure. The biological expedience of this is reduction of excitability and reactivity. Attenuation of the defense reaction of the organism is effected via the endocrine system (increased secretion of ACTH, glucocorticoids) and autonomic branch of the nervous system.

At the present time, we observe a tendency to reduce to the stress reaction the reactions of the body not only to excessive, but any nonspecific stimuli. The theory of N. V. Lazarev concerning development of a state of nonspecific heightened resistance (SNHR), different from stress, that occurs physiologically in response to administration of certain pharmacological agents is an exception [24, 25, 33, 6].

Development of the stress reaction, in which defense is interwoven with injury, is biologically undesirable with exposure to mild and moderate physiological factors. Nevertheless, the reaction of diverse biological activity to MF is often equated with stress, regardless of MF parameters and duration of exposure. The influence of Selye's theory is so strong that if the change under the influence of MF does not fit into the concept of stress or even contradicts it, authors still try to attribute the changes they demonstrate to development of stress. Thus, activation of the reticuloendothelial system was observed in mice after long-term exposure to SMF [stationary magnetic fields] with intensity of 4200 Oe: lack of increase (even some decrease) in weight of adrenals, constriction of fascicular zone (instead of expansion during stress) and lack of increased corticosterone secretion, demonstrable both in blood plasma and the adrenals [50]. The authors called these changes "specific stress"; however, the concept of "specific" is incompatible with the concept of "stress," which reflects expressly nonspecific changes in the organism.

The foregoing does not mean that we consider it impossible to induce stress with MF. Like any stimulus raised to a certain level, MF can also be a stressor.

It was possible to obtain development of typical stress by means of MF, with reduction of the thymus, lymphopenia, increased secretion of glucocorticoids, decrease in mineralocorticoids, functional activity of the thyroid, reproductive glands, and development of trophic ulcers.

The question of significance of strength of stimulation to the nature of occurring changes was repeatedly raised in physiology. N. Ye. Vvedenskiy discovered the patterns of force relations: parabiotic phases related to a change in functional state of the reacting substrate. I. P. Pavlov and his disciples demonstrated that the conditioned reflex depends on the strength of a stimulus as the universal pattern of cortical activity [30, 31, 27a].

With increase in dosage (strength) of a factor, one observes three stages in the CNS reaction: preventive inhibition, excitation and secondary (supraliminal) inhibition [34]. The phase of initial depression is particularly typical of weak stimuli. The CNS appears to be protected by inhibition on two sides. Primary (preventive) inhibition protects the CNS against the effects of weak stimuli that are not significant to the organism. Secondary supraliminal inhibition protections the CNS from overstimulation, depletion and death.

Since factors of different strength induce different responses in the CNS, the reaction to them of the organism as a whole must also vary. Our studies revealed that at least three adaptational reactions can develop, depending on the force of the stimulus: 1) reaction to weak, threshold (for general reactions) stimulation (low doses), 2) reaction to moderately strong (dose) and 3) reaction to excessive, strong stimulation--stress. The reaction to a weak, threshold stimulus is called the "conditioning reaction" [39]. This name stresses the fact that any sort of training or conditioning is based on an adaptational reaction, which develops in time with repeated exposure to threshold stimuli and leads to greater resistance of the organism. In response to a stimulus of moderate force (dosage), there is development of another reaction, which is called the activation reaction [9], since stable activation of physiological defense systems is observed with it.

The above reactions differ from both stress and one another, with regard to the sets of changes in the nervous and endocrine system, metabolism, state of defense forces and nature of resistance; like stress, these reactions occur in stages. At the first stage of the conditioning reaction, the "orientation stage," there is concurrent increase in secretion of glucocorticoids and mineralocorticoids, some increase in thyroid and reproductive gland function, without depression of the thymolymphatic system. The thymus does not decrease in size, it is even somewhat enlarged during the entire first stage of the conditioning reaction. There are none of the other signs inherent in the first stage of stress: leukocytosis, aneosinophilia, leukopenia, neutrophilia and ulcers of the gastrointestinal mucosa. In the brain, there is prevalence of protective inhibition, with some decrease in excitability. By virtue of these changes, readiness to respond to the next stimulus is developed at the orientation stage.

Thereafter, with regular repetition of weak, threshold stimuli, there is development of the "reorganization stage," the essence of which consists of gradual change in correlation between glucocorticoids and mineralocorticoids in favor of the latter, and a change in metabolic processes to a lower, more economical level.

The "conditioned stage" occurs after the "reorganization stage." This stage is characterized by some prevalence of mineralocorticoids over glucocorticoids, increased function of the thyroid and reproductive glands. The thymus is enlarged. There are minimal energy expenditures and prevalence of anabolic type of metabolism.

An increase in nonspecific resistance of the organism is already noted at the first stage of the conditioning reaction, but at the conditioned stage there is more significant increase in resistance.

There is development of the activation reaction in response to moderate strength (dose) of stimulation, for which two stages are described [9, 10]. The biological sense of the activation reaction is to enhance the defense response to the stimulus, with which the organism can cope, unlike the case of an excessively strong stimulus, by increasing the activity of defense systems and which, at the same time, is no longer a weak stimulus. At the first stage, the "stage of primary activation," there is an increase in adrenocortical activity, mainly due to secretion of mineralocorticoids, increased function of the thyroid, sex glands, thymolymphatic system and connective tissue system. The thymus is considerably enlarged, not only in comparison to the anxiety reaction, but to the orientation stage, and it remains enlarged throughout the first stage of the activation reaction. The number of eosinophils is in normal range, the lymphocyte count is higher and that of neutrophils is lower than in the orientation phase. There are no ulcers or effusions of blood in the gastrointestinal mucosa. In the brain, there is prevalence of moderate physiological excitation. Good equilibrium of processes of anabolism and catabolism is observed at the stage of primary activation.

The stage of stable activation develops upon systematic repetition of moderate stimuli. The changes in the neuroendocrine system are analogous to those observed at the stage of primary activation. Activation of the thymo-lymphatic system and connective tissue system is also retained. Relatively stable function of these systems is maintained by phasic metabolic changes. There is more expenditure of energy than in the conditioning reaction and less than with stress.

With development of the activation reaction, nonspecific resistance of the organism increases faster and more significantly than with the conditioning reaction.

In order to determine the nature of general, nonspecific, adaptation reactions that develop with exposure to MF, we undertook a study of the same indices, on the basis of which GAS, SNHR, the conditioning and activation reactions were demonstrated, i.e., we examined the parameters of functional activity of the pituitary, adrenal cortex, thyroid and state of the thymus-lymphatic system.

We exposed the head of animals of SMF and VMF [variable magnetic fields] with intensities of 100-500 Oe, at a frequency of 0.03 and 1 Hz, obtained by eccentric rotation of permanent magnets and VMF at a frequency of 50 Hz in intermittent and continuous modes using the Polyus apparatus of the All-Union Scientific Research Institute of Medical Instrument Making [35]. We examined hormonal indices 6 h after 10-20 min exposure and once a week in the case of daily exposure for several (2-3) months.

After single exposure to SMF and VMF, there was no substantial change in levels of 17-hydroxycorticosteroids (17-HCC) in blood; blood serum sodium content did not change with exposure to SMF and increased with VMF; blood serum potassium was lower in both cases. These changes are an indirect indication of prevalence of mineralocorticoids over glucocorticoids. Examination of cellular composition of the hypophysis revealed that there was a substantial increase in gonadotrophs after exposure to VMF (9.5±0.3%, versus 5.4±1.0%,in the control), whereas the amount of acidophils and thyrotrophs remained in the normal range. The thymus became enlarged, particularly under the effect of 1 Hz VMF. Leukocyte count, percentage of lymphocytes, neutrophils and eosinophils with exposure to SMF did not differ from normal (the lymphocyte count being in the lower have of the normal range and that of neutrophils, in the upper half). With exposure to VMF (both intermittent, low-frequency, 50 Hz, and infralow-frequency, 1 Hz), there was also no significant change in total number of leukocytes and relative number of lymphocytes, but the percentage of lymphocytes increased with decrease in number of neutrophils (Table).

Concurrently with the increase in number of lymphocytes, there was an increase in blast transformation (43.7±4.2%, versus 22.0±3.3% in the control), which is indicative of activation of T lymphocytes.

Hyperplasia of the thymus indicates indirectly (in addition to the data on elevation of blood Na/K ratio) a prevalence of secretion of adrenocortical mineralocorticoids over secretion of glucocorticoids. This is also indicated by the relative lymphocytosis, which usually accompanies hyperplasia of the thymus.

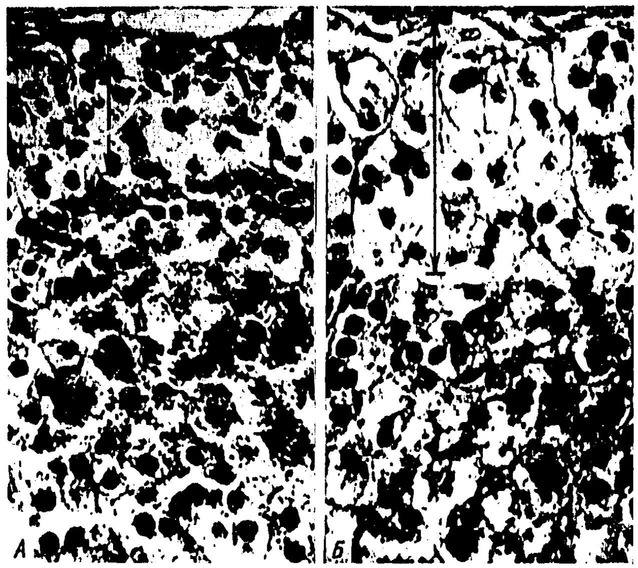


Figure 1. Sections of rat adrenals in the presence of stress (A) and activation reaction induced by VMF (Б). Staining according to Purvis and Grisbach; objective 40×, ocular 7×

Number of leukocytes, lymphocytes, neutrophils, eosinophils and weight of rat thymus after single exposure to SMF and VMF

Index	Control ($n = 25$)	SMF, 300 Oe ($n = 35$)	VMF, 300 Oe, 1Hz ($n = 25$)	VMF, 300 Oe, 50 Hz (intermit. $n = 27$)
	M±m	M±m, P	M±m, P	M±m, P
Leukocyte count	10720±705	11900±950 >0,2	11010±500 >0,2	11765±2340 >0,2
Lymphocytes, %	62±1,5	58±2,5 >0,1	73±1,5 ∠0,001	69±1,5 ∠0,005
Neutrophils, %	30±1,5	30±2,0 >0,2	22±2 ∠0,01	24±1 ∠0,005
Eosinophils, %	2±0,5	3,0±0,5 >0,1	2,0±0,5 >0,5	2±0,5 >0,5
Thymus weight, mg/100 g	133±5	206±8,5 ∠0,001	232±10 ∠0,001	180±22 ∠0,05

After numerous exposures to MF, there was no difference in 17-HCC level over a period of 1 month, as compared to the norm (5.14±0.62 µg%). Sodium content was elevated already after the first week of exposure and continued to rise for 2 weeks, more so in the case of VMF (135.2±0.88 µg%, versus 123.5±2.9 µg%, $P<0.005$). Potassium content was somewhat elevated, more so with the use of SMF (7.4±0.15 mg%, versus 6.0±0.1, $P<0.01$). Thus, the Na/K ratio was higher under the influence of VMF than SMF; consequently, with repeated exposure to MF the ratio of mineralocorticoids to glucocorticoids was higher under the influence of VMF. With exposure to SMF, although the ratio was somewhat lower, it was also indicative of prevalence of mineralocorticoids. This was also indicated by enlargement of the glomerular zone of the adrenal cortex and hypertrophy of cell nuclei (Figure 1). The weight of the thymus and percentage of lymphocytes were higher. Studies of these parameters for several months (with daily exposure to MF) revealed minor phasic changes. Protein bound iodine (PBI) content of plasma was equally increased after 1 week and 1 month of exposure to VMF (5.6±0.5 µg%, versus 2.6±0.15, $P<0.01$).

Functional and morphological studies revealed that there was an increase in number of thyrotrophs in the anterior lobe of the pituitary (9.6±0.4%, versus 3.2±0.9% in the control, $P<0.001$), in height and size of thyroid epithelial nuclei (12.1±0.1 µm, versus 8±0.7 µm, $P>0.001$ and 6.1±0.1 µm, versus 5.4±0.1 µm, $P<0.001$, respectively) [4]. Thyroxine uptake, determined 24 h after giving labeled thyroxine (^{131}I) (in doses of 1 µCi and 1.5 µCi/100 g weight) by tissues varied after exposure to SMF and VMF for 1 month. SMF did not alter thyroxine uptake and VMF increased it. There was a decrease in fixing of administered thyroxine in the tissues of the thyroid proper under the influence of both SMF and VMF, which is also indicative of increased hormonal activity thereof at this time (1 month) under the influence of both types of stimuli. Thus, as a result of exposure to the MF we used, thyroid function increased, whereas an increase is typical of the "stress" reaction, as we have already indicated.

Examination of the cellular composition of the hypophysis also revealed that not only an increase in thyrotrophs, but in gonadotrophs, is observed after numerous exposures to MF (Figure 2). There was no change in number of acidophils. It is known that a decline of gonadotropic function of the pituitary is observed in the presence of stress. The lack of changes in number of acidophils with exposure to MF also distinguishes the reaction induced by MF with the parameters tested from stress, since acidophils are considered to be ACTH producers.

Thus, the adaptive reactions induced by MF of the parameters used differed from stress, and they were characterized by hormonal changes, changes in morphological composition of blood inherent in the conditioning reaction in the case of exposure to SMF, and the activation reaction in the case of VMF [20, 19].

A special study of the reaction of the thymicolymphatic system to MF revealed signs of stimulation combined with hyperplastic processes [8].

Although, in the authors' opinion, these changes resemble the resistance stage of the GAS, to us it is important that, in essence, a different effect was obtained with VMF of relatively low intensity (200 Oe) and low frequency (50 Hz), with respect to the thymicolymphatic system, than in the case of stress: after 6 h there were no changes in the thymicolymphatic system, in particular, no involution of the thymus; after 12-24 h there were signs of irritation and by the 3d day there was development of proliferative processes.

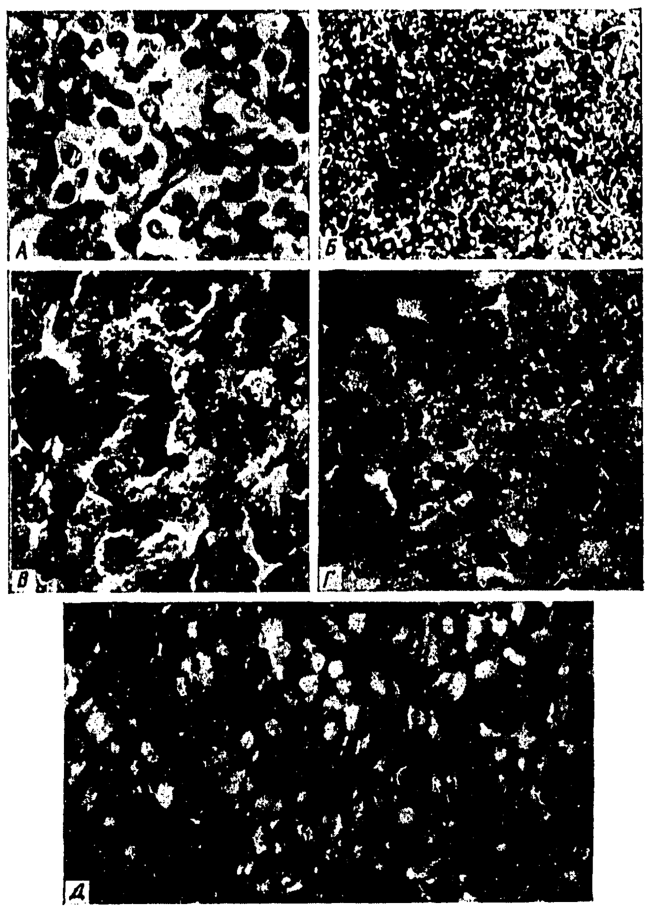


Figure 2. Sections of hypophysis of intact rat (А, Б) and after exposure to VMF (В, Г, Д)

The changes in the CNS also differed with exposure to SMF and VMF. SMF caused a decrease in excitability--30-40% elevation of thresholds of direct electrical stimulation, which is consistent with data on the predominantly inhibitory effect of SMF on the CNS [43, 26]. VMF of the same intensity led, on the contrary, to increased excitability (20-30% lowering of thresholds of stimulation, as compared to base levels) [18, 23].

The possibility of enhancing the excitatory process by VMF is of great interest, with regard to gaining understanding of the mechanism of action of MF. A special study of the nature of the effects of magnetic and electric fields on the CNS stressed the fact that with MF one could obtain only varying degrees of enhancement of inhibitory processes, whereas only the electric field could raise the level of excitability [51]. Thus, MF was described as a special stimulus, with inhibitory action on the CNS.

We believe that an explanation of the difference in directions of changes in excitability under the influence of SMF and VMF can be offered from the vantage point of MF being a nonspecific stimulus, on the basis of the pattern of action of nonspecific stimuli: nature (quality) of developing changes as a function of strength (quantitative measure) of effect on the organism. As we have already stated, development of a reaction of the CNS with three phases is typical of the effects of such stimuli, with increase in strength of stimulation: primary (preventive) inhibition, excitation and secondary (supraliminal) inhibition [34]. The effect of SMF is similar to the first phase of the reaction, the reaction to weak stimuli, while that of VMF resembles the second reaction to stimuli of a "moderate" force (dosage).

Although VMF increased excitability immediately after exposure, it dropped to the base level or lower in the intervals between daily exposures. One would think that intensification of the excitatory process occurred in the presence of a rather strong inhibitory process. According to [34], this is typical of stimuli of "moderate" force (dosage).

The obtained facts corroborate the conceptions found in the literature concerning the greater biological activity of VMF, as compared to SMF [38, 15 and others].

As was demonstrated by I. P. Pavlov, excitation and inhibition are two processes that interact constantly. For this reason, a stimulant such as caffeine, for example, strengthens cortical inhibition and has a tonic effect on the cortex in small doses, while bromide affects not only the inhibitory process but, in large doses, the excitatory process [27].

There are also morphological changes corresponding to the functional change in the brain under the influence of MF. Glioneuronal correlations are a fine indicator of the functional state of the CNS. Activation of neuroglia with change in glioneuronal correlations is considered a manifestation of a nonspecific adaptive reaction to weak stimuli [1]. Thus, a similar neuroglial reaction (especially of astrocytes) was observed in the cerebral cortex in the presence of all nonsupraliminal inhibitory states, including sleep inhibition [22, 1, 2]. Weak stimuli--small doses of toxic agents, low doses of radiation--induced activation of neuroglia in the cerebral cortex, whereas severe poisoning led to depression of neuroglia, associated with dystrophic changes and destruction of neurons. An increase in number of astrocytes, oligodendroglial and microglial cells varying in degree, depending on MF exposure, were observed under the influence of SMF [3]. Long-term, continuous exposure to SMF induced productive-dystrophic changes in the neroglia with dystrophic changes in neurons [46].

In our experiments with VMF, we also observed glial activation, mainly in the hypothalamus. The reaction of microglia and oligodendroglia was more marked, that of astrocytes was less marked. There was thickening and fragmentation of microglial cell processes with increase in number. The reactive changes in the microglia were diffuse, but more marked in the hypothalamus. The oligodendroglial changes consisted of appearance of markedly argyrophilic granules in the cell processes. Intensification of glioneuronal contacts was particularly typical, and it consisted of the fact that the nuclei of glial satellites were closely adherent to neuronal perikaryons (Figure 3), to the extent of accumulation of several satellites on one perikaryon [21].

Figure 3. Arrangement of satellite nuclei on the perikaryon surface of large neurons from the lateral hypothalamic nucleus of an animal with activation reaction and resorption of tumor following exposure to VMF. Staining according to Einarson; objective 100×, ocular 6.3×

With reference to neurons, there was hyperchromatosis of cytoplasm (when stained for RNA and tigroid), increased argyrophilia and hypertrophy of some neurons. The destructive changes typical of stress were not observed under the above experimental conditions. Thus, activation of neuroglia may characterize not only a state of protective inhibition, induced by weak stimuli, but a state of moderate excitation induced by moderate stimuli. Physiologically, this is justified, since restoration of metabolic resources of the neurons through the glia is necessary to maintain a state of active function.

The nature of the changes in the organism observed with various adaptation reactions determines their influence on the pro- and anti-inflammation potential of the organism. The first stage of stress has a very marked anti-inflammation effect. The use of glucocorticoids in the presence of various inflammatory processes is related to this. However, in view of the adverse effect of this stage of stress on the defense systems of the organism, glucocorticoids should be used with great caution.

The first stage of the conditioning reaction has a mild anti-inflammation effect without elements of lesion. The anti-inflammation effects of SMF and VMF, with parameters that induce development of the conditioning reaction, is related to the developing of this reaction.

The activation reaction increases the inflammation potential, so that it is desirable to induce this reaction for therapeutic purposes in the presence of pathological processes associated with a decrease thereof: neoplasms, chronic inflammatory processes with a sluggish course.

Each of the adaptation reactions affects the level of nonspecific resistance of the organism. However, the mechanism of enhancement of resistance varies. In the case of stress, the increase in resistance is obtained, as Selye himself indicates, at a high price: aside from elements of injury, stress is associated with great expenditure of energy and prevalence of catabolic processes. For this reason, the resistance stage (with exposure to a strong stressor) is followed by the depletion stage. During the depletion stage, the changes in the neuroendocrine system are similar to those of the anxiety reaction. However, there is gradual decline of the reaction level due to depletion of reserves. In our opinion, the change to the resistance stage is related to development in the brain, after exposure to a strong stimulus, of marked excitation at first, then supraliminal inhibition leading to decreased excitability. Against the background of diminished excitability, strong stimuli induce the responses inherent to moderate or even weak stimuli, rather than strong ones.

At the first stage of the conditioning reaction, there is some increase in resistance due to prevalence of protective inhibition in the brain and decreased excitability, i.e., resistance is passive. At the conditioning stage, which occurs only after numerous repetitions of weak stimuli, there is more significant increase in resistance of the organism due to a genuine increase in activity of the organism's defense systems, i.e., an increase in active resistance. At the first stage of the conditioning reaction, induced by various means including SMF, it is possible to obtain a protective effect against the deleterious influence on the organism of antineoplastic chemotherapy and radiation therapy [42, 17]. No influence on growth of experimental tumors was observed at the first stage. At the conditioned stage, a protective effect against antineoplastic chemopreparations and radiation was also obtained. Moreover, growth of tumors transferred to animals at the conditioned stage (after exposure to MF for 1.5-2 months) was inhibited to total resorption, i.e., at this stage of the conditioning reaction an increase was observed in antineoplastic resistance of the organism.

There is rapid increase in resistance with the activation reaction, and it is significant due to rapid stimulation of defense systems. For this reason, when it is necessary to increase resistance rapidly, preference should be given to this reaction. It was possible to obtain protection against toxic antineoplastic chemotherapeutic agents and radiation by inducing the activation reaction using different methods, including low-frequency VMF. Systematic maintenance of the activation reaction by means of numerous exposures to VMF of specific parameters led to inhibition of growth and total resorption of experimental tumors, both transferred and those induced by carcinogens [40, 17, 41]. In the cases where it was not possible to systematically maintain the activation reactions and animals often developed stress, there was even enhancement of tumor growth.

On the basis of the foregoing, we do not recommend the use of stress to enhance resistance for therapeutic purposes. The activation reaction is the most suitable for this. If it is necessary to obtain and anti-inflammation effect, one should first induce development of the conditioning reaction, and when the acuity of the inflammatory process regresses one can turn to the activation reaction.

Attribution of the mechanism of therapeutic effects of MF to development of systemic reactions does not rule out the role of local reactions in these effects. However, there are extremely convincing data indicative of the priority of systemic reactions over local ones. Thus, it was found possible to obtain a therapeutic response in patients with various pathological processes in the lungs from brief magnetization of the food in an SMF, which the author relates to stimulation of immunobiological activity of the organism [36, 37]. An optimum response was obtained in patients, whose blood changes were typical of the activation reaction: increased number of lymphocytes in peripheral blood. The author obtained analogous changes in experiments on albino rats with local exposure of the tail to the same MF. Proliferation of lymphoid tissue was also observed.

The results we obtained indicate that the antineoplastic effectiveness of MF, with local exposure of the tumor, does not differ appreciably from the antineoplastic efficacy of MF with direct exposure of the head. Thus, with the use of MF on the tumor, the number of animals presenting inhibition of tumor growth constituted 73.8%, and with exposure of the head to MF, the figure was 81%. The morphological changes associated with tumor resorption consisted of lymphocytic infiltration of the tumor, lysis of tumor cells and replacement of tumor tissue with connective tissue.

During resorption of tumors, regardless of point of application of MF, in the leukocyte formula we observed an increase in number of lymphocytes, decrease in segmented neutrophils and normalization of number of leukocytes. There was significant increase in weight of the thymus. Functional activity of the thyroid increased. There was a drop in blood plasma 17-HCC and potassium, enlargement of the glomerular zone of the adrenal cortex, and the condition of the thymicolymphatic system was indicative of prevalence of mineralocorticoid function of the adrenal cortex, over glucocorticoid function.

Thus, the changes occurring in the organism during tumor resorption, under the influence of exposure to MF of both the head and the tumor, were indicative of development of the general, nonspecific, adaptational activation reaction [41].

In view of the fact that magnetotherapy is being used more and more for the most diverse diseases, while the nature of MF (SMF, VMF, etc.), conditions and parameters thereof are often selected empirically, the possibility of deliberately inducing specific adaptation reactions with MF acquires special significance. Simple indices have been developed, that permit description of the developing reaction (according to morphological composition of formed elements of white blood) within 6-24 h after exposure [12, 13]. This makes it possible to operationally and flexibly alter the MF parameters or magnetization conditions for adjustment purposes, to obtain the desired changes. Thus, in the case of development of stress, the initial MF parameters--intensity or exposure time--should be reduced until the required reaction is obtained, and in the case of development of the conditioning reaction they should either be left unchanged if it is desirable to develop this reaction, or else increased until the activation reaction is obtained, etc.

Thereafter, a specific adaptation reaction should be maintained in the organism for a long time to obtain the therapeutic response. The experimental and clinical studies have shown that, for this purpose, it is necessary to regularly monitor the organism's response, since delivery of the same dosage (properly selected at the start) does not elicit development of the same (as initially induced) reaction. Moreover, both experimental and clinical studies revealed that numerous exposures to MF of the same intensity and with the same exposure time (VMF of 30 Oe, 50 Hz, delivered by a Polyus apparatus for 10 min daily) consistently lead to an undulant pattern of adaptation reactions, with prevalence of the one that was originally induced (Figure 4). Each reaction lasts for 1 to 3 weeks.

One cannot obtain stable maintenance of the same reaction in such cases, and the therapeutic response is not optimal, although it may be observed by virtue of the beneficial effect of MF at the time it induces (be it temporarily) the required adaptation reaction.

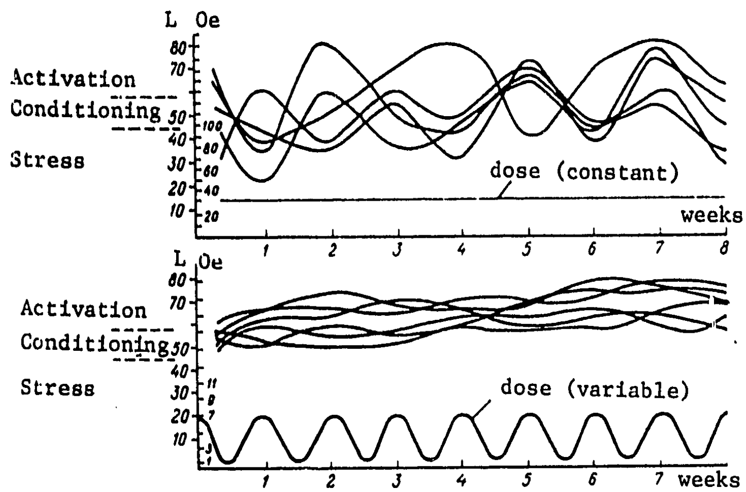


Figure 4. Course of nonspecific reactions in rats, with constant VMF parameters (top) and undulant changes therein (bottom). X-axis, time; y-axis, lymphocytes (L).

In order to maintain development of the same adaptation reaction, experiments were conducted with MF of varying intensity (Figure 4, bottom). After the initial selection of intensity and exposure time, we worked with those that induced the activation reaction. The MF intensity was then gradually decreased over a period of 1 week, then gradually increased over the next week to the original level. Blood tests were made at this time. It was possible to induce and maintain for a long time (3 months) the same reaction, the activation reaction, with such undulant change in dosage. Consequently, in order to maintain the adaptation reaction that is the most desirable in a given case, one should periodically (undulantly) alter the "dosage" of MF (with respect to either intensity and other field parameters, or exposure time).

Thus, with long-term use (repeated many times) of a stimulus of the same force (MF with the same parameters), different adaptation reactions appear in a living system, and they are related to the force of the excitatory and inhibitory processes in the CNS and correlation between them. A fluctuating (undulant) process of alternation of different reactions occurs. Conversely, in order to purposefully maintain a specific reaction, the dosage should be systematically altered in the direction of increase or decrease, which should also be fluctuating (undulant) in nature and adjusted in accordance with the organism's reaction.

APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000100030004-3

Understanding of the nature of correlation between dosage of treatment and the organism's response makes it possible to control the resistance level of the organism by means of MF as nonspecific stimuli for preventive and therapeutic purposes. Adaptation reactions can be used for theoretically substantiated and purposeful magnetotherapy.

However, the reactions of the organism to MF varying in biological activity are not limited to the three adaptation reactions. If only these reactions developed with increase in intensity (or exposure time), the last one being stress, further increase in excess of the stressor "dosage" should, according to H. Selye, lead to death of the organism. Conversely, with any decrease in dosage inducing the conditioning reaction, one should not observe any changes in the organism, since the dosage would become subliminal. However, this is not the case in reality. There is extensive material in the literature dealing with magnetobiology on the biological effects of MF over an enormous range of intensities, from fractions of an oersted to hundreds of thousands, and over an exposure time range of seconds to many months. Moreover, the changes in the organism are not so different with a wide range of intensities, exposure time and other parameters of MF, and they often fail to show an increase with increase in "dosage." Occasionally, weaker fields have a stronger effect than powerful ones [32, 29, etc.], and the same changes are observed with different intensities [14].

We succeeded in inducting the "activation" reaction with both low-frequency MF (0.03 and 1 Hz), 100-300 Oe and daily exposure for 10-20 min, and 50 Hz MF of 19-20, 5-7 and even less than 1 Oe, with daily exposure for 2 min (3 times for 40 s at a time, at 3-5 min intervals), and then even a negligible increase in "dose" with regard to intensity or exposure time led to development of stress in a number of cases. At the same time, the use of superstrong MF (40,000 Oe) failed to elicit any particular changes [5].

How then can we interpret all these facts, if we agree with Selye that an increase in magnitude of a stressor or duration of its action leads to development of depletion and subsequent death?

To examine this question, we tested on white rats the effects of MF with intensities of 1 to 300 Oe, delivered by the Polyus device of the All-Union Scientific Research Institute of Medical Instrument Making, with step-by-step 1.5-fold change in intensity in each experimental series. The current was sinusoidal, field frequency was 50 Hz and the field was intermittent (2 s field, 2 s pause). The developing adaptation reaction was evaluated by the correlation between formed white blood elements, number of leukocytes, weight of thymus and proportion of glucocorticoid and mineralocorticoid hormones of the adrenal cortex. MF were used daily for 2 min (3 times, 40 s at a time, 3-5 min intervals). The results revealed that there is a periodic succession of triads of adaptation reactions (conditioning, activation, stress) to the tested range of intensities, with a "zone of areactivity" between these reactions, within which the MF appears to be ineffective [11].

A comparison of adaptation reactions developing on different levels (of reactivity) revealed that the set of changes characterizing each of the reactions is similar in many respects. This explains the production of similar changes in the organism with different intensities of MF. At the same time, there are also some differences in level of hormone secretion and energy metabolism (studies conducted with M. N. Kondrasheva, Ye. I. Mayevskiy et al.). Further investigation of differences with the development of the same reaction on different levels of reactivity will make it possible to deliberately induce a specific reaction on a specific level of reactivity.

The possibility of development of stress with low intensities, of conditioning and activation reactions with high intensities enables us to comprehend why weak fields occasionally have a stronger effect than strong ones. The organism reacts on each level only to an increment of MF in relation to the "zone of areactivity," rather than the entire magnitude of MF.

Investigation of the nature of enhancement of resistance in the presence of the very same adaptation reactions developing on different levels also failed to demonstrate a substantial difference. Thus, A. I. Shikhlyarova was able to obtain increased antineoplastic resistance, to induce inhibition and resorption of tumors in about the same percentage ofcases by means of development of the activation reaction induced by MF of 1, 7, 30 and 200 Oe (with the same exposure time) [49]. Subsequent experiments even demonstrated the advantage of using low intensities for development of activation.

The "principle of periodicity," formed in the course of many centuries of evolution, with respect to development of adaptation reactions is a highly purposeful form of preserving homeostasis in the presence of a wide range of changes in environmental factors. Knowledge of this principle and use thereof will broaden substantially the possibilities of controlling resistance of the organism by means of MF.

BIBLIOGRAPHY

1. Aleksandrovskaya, M. M. "Adaptational Mechanisms in the Central Nervous System," ARKHIV PATOLOGII [Archives of Pathology], 30, 8, 1968, pp 26-34.

2. Idem, "Morphological Correlates of Functional Changes in the Central Nervous System, According to Results of Examining Glioneuronal Correlations," ZHURN. VYSSH. NERV. DEYAT. [Journal of Higher Nervous Activity], 19, 1, p 156 [no year given].

3. Aleksandrovskaya, M. M., and Kholodov, Yu. A. "Trace Reactions of the Cat Brain Neuroglia to Stationary Magnetic Fields," in "Tezisy dokladov soveshch. po izucheniyu vliyaniya magnitnykh poley na biol. ob"yekty" [Summaries of Papers Delivered at Conference Dealing With Effects of Magnetic Fields on Biological Objects], Moscow, 1966, p 3.

(FOUO 8/79)

1 MARCH 1979 EFFECTS OF NONIONIZING ELECTROMAGNETIC RADIATION 2 OF 2

4. Bordyushkov, Yu. N.; Gashnikova, L. I.; and Kvakina, Ye. B. "Reaction of the Endocrine System to Low-Frequency MF and SMF," in "Gigiyenicheskaya otsenka magnitnykh poley" [Hygienic Assessment of Magnetic Fields], Moscow, 1972, p 48.

5. Borodkina, A. G.; Petrovich, I. K.; Anashkin, O. B.; and Nakhil'nitskaya, Z. N. "Effects of Superhigh Intensity SMF on Morphological Composition of Peripheral Blood," TRUDY KIRG. MED. IN-TA (Frunze) [Works of Kirgiz Medical Institute], 100, 1974, p 78.

6. Brekhman, I. I. "Ginseng," Leningrad, Medgiz, 1957.

7. Vasil'yev, N. V. "Immunological Reactivity of the Organism to Immunization With Diverse Antigens," doctoral dissertation, Tomsk, 1968.

8. Idem, "Essays on the Role of Hemopoietic Tissue in Antibody Production," Tomsk, Izd-vo Tomsk University, 1975.

9. Garkavi, L. Kh. "General Nonspecific Adaptation 'Activation Reaction' Contributing to Organism's Fight Against Tumors. Problems of Clinical Oncology and Neuroendocrine Disorders in the Presence of Malignant Neoplasms," in "Trudy Rostovskogo nauch.-issled. onkologicheskogo in-ta" [Works of Rostov Scientific Research Institute of Oncology], Rostov-na-Donu, 1968, p 341.

10. Idem, "Adaptational 'Activation Reaction' and Its Role in the Mechanism of Antineoplastic Effect of Hypothalamic Stimulation," doctoral dissertation, Donetsk, 1969.

11. Garkavi, L. Kh., and Kvakina, Ye. B. "The Periodicity Principle in the Organism's Reaction to Magnetic Fields as a Nonspecific Stimulus," Mater. III Vsesoyuz. simp. 'Vliyaniye magnitnykh poley na biol. ob"yekty'" [Proceedings of 3d All-Union Symposium on "Effects of Magnetic Fields on Biological Objects"], Kaliningrad, 1975, pp 18-19.

12. Garkavi, L. Kh.; Kvakina, Ye. B.; and Ukolova, M. A. "Changes in White Blood Composition as a Criterion of Adaptation Reactions of the Organism to Magnetic Fields and Other Nonspecific Agents," TRUDY KIRG. MED. IN-TA (Frunze), 100, 1974, pp 23-25.

13. Idem, "The Role of Adaptation Reactions in Pathological Processes, and Simple Criteria of These Reactions in Man," in "Regulyatsiya energeticheskogo obmena i ustoychivost' organizma" [Regulation of Energy Metabolism and Resistance of the Organism], Pushchino, 1975, pp 172-182.

14. Gorshenina, T. I,, and Frumkis, A. E. "Morphological Characteristics of Effects of Variable (50 Hz) Magnetic Field of Low Intensity Under Experimental Conditions," TRUDY KIRG. MED. IN-TA (Frunze), 100, 1974, pp 84-86.

15. Dubrov, A. P. "Heliogeophysical Factors and Dynamics of Secretion of Organic Substances by Plant Roots," in "Problemy kosmicheskoy biologii" [Problems of Space Biology], Moscow, Nauka, Vol 18, 1973, pp 67-96.

16. Druz', V. A., and Madiyevskiy, Yu. M. "Effects of Stationary Magnetic Field and Low-Frequency Electromagnetic Fields on Hydration Capacity of Surviving Tissues," BIOFIZIKA [Biophysics], 11, No 4, 1966.

17. Kvakina, Ye. B. "Enhancement of Nonspecific Antineoplastic Resistance of the Organism by Means of Contact-Free Stimulation of the Hypothalamus," author abstract of doctoral dissertation, Moscow, 1972.

18. Kvakina, Ye. B.; Kotlyarevskaya, Ye. S.; and Kvakin, S. D. "Change in Hypothalamic Excitability Under the Influence of Magnetic Fields," "Mater. Vsesoyuz. soveshch. po izucheniyu vliyaniy magnitnykh poley na biol. ob"yekty" [Proceedings of All-Union Conference on the Effects of Magnetic Fields on Biological Objects], Moscow, 1969, pp 103-106.

19. Kvakina, Ye. B.; Nikolayeva, V. I.; and Ukolova, M. A. "Nature of Nonspecific Reaction of the Organism in Response to Long-Term Exposure to Low-Frequency VMF," in "Reaktsiya biologicheskikh sistem na slabyye magnitnyye polya" [Reaction of Biological Systems to Weak Magnetic Fields], Moscow, 1971, pp 122-123.

20. Kvakina, Ye. B., and Ukolova, M. A. "Various Adaptation Reactions, as Related to Force of Magnetic Field," "Mater. II Vseosyuz. soveshch. po izucheniyu vliyaniya magnitnykh poley na biol. ob"yekty," Moscow, 1969, p 107.

21. Kvakina, Ye. B.; Shibkova, S. A.; and Isadzhanova, S. Kh. "Morphological Changes in the Hypothalamus With Resorption of Tumors Under the Influence of a Variable Magnetic Field," VOPROSY ONKOL. [Problems of Oncology], 20, 1974, p 89.

22. Klossovskiy, B. N., and Kosmarskaya, Ye. N. "Functional and Inhibited State of the Brain," Moscow, Medgiz [no year given].

23. Kotlyarevskaya, Ye. S. "Investigation of Functional State of the Hypothalamic Region of the Brain as Related to Antineoplastic Effect of Magnetic Fields," author abstract of candidatorial dissertation, Rostov-na-Donu, 1974.

24. Lazarev, N. V. "Comparison of Nonspecific Defense Reactions Affecting Generalization of Infections and Metastases of Tumors," VOPROSY ONKOL., 11, 1962, p 20.

25. Lazarev, N. V., and Rozin, M. A. "Nonspecificity of Adaptation Reactions," in "Voprosy tsitologii i obshchey fiziologii" [Problems of Cytology and General Physiology], Moscow--Leningrad, 1960, p 137.

26. Luk'yanova, S. N. "Analysis of Central Nervous System Reaction to Stationary Magnetic Fields," candidatorial dissertation, Moscow, 1970.

27. Madieyvskiy, Yu. M. "Hydration Capacity of Tissues and Changes Therein in Vitro and in Vivo," doctoral dissertation, Moscow, 1968.

27a. Mayorov, F. P. "History of Teaching on Conditioned Reflexes," Moscow, Izd-vo AMN SSSR [USSR Academy of Medical Sciences]. 1948.

28. Mar'yanovskaya, G. Ya. "Mechanism of Central and Peripheral Effects of Magnetic Fields (on the Model of the Neoplastic Process)," author abstract of candidatorial dissertation, Rostov-na-Donu, 1974.

29. Muzalevskaya, N. I., and Larkina, T. A. "Change in Coagulation and Anticoagulation Systems of Albino Rats Under the Influence of Weak Variable Magnetic Fields in the Infralow Range of Frequencies Under Experimental Conditions," TRUDY KIRG. MED. IN-TA (Frunze), 100, 1974, p 90.

30. Pavlov, I. P. "The Problem of Sleep," in "Poln. sobr. soch." [Complete Collection of Works], Moscow--Leningrad, Izd-vo AN SSSR [USSR Academy of Sciences], Vol 3, 1951, p 409.

31. Idem, "Physiology of the Cerebral Hemispheres," Ibid, Vol 5, 1952, p 486.

32. Presman, A. S. "Electromagnetic Fields and Living Nature," Moscow, Nauka, 1968.

33. Rozin, M. A. "Nonspecifically Heightened Resistance Under the Effect of Some Pharmacological Agents," in "Nespetsificheskaya lekarstvennaya profilaktika i terapiya raka" [Nonspecific Drug Prevention and Therapy of Cancer], Moscow, Meditsina, Ch 2, 1966, p 21.

34. Simonov, P. V. "Three Phases of Reactions of the Organism to an Increasing Stimulus," Moscow, Izd-vo AN SSSR, 1962.

35. Solov'yeva, G. R., and Yeremin, V. A. "Experimental Device for Magnetotherapy," NOVOSTI MEDITSINSKOGO PRIBOROSTROYENIYA [News in Medical Instrument Making], No 3, 1971, p 53.

36. Stasyuk, G. A. "Substantiation of Clinical Use of Stationary Magnetic Fields," "Mater. Vsesoyuz. simp. 'Vliyaniye iskusstvennykh magnitnykh poley na zhivyye organizmy'" [Proceedings of All-Union Symposium on "Effects of Artificial Magnetic Fields on Living Organisms"], Baku, 1972, p 133.

37. Idem, "Dynamics of Some Morphological and Cytochemical Indices of Human Blood Leukocytes During Partial Magnetization of the Body," Mater. III Vsesoyuz. simp.," Kaliningrad, 1975, p 164.

38. Toroptsev, I. V. "Morphological Characteristics of Biological Effects of Magnetic Fields," ARKH. PATOL., No 3, 1968.

39. Ukolova, M. A.; Bordyukov, Yu. N.; and Garkavi, L. Kh. "General Non-specific Adaptation Conditioning Reaction Which Prevents Tumor Development in the Organism. Problems of Clinical Oncology and Endocrine Disorders in the Presence of Malignant Neoplasms," "Trudy Rostovskogo nauch.-issled. onkologicheskogo in-ta," Rostov-na-Donu, 1966, p 321.

40. Ukolova, M. A., and Kvakina, Ye. B. "Effects (Direct and Via the Nervous System) of Magnetic Fields on Experimental Tumors," in "Vliyaniye magnitny,h poley na biologicheskiye ob"yekty," Moscow, Nauka, 1971, p 147.

41. Ukolova, M. A.; Kvakina, Ye. B.; Mar'yanovskaya, G. Ya.; and Garkavi, L. Kh. "Central and Peripheral Mechanisms of Antineoplastic Action of MF," TRUDY KIRG. MED. IN-TA (Frunze), 10C, 1974, p 14.

42. Ukolova, M. A.; Kvakina, Ye. B.; and Rudoy, F. M. "Protective Effect of MF During Administration of Antineoplastic Chemotherapeutic Agents," "Mater. II Vsesoyuz. soveshch. po izucheniyu vliyaniya magnitnykh poley na biol. ob"yekty," Moscow, 1969, p 240.

43. Kholodov, Yu. A. "Effects of Electromagnetic and Magnetic Fields on the Central Nervous System," Moscow, Nauka, 1966.

44. Idem, "Direct Effect of Electromagnetic Fields on the Central Nervous System," doctoral dissertation, Moscow, 1967.

45. Idem, "Magnetism in Biology," Moscow, Nauka, 1970.

46. Idem, "Effects of Magnetic Fields on the Nervous System," in "Vliyaniye magnitnykh poley na biol. ob"yekty," Moscow, Nauka, 1971, p 124.

47. Idem, "Reaction of the Human and Animal Organism to Magnetic Fields," in "Problemy kosmicheskoy biologii," Moscow, Nauka, Vol 18, 1973, pp 143-163.

48. Chizhevskiy, A. I. "We and the Sun," Mir, Znaniye, 1963.

49. Shikhlyarova, A. I. "Possible Overdosage in Therapeutic Use of Weak Magnetic Fields," "Mater. III Vsesoyuz. simp.," Kaliningrad, 1975, p 170.

50. Barnothy, M. F., and Sumegy, J. "Effects of the Magnetic Fields on Internal Organs and Endocrine System of Mice," in "Biological Effects of Magnetic Fields," New York, Plenum Press, 2, 1969, p 103.

51. Becker, R. O. "The Neural Semiconduction Control System and Its Interaction With Applied Electrical Current and Magnetic Fields," "Proc. 11th Intern. Congr. Radiol.," 1965, p 1753.

52. Selye, H. "Thymus and Adrenals in the Response of the Organism to Injuries and Intoxications," BRIT. J. EXPTL. PATHOL., 17, 1936, p 234.

53. Idem, "Essays on the Adaptation Syndrome," Moscow, Medgiz, 1960.

54. Idem, "On the Level of the Integral Organism," Moscow, Nauka, 1971.

10,657
CSO: 8144

PSYCHOPHYSIOLOGICAL ANALYSIS OF NERVOUS SYSTEM REACTIONS TO MAGNETIC FIELDS

Moscow REAKTSII BIOLOGICHESKIKH SISTEM NA MAGNITNYYE POLYA in Russian 1978 signed to press 24 Feb 78 pp 167-177

[Article by Yu. A. Kholodov, Institute of Higher Nervous Activity and Neurophysiology, USSR Academy of Sciences, Moscow]

[Text] It is known from the history of magnetobiology that the first experiments in this branch of science were conducted on man [6]. Then animal experiments began to prevail, but we are no again witnessing a revival of interest in human magnetophysiology, since the results have a direct bearing on magnetotherapy and magnetohygiene. Theoretical hygienic research is being pursued the most intensively [2], and it includes investigation of human reaction time.

Human Reaction Time During Exposure to Magnetic Fields

It was shown in the comprehensive work of Yu. A. Ryabchuk [5] that most subjects presented an increased time of reaction to photic, sonic and tactile stimuli with exposure of the head to SMF [stationary magnetic field] or VMF [variable magnetic field] of 50 Hz and intensity of 100 Oe, i.e., an inhibitory process occurred in the CNS [central nervous system].

However, it is known that the hands are subjected to maximum influence of MF in the course of performing work [2]. We failed to find information in the literature concerning change in human reaction time in the case of local exposure of the upper extremity to MF, and for this reason decided to test the possibility of such an effect under experimental conditions.

The subject, who was in an isolated soundproof chamber, sat in a comfortable armchair (Figure 1). A solenoid (C_1), which we previously used in experiments on rabbits, was attached to the left arm of the chair, and a tumbler (K_2) was put on the right arm; the subject could use the latter to switch sound on or off (according to position of the key (K_1) controlled by the experimenter). Other keys (K_3 and K_4) controlled MF exposure time and localization, since a second solenoid (C_2) was put on the subject's head. A 1000 Hz sound was generated by means of a sound generator (SG) and dynamic loudspeaker (D), and concurrently a counter was switched on (CT) that measured time with accuracy of 0.001 s.

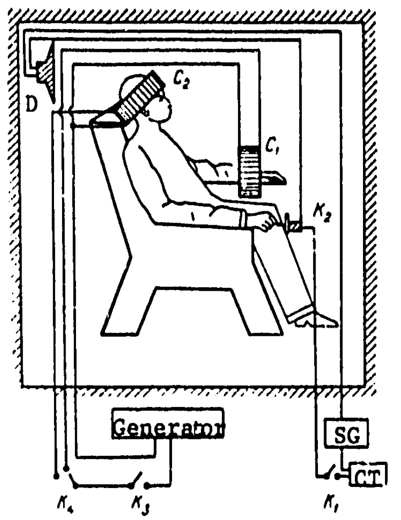


Figure 1.
Diagram of experimental set-up for studying the effects of MF on the human CNS. Described in the text.

The subject was instructed to press tumbler K as quickly as possible in response to sound. He thereby turned both the sound and counter off. The experimenter recorded the reaction time. The test was repeated after 30-60 s. The experimenter could turn on one of the solenoids for 1-2 min without being noticed by the subject, and then determine reaction time under the influence of the PMF [pulsed magnetic field] (most often at a frequency of 9 Hz) on different locations. The subject would report to the experimenter appearance of any sensations, if he related them to the suspected effect of PMF. The experiment lasted 10-20 min.

A total of 109 PMF stimuli were delivered to 15 subjects. The overall conclusion is that, in most of the subjects, PMF inhibited reaction time, and the most vivid effect was observed with the first few exposures to PMF. For example, reaction time changed from 337±7 to 407±22 ms ($P<0.01$) for the sum of the first 2 deliveries of PMF to subject E., i.e., it increased by about 20%. After discontinuing exposure of the hand to PMF, reaction time reverted to the initial level of 348±18 ms. Consequently, exposure of the hand to PMF of about 200 Oe and 9 Hz could reliably and reversibly extent the latency period of the motor reaction of the other hand.

Interestingly enough, exposure of the head to PMF altered reaction time to a lesser extent. While the subjects often guessed correctly the time of exposure (especially with the first few deliveries) in the case of PMF to the hand, the sensations occurred very seldom with exposure of the head. It is opportune to mention here that concurrent determination of reaction time to sound and possibility of sensation under the influence of PMF increased tension in the subjects, and we decided to conduct a separate series of experiments dealing with sensory indication of magnetic effects. Extensive experimental material is needed to derive comprehensive conclusions about the nature of changes in human reaction time under the influence of PMF, and we hope to accumulate it as a result of our subsequent investigations.

Sensory Indications of Magnetic Effects on Man

Experiments were conducted under the same conditions as in the preceding series of tests. The only difference was that the subject was instructed to press tumbler K_2 (Figure 1) upon appearance of a sensation in the region of the left hand or head. This turned on the loudspeaker, and the experimenter recorded the time of appearance of the sensation. Since our subjects very rarely reported a sensation with delivery of PMF to the head, we conducted the main part of the experiments with delivery of 9 Hz PMF to the hand. If the subject did not react to the PMF over a period of 60 s, the solenoid was switched off, and the experimenter recorded absence of reaction to PMF. If the sensation occurred sooner than 30 s after turning the solenoid on, the duration of the effect constituted half a minute (Table 1).

Table 1. Log of experiment (subject M., 30 October 1975); experiment started at 1127 hours and ended at 1139 hours.

PMF exposure time, h, min and s	Duration of signal delivery, s	Reaction latency period, s
11.28.30—29.00	28.55	25
11.30.00—30.30	29.40	29
	30.29	
11.31.30—32.30	—	—
11.33.30—34.30	34.25	55
11.36.00—36.30	36.29	29
11.37.00—38.00	37.35	5

In other words, the PMF functioned for no more than a minute and not less than 30 s. These conditions enabled us to separate the test time, which did not exceed 20 min, into 30-s intervals, and to describe each interval (regardless of whether the solenoid was on or off) according to presence or absence of reaction. The reliability of differences between "magnetic" and "nonmagnetic" intervals was evaluated with the criterion of Student for alternative variability. The calculations were made using the following formulas:

$$P_b = \frac{K_1 + K_2}{N_1 + N_2}, \quad (1)$$

$$\sigma = \sqrt{(N_1 + N_2) P_b (1 - P_b)}, \quad (2)$$

$$t = \left| \frac{N_2 P_b - K_2}{\sigma} \right|, \quad (3)$$

where N_1 is the number of 30-s intervals with exposure to PMF, N_2 is the number of 30-s intervals without PMF, K_1 is the number of signals with PMF, K_2 is the number of signals without PMF, P_B is the probability of appearance of signal provided that the intervals with and without PMF belong to the same set, σ is the standard deviation and t is the criterion of Student.

The results of experiments conducted on 6 subjects are listed in Table 2.

Table 2. Results of sensory indication of effects of pulsed magnetic field on left hand (6 subjects)

Subjects	Number of tests	Number of 30-second intervals		Number of signals		Relative frequency of signals, %		Student criterion
		with PMF	without PMF	with OMF	without PMF	with PMF	without PMF	
Kh.	16	267	207	16	10	6	5	0.05
R.	5	41	75	14	24	34	32	0,1
G.	5	32	80	14	24	41	30	0,1
E.	7	62	110	38	24	61	22	2,9
M.	6	88	185	59	38	67	20	3,6
V.	9	68	159	50	38	73	24	3,3

The results listed in Table 2 show convincingly that the first 3 subjects could not determine, with statistical reliability, the time of exposure to PMF, whereas the last 3 could reliably distinguish ($P<0.05$, when $t>2.0$) between intervals with and without PMF. Interestingly enough, the results for subjects E. and M. were similar.

There are radical differences that emerge between the two groups of subjects, one of which could be called "magnetosensitive." Incidentally, expressly in subjects E. and M. there was the most distinct change in reaction time to sound during exposure to PMF. The method of sensory indication of MF can be used for occupational screening of individuals who will have to be exposed to MF under industrial conditions.

Vague sensations, similar to pricking, cold, heat or heaviness of the hand, occurred after a certain latency period, which constituted 21.8±3.3 s for subject E. and 23.8±2.7 s for M. We see that these figures do not differ from one another.

A comparison of mean latency periods of human sensory reactions and rabbit EEG reactions (24.4±1.4 s, taken from the work of our graduate student, R. A. Chizhenkova [7]) indicates the similarity of central and peripheral mechanisms of action of MF on the organism.

The similarity of these reactions is even more demonstrable in the analysis of distribution of latency periods of reactions to MF (Figure 2). The three peaks in distribution of latency periods of sensory reactions to MF of subjects E. and M., and of the EEG reactions of rabbits to MF are indicative of similar dynamics of expression of effects of MF on different

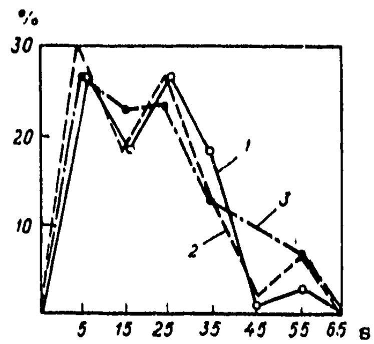


Figure 2.
Dynamics of latency periods of sensory reactions to MF in subject M. (1), subject E. (2) and EEG reaction of rabbits (3).

X-axis, time (s); y-axis, number of reactions (%)

biological systems. Determination of the causes of this similarity would permit wiser use in the future of magnetobiological effects for practical purposes. At any rate, the similarity of distribution of latency periods of human sensory reactions and rabbit EEG reactions lead us to expect that it will be possible to extrapolate to clinical practice the data obtained on the rabbit, on whom more extensive experimental interventions are feasible.

Changes in Rabbit Spontaneous EEG After Exposure of the Head to Pulsed Magnetic Fields

Of the seven biotropic parameters listed in the introduction, we selected for experimental analysis the frequency, pulse shape (sinusoidal and square wave) and localization of MF (on the CNS and peripheral parts of the body). In this series of experiments, only the animal's head was exposed to the field.

We took into consideration mainly the frequency characteristics of MF, and this determined the choice of methods of analyzing the EEG. We planned to evaluate the frequency spectrum of each EEG lead and coherence function between pairs of leads from different parts of the cerebral cortex.

The selected MF parameters implied in advance that the EEG could not be recorded during exposure due to induction, but the data in the literature, which were indicative of a prolonged magnetobiological aftereffect led us to expect that the information from the brain immediately after exposure would furnish an adequate amount of data about the reaction.

For these experiments, we outfitted a shielded, soundproof chamber for electrophysiological tests. We set up concurrent recording of biopotentials on an ink-tracing recorder and magnetic tape. In some cases, the biopotentials were fed directly into a Dnepr digital computer (Figure 3).

A waking rabbit, in whom nichrome electrodes were implanted epidurally in the cranial bones (4 or 6 electrodes, depending on the objective of the experiment), was immobilized with bandages around the paw to a wooden joint. The head was also secured sith bandages to a narrow ledge on the stand. The stand with the animals was put in the chamber.

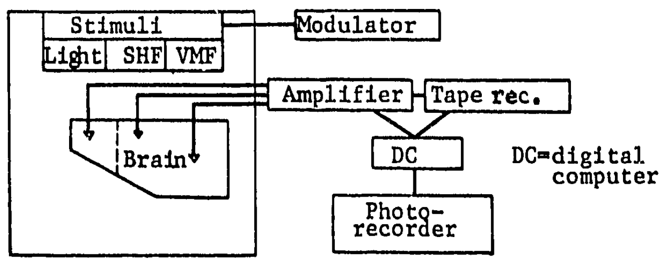


Figure 3. Diagram of experimental set-up for recording and processing biopotentials of the rabbit brain. Explained in the text.

A solenoid, with inside diameter of 150 mm and height of 60 mm, which was put on the rabbit's head, was used to generate MF. The solenoid was suspended on a cord and did not touch the rabbit or stand.

Sinusoidal current was fed to the solenoid by means of a low-frequency amplifier, which assured generation of the selected frequencies of VMF. To generate PMF, a VS-26 rectifier was used to power the solenoid by means of an electronic key controlled by an ESU-1 electrostimulator, which formed pulses lasting 90-100, 15 or 1.5 ms, depending on the frequency of delivery of pulses of 2, 5, 9, 50 or 500 Hz.

Measurement of MF intensity with a teslameter showed that it constituted 50 Oe in the middle of the solenolid and about 200 Oe at the coil. Consequently, we were using heterogeneous PMF with force line directed along the longitudinal axis of the body. No vibration was observed when the solenoid was on.

Exposure to PMF and VMF lasted 1-2 min (longer exposure caused the solenoid to heat up), and the interval between exposures constituted 15-20 min, which ruled out summation or adaptation processes in the rabbits' CNS.

In all, about 1000 deliveries of various MF and about the same number of background EEG's were recorded on 20 rabbits.

A comparison of results of computer processing of a 4-s segment of the EEG recorded before MF to the same EEG segment recorded 30-40 s after turning the solenoid off showed that slow rhythms in the delta range began to dominate in the cortical regions examined after exposure to PMF or VMF. This trend was more marked after the use of PMF at a frequency of 2 Hz.

The frequency characteristics of the EEG (Figure 4) of the visual cortex of the left hemisphere (A) and sensorimotor cortex of the right hemisphere (Б) of rabbit No 51 illustrate the above thesis well. While the background EEG (I) shows frequencies in both the delta and theta ranges, after use of 2 Hz PMF (II) delta rhythm began to dominate in both EEG's. Usually, such EEG changes were observed after exposure to any of the MF used, but in this experiment, after use of 5 Hz PMF (III), the stimulation rhythm began to dominate on the EEG (particularly in the sensorimotor cortex). Such "atypical" EEG changes, manifested by prevalence of theta frequencies after MF, were observed in only six experiments.

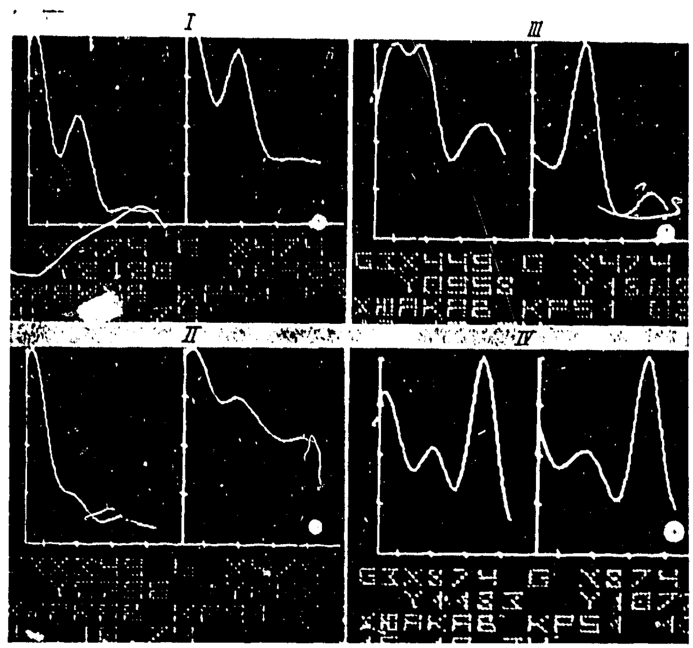


Figure 4. Curves of power spectrum of EEG of visual region of left hemisphere (A) and sensorimotor cortex of right hemisphere (Б) in the rabbit, background (I) and after exposure to PMF of 2 Hz (II), 5 Hz (III) and 9 Hz (IV).
X-axis, EEG frequency (Hz); y-axis, incidence of indicated frequencies in relative units.

A very unique result (IV) was obtained, when we observed a 9 Hz rhythm imposed by the stimulus after delivery of PMF of 9 Hz, and it appeared in 4 out of the 6 cortical regions recorded. However, this exception (the only one!) merely confirms the rule, according to which there is most often a nonspecific synchronization reaction, characterized by prevalence of delta rhythm on the EEG of the cortical regions studied, to exposure of the rabbit heat to PMF or VMF of the indicated parameters (as well as SMF, SHF field or moving MF generated by a GIMP generator), in all of the EEG leads.

Analysis of spatial synchronization of biopotentials of different parts of the cerebral cortex revealed that there was a decrease in coherence between biopotentials of the tested cortical regions in the theta range after exposure to various MF, as compared to the background EEG's.

More encouraging data were obtained when we compared the coefficients of correlation of biopotentials of the 4 regions of both cerebral hemispheres (Table 3) in rabbits Nos 61-64.

Table 3. Mean values of coefficients of correlation between bioelectric potentials of sensorimotor (1, 3) and visual (2, 4) regions of cerebral cortex of 4 rabbits and relative (%) change in these indices after exposure of the head to pulsed magnetic fields

Number of tracings	Treatment	Frequency, Hz	Pairs of leads					
			1–2	1–3	1–4	2–3	2–4	3–4
55	Background	—	0,686	0,733	0,603	0,588	0,614	0,502
33	PMF	2	–4,2	–4,7	–2,1	–1,1	–11,7	+6,9
44	PMF	5	+4,9	+5,4	+13,9	+17,6	+6,8	+29,8
29	PMF	9	+8,1	+12,9	+10,7	+11,3	–1,6	+27,8
18	PMF	50	+2,1	–29,4	–0,6	+2,2	+9,1	–19,9
8	PMF	500	+19,5	+26,0	+20,7	+36,2	+31,2	+51,2

The submitted results indicate that a finer analysis of bioelectrical potentials of the brain can demonstrate a certain specificity, against the background of predominant nonspecific reactions of the brain, which occur under the influence of any of the electromagnetic fields used.

It is important to stress that visual and computer processing of the EEG clearly indicates the prevalence of inhibitory processes in the CNS after exposure to MF, since prevalence of slow waves on the EEG, decreased coherence of theta rhythm and decline of coefficient of correlation are associated with sleep, extinction of conditioned reflex and development of inhibitory associations. The results listed in Table 2 suggest that with increase in frequency of PMF there is an increase in contribution of the excitatory process in CNS function.

For a reasonable hygienic assessment of MF, one must know the mechanism of onset of the inhibitory process in the CNS, which can lower the productivity of an operator's mental work. For this purpose, we broadened the plan of studies on animals, including in it experiments for determination of the effects of MF on processing of visual signals.

Investigation of Evoked Potentials in Rabbit Visual Cortex in Response to Flash After Exposure to Various Magnetic Fields

We selected a photic stimulus for analysis, since visual stimuli deliver most information to the mammalian CNS. Experiments were conducted on three rabbits. The methods of recording the EEG and delivering MF to the animal's head were described previously (see Figure 3).

Determination of parameters of the evoked potential (EP) in response to a 0.6 ms flash of light varying in brightness was made using the Dnepr digital computer. The retina of one eye was exposed to the flash (the flash was delivered to the retina after attachment of a blepharostat via a light guide, locally) 10 times before exposure to MF of the indicated parameters and 10 times after exposure. Averaged EP indices were recorded on photographic film and compared to one another.

In all, each of the 3 rabbits was exposed for 10 5-min periods to PMF of 2, 5 and 9 Hz, 19 times to VMF of 50 Hz and 16 times to SMF.

Figure 5 shows that after exposure to PMF (boldface line) there was no change in EP latency period (distance between the arrow and start of the first positive wave along a horizontal line). The amplitude and duration of components of the primary EP, positive phase (downward deflection), negative phase (upward deflection) and the next positive phase did not present changes in the same directions, although they did vary. It was found that the slow negative wave is the most labile index of EP. After exposure to the PMF, this wave had a tendency toward increase in both duration and amplitude. A similar type of EP change was observed after use of VMF and SMF. In other words, as in the case of analysis of the spontaneous EEG of the rabbit, the study of EP demonstrated the nonspecific aspect of the CNS reaction to various MF.

The second similarity in the series of studies we compared was that the increase in the slow negative wave corresponds to onset of inhibitory postsynaptic potentials in cortical neurons, i.e., prevalence of the inhibitory process in the CNS.

Discussion

The results submitted raise the question of similar effects on the CNS of reflex and central magnetic factors. True, the head was exposed to them in experiments on rabbits, while peripheral exposure involved experimentation with human subjects. However, G. Ya. Mar'yanovskaya [4] also mentions this similarity in her study on rats of the model of the neoplastic process under the central and peripheral effects of MF.

Consequently, under certain conditions, local, peripheral exposure to MF can demonstrate a response of the organism similar to the one induced under the direct effect thereof on the CNS. When analyzing this effect, one should make a more comprehensive study of the local reactions of the cutaneous

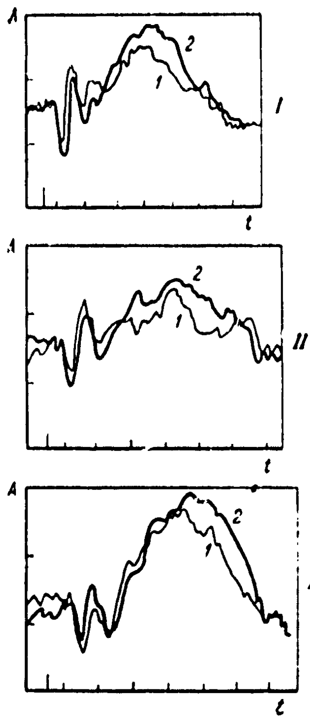


Figure 5.
Averaged EP of visual cerebral cortex of the rabbit in the background (1) and after PMF (2) of 2 Hz (I), 5 Hz (II) and 9 Hz (III). X-axis, time, 20 ms spacing; y-axis, amplitude, 200 mV spacing; arrow--flash of light

analyzer. Let us recall that the sensations occurring in man with peripheral exposure to MF are related expressly to the cutaneous analyzer. However, since MF has a penetrating action, it can directly affect sensory nerve fibers or composition of flowing blood (see this collection).

Recently, an interesting report was published [8] concerning the magnetic properties of the frog's sciatic nerve, which was attracted to the pole of a permanent magnet with intensity of 580 Oe after being suspended on a thread. Other frog tissues failed to demonstrate this effect. However, the frog's olfactory nerve and rat's peripheral nerve were also attracted to the magnet's pole.

Such magnetic properties of the nerve persisted after it was treated with distilled water, 10% table salt solution or formaldehyde, as well as after air-drying the nerve. The demonstrated effect disappeared only after soaking the nerve in chloroform or methyl alcohol solution.

It is assumed that phospholipids may be responsible for such unusual magnetic properties of nerves.

Another report [1] should be considered equally interesting; it deals with the change in nature of reaction of a fish central neuron with change in direction of MF. This fact could be interpreted as a specific nature of MF perception by electric fish, as well as difference in reactions of sensory and motor nerves to MF. It then becomes understandable why MF lowers sensitivity to a peripheral stimulus [6] but increases motor activity. A report has been published to the effect that a 4-fold increase in horizontal component of the geomagnetic field led to an increase in motor activity of 3 out of 12 salmon [9]. Similar exposure of birds also increased their motor activity and disrupted their orientation [3].

Determination of the causes of such individual differences is one of the pressing problems of neuromagnetobiology.

BIBLIOGRAPHY

1. Andrianov, Yu. N. "Electrophysiological Study of Functional Properties of Central Neurons of the Electroreceptor System of Fish," author abstract of candidatorial dissertation, Leningrad, 1975.

2. Vyalov, A. M. "Clinicohygienic and Experimental Data on the Effects of Magnetic Fields Under Industrial Conditions," in "Vliyaniye magnitnykh poley na biologicheskiye ob"yekty" [Effects of Magnetic Fields on Biological Objects], Moscow, Nauka, 1971, p 165.

3. Lutsyuk, O. B. "Experimental Studies of Orientation Behavior of Nocturnal Migrants Out of Doors and in the Planetarium," author abstract of candidatorial dissertation, Kiev, 1975.

4. Mar'yanovskaya, G. Ya. "Mechanism of Central and Peripheral Action of Magnetic Fields (on the Model of the Neoplastic Process)," author abstract of candidatorial dissertation, Rostov-na-Donu, 1974.

5. Ryabchuk, Yu. A. "Effect of Stationary and Variable 50 Hz Magnetic Fields on the Central Nervous System of Individuals Performing Operator Functions," candidatorial dissertation, Tomsk, 1975.

6. Kholodov, Yu. A. "Reactions of the Nervous System to Electromagnetic Fields," Moscow, Nauka, 1975.

7. Chizhenkova, R. A. "Investigation of the Role of Specific and Nonspecific Elements in Electric Reactions of the Rabbit Brain Induced by Electromagnetic, Ultrahigh Frequency and Superhigh Frequency, or Stationary Magnetic Fields," candidatorial dissertation, Moscow, 1966.

8. Kolys, P. "Strong and Permanent Interaction Between Peripheral Nerve and Constant Inhomogenous Magnetic Field," ACTA PHYSIOL. ACAD. SCIENT. HUNG., 43, No 1, 1973, p 89.

9. Varanelli, C. C., and McCleave, J. D. "Locomotor Activity of Atlantic Salmon Under Various Light Conditions and in Weak Magnetic Fields," ANIMAL BEHAV., 22, No 1, 1974, p 78.

10,657
CSO: 8144

UDC: 612.349.014.426

EFFECTS OF VARIABLE INDUSTRIAL FREQUENCY MAGNETIC FIELD ON FUNCTIONAL STATE OF THE THYROID AND THYROXINE UPTAKE BY RAT ORGANS

Moscow BYULLETEN' EKSPERIMENTAL'NOY BIOLOGII I MEDITSINY in Russian No 11, 1978 pp 544-546

[Article by N. A. Udintsev, V. Yu. Serebrov and G. I. Tsyrov, Department of Biochemistry (headed by Prof N. A. Udintsev), Magnetobiological Laboratory (headed by S. V. Taranov) and Clinical Radioisotope Laboratory (headed by Docent G. I. Tsyrov), Tomsk Medical Institute, submitted 25 Jan 78 (presented by N. V. Toroptsev, Academician of the USSR Academy of Medical Sciences)]

[Text] A study was made of uptake of ^{131}I by the thyroid and of thyroxine by tissues of several organs, as well as protein-bound iodine (PBI) content of blood plasma of albino rats exposed to variable magnetic fields (MF) of 200 Oe intensity at the industrial frequency for different periods of time and at different intervals. It was established that there is an increase in PBI in response to 15-min exposure. With increase in exposure time to 6.5 h and especially 24 h, the PBI level drops and there is a decrease in thyroxine uptake by tissues of the testes, heart, liver and spleen. In the case of multiple exposure to variable MF (up to 6.5 h a day for 5 days), there is a substantial increase in ^{131}I content of the thyroid, PBI level, whereas uptake of thyroxine by tissues diminishes significantly. It is assumed that thyroid function and the reaction of tissues to thyroxine change in accordance with the duration and frequency of exposure to MF (BYULL. EKSPER. BIOL., No 11, 1978, p 544).

Key words: variable magnetic field; thyroid gland; thyroxine.

The increasing use of devices that generate magnetic fields (MF) in industry and the national economy, and use thereof for therapeutic purposes in medicine make it necessary to conduct a comprehensive analysis of the biological effects of MF on man and animals. MF are stress factors [1, 6], in the adaptation to which the thyroid plays an important role [9]. However, its condition when exposed to variable MF has not been sufficiently studied.

Our objective here was to test the reactions of this gland and uptake of labeled thyroxine by animal tissues after exposure to variable MF of industrial frequency for different periods of time.

Methods

Experiments were conducted on 280 mongrel albino rats weighing 150-180 g, which were put in a variable 200 Oe, 50 Hz MF for 15 min, 6.5 and 24 h, as well as for 6.5 h per day for 5 days. We assessed the functional state of the thyroid according to uptake of ^{131}I 2-48 h after subcutaneous injection of 0.5 μCi of the isotope on a DSU-61 unit. We assayed PBI of blood plasma per milliliter of heparinized plasma by the method in [5] using a GAMMA instrument (Hungary--United States). Thyroxine-^{131}I (Institute of Nuclear Research, Poland) content, after hypodermic injection at the rate of 1 μCi/100 g weight, was assayed in the adrenals, heart, thymus, spleen, testes, hypothalamus, lymph nodes, liver and thyroid 24 h after injecting the thyroxine [8]. The isotope was given immediately after exposure to MF and there was 15-min exposure to MF after administration of the isotope.

The obtained data were submitted to processing with the use of the Wilcoxson-Mann-Whitney criterion [3].

Results

It was established (Table 1) that single 15-min exposure to variable MF raised appreciably the plasma PBI level; however, no marked accumulation of iodine in the thyroid was demonstrated; nor was there any change in uptake of thyroxine by tissues. Other researchers also observed a similar reaction in the thyroid [2].

It is known that the hypothalamus is the most sensitive to MF [7]. Increased ACTH synthesis was also observed under the influence of MF [11]. It may be assumed that stimulated secretion of hypophyseal thyrotropic hormone is the cause of activation of thyroid function.

Table 2 shows that with increase in exposure to 6.5 h and, especially, 14 h, a negligible decrease in iodine uptake by the thyroid is associated with a substantial decrease in PBI. In the case of exposure for 6.5 h, there is decreased thyroxine uptake by hepatic and spleen tissue, and in the case of 24-h exposure this also applies to tissues of the heart, testes and thymus. The cause of these changes may be hypoxia [10, 12], which develops under the influence of variable MF, in which there is inherent decrease in thyroid function [1].

A different response was demonstrated in the case of multiple exposure to variable MF (6.5 h per day for 5 days). Under these conditions, there was an increase both in iodine content of the thyroid and PBI level; however, uptake of labeled thyroxine was reliably diminished in virtually all organs examined (see Table 2).

Table 1. Effects of variable MF for different periods of time on blood plasma PBI in albino rats (M±m)

Time after exposure, h	Duration of exposure to variable MF							
	15 min		6.5 h		24 h		6.5 h/day for 5 days	
	control	exper.	control	exper.	control	exper.	control	exper.
	^{131}I uptake, % of given dose							
12	53,06±0,95	51,39±0,99	53,44±1,03	51,64±1,77	47,43±3,33	45,23±4,07	58,96±2,37	53,01±1,81*
	48,57±0,89	47,39±0,97	43,38±1,03	43,19±0,63	45,25±2,68	44,15±3,61	57,18±1,99	59,63±1,02
	Blood plasma PBI (per 10 mℓ)							
24	2,94±6,59	4,72±0,88*	2,68±0,32	1,69±0,16*	0,475±0,122	0,245±0,042*	1,48±0,49	2,02±0,31*
48	4,35±0,33	4,71±0,54	2,41±0,24	2,62±0,24	1,60±0,23	1,57±0,31	3,04±0,62	3,41±0,53

* $P<0,05$.

Table 2. Thyroxine-^{131}I uptake by organ tissues (% given dose per 1000 mg organ weight) (M±m)

Organs examined	Duration of exposure to variable MF					
	6.5 h		6.5 h/day, 5 days		24 h	
	control	experiment	control	experiment	control	experiment
Testes	0,0953±0,0095	0,0898±0,0069	0,1394±0,0141	0,1141±0,0068*	0,1162±0,0101	0,0813±0,0021*
Adrenals	0,337±0,061	0,252±0,064	0,520±0,127	0,365±0,084*	0,569±0,102	0,498±0,031*
Heart	0,0959±0,0057	0,0935±0,0056	0,2589±0,0274	0,2034±0,0077*	0,2073±0,0193	0,1816±0,0211*
Liver	0,231±0,021	0,222±0,022*	0,640±0,046	0,385±0,026*	0,322±0,023	0,261±0,015*
Spleen	0,0693±0,0045	0,0563±0,0041*	0,129±0,012	0,108±0,007*	0,132±0,011	0,093±0,006*

* $P\leq0,05$.

Note: Data for the hypothalamus, thymus and lymph nodes, as well as for 15-min exposure to MF are not submitted because they are unreliable.

The results of these studies warrant the conclusion that variable MF (200 Oe) of industrial frequency has a substantial effect on thyroid function. The correlation between ^{131}I uptake by this gland, PBI content of plasma and degree of uptake of thyroxine by tissues changes according to duration and frequency of exposure to variable MF.

BIBLIOGRAPHY

1. Vasil'yev, G. A.; Medvedev, Yu. A.; and Khmel'nitskiy, O. K. "The Endocrine System in the Presence of Hypoxia," Leningrad, 1974.

2. Garkavi, L. Kh.; Kvakina, Ye. B.; and Ukolova, M. A. in "Regulyatsiya energeticheskogo obmena i ustoychivost' organizma" [Regulation of Energy Metabolism and Resistance of the Organism], Pushchino-na-Oke, 1975, p 172.

3. Gubler, Ye. V., and Genkin, A. A. "Use of Nonparametric Statistical Criteria in Biomedical Research," Moscow, 1973.

4. Degen, I. L. VRACH. DELO [Medical Record], No 3, 1971, p 124.

5. Idem, KLIN. KHIR. [Clinical Surgery], No 3, 1971, p 75.

6. Kvakina, Ye. B., and Garkavi, L. Kh. in "Fiziko-matematicheskiye i biologicheskiye problemy deystviya elektromagnitnykh poley i ionizatsii vozdukha" [Physicomathematical and Biological Problems of Effects of Electromagnetic Fields and Air Ionization], Moscow, 1975, p 52.

7. Kotlyarevskaya, Ye. S. "Investigation of Functional State of Hypothalamic Region of the Brain Under the Antineoplastic Effect of Magnetic Fields," author abstract of candidatorial dissertation, Rostov-na-Donu, 1974.

8. Mirkhodzhayev, A. Kh., and Rakova, V. A. PROBL. ENDOKRINOL. [Problems of Endocrinology], No 2, 1964, p 86.

9. Skebel'skaya, Yu. B. Ibid, No 1, 1963, p 111.

10. Udintsev, N. A.; Kanskaya, N. V.; et al. BYULL. EKSPER. BIOL. [Bulletin of Experimental Biology], No 6, 1976, p 670.

11. Udintsev, N. A., and Moroz, V. V. PAT. FIZIOL. [Pathological Physiology], No 6, 1976, p 72.

12. Khlynin, S. M. in "Biokhimiya ekstremal'nykh sostoyaniy" [Biochemistry of Extreme States], Chelyabinsk, 1977, p 24.

13. Yasnogorskiy, V. G. "Trudy Tsentral'nogo NII kurortologii i fizioterapii" [Works of the Central Scientific Research Institute of Balneology and Physiotherapy], Vyp 29, 1975, p 87.

10,657
CSO: 1870

PECULIARITIES OF DISRUPTIONS IN THE SELECTION REACTION IN RATS EXPOSED TO A MODULATED AND PERMANENT ELECTROMAGNETIC FIELD

Moscow UPRAVLENIYE POVEDENIYEM ZHIVOTNYKH in Russian 1978 pp 6-7

[Article by G. D. Antimoniy and G. K. Vasina, Institute of Normal Physiology, USSR Academy of Medical Sciences]

[Text] This study investigated the effect of an electromagnetic field (EMF) on the selection process by an animal of the reinforcement side in a maze. A comparison was made of the effect of modulated and non-modulated EMF and the nature of the restoration of the behavioral reaction in the days following irradiation. The experiments were conducted in a special automated maze. It was shown that the effect of the modulated EMF (80-100 V/m; 39 MHz) on the day of irradiation produces errors in the selection of the reinforcement side on an average up to 18% (d > 0.01). On the second day after irradiation a reduction in the number of erroneous reactions on the average to 11% (d > 0.01) occurred practically in all the animals. Further the number of erroneous reactions again rose to 15% (d > 0.01). In different animals the secondary rise in the number of errors in selecting the reinforcement side was traced from the third through the sixth day after single irradiation. In the following days of observations the number of erroneous reactions was continuously reduced, and by the eighth day all the animals had practically completely restored their ability to select the reinforcement side.

The effect of the non-modulated EMF with the same intensity of the field did not result in the appearance of erroneous reactions in selecting the reinforcement side either on the day of irradiation, or in the subsequent days.

In the intact trained animals there was a natural increase in the reaction time as the drinking motivation was satisfied. Here the total number of drinking reactions during the experiment averaged 30. Exposure to modulated EMF resulted in a considerable increase in the reaction time already after the animal had run 3-5 times to the drinking bowl. In addition, in animals during the irradiation with modulated EMF the total number of drinking reactions during the experiment was reduced on the average to 15 (d > 0.01). Exposure to non-modulated EMF, despite the complete absence of erroneous reactions, was also accompanied by a faster increase in the reaction time as compared to the intact animals, as well as a reduction in the total number of drinking reactions in the experiment on the average to 13 (d > 0.01). In the restorative period in the rats after exposure to modulated EMF the number of drinking reactions during the experiment practically approached that of the intact rats, however the time of the actual reaction increased from the first approach of the animals to the drinking bowl.

9035
CSO: 1870

REACTION OF DROSOPHILA TO ELECTRICAL FIELD

Moscow UPRAVLENIYE POVEDENIYEM ZHIVOTNYKH in Russian 1978 pp 13-14

[Article by V. M. Afonina and V. B. Chernyshev, biological department of Moscow State University]

[Text] It can be hypothesized that insects perceive the electrical field as the force of interaction between the charge of their body and the surroudning field (Chernyshev, 1975). A scan of the soil surface from the fields revealed a pronounced accumulation of small insects in this zone (Tshernyshev, Ershova, Tikhonova, Shakhanova, 1973).

Edwards (1960) showed that drosophila can react to an artificial electrical field by stopping movement. We studied this reaction of drosophila (Drosophila melanogaster) and drew the following conclusions. The percentage of individuals reacting to the field is directly proportional to its intensity. The minimum potential at which a reaction was still observed--2 volts per 1 cm. The natural gradient of the atmospheric potential is altered in the interval approximately from one to hundreds of volts per centimeter. Consequently, drosophila react to an increase in the gradient of the potential (usually occurring before bad weather) by a reduction in activity, and most likely, withdrawal to shelter. The higher the air humidity promoting the escape of the body charge ofthe insect, the lower the level of its reaction. However, with relative air humidity below 30%, which clearly goes beyond the limits of the norm for drosophila, the reaction to the electrical field is reduced to zero.

The level of reaction is always higher in the variable field than in the permanent; it is especially high with frequency of changes in the field--10 Hz. Apparently, the strength of the interaction of charges can be perceived through oscillations in the setae on the body of the drosophila or extremities, including the wings.

Besides these relationships, we observed a variability in the level of the reaction that is difficult to explain. With the standard experiments for almost two summer months on individual days the reaction dropped almost to zero, or was raised almost to 100%. We add that in the city laboratory the level of the reaction was, as a rule, considerably lower than in the rural locality. In winter the flies were practically insensitive to the field.

No correlation was observed between the reaction level and the natural changes in ionization and electrical conductivity of the air and the level of electromagnetic oscillations of atmospheric origin. An artificial rise, as well as decrease in the level of these factors in natural limits did not affect the reaction of drosophila to the electrical field. The reaction level of the drosophila also was not linked to atmospheric pressure and the turbulence of the geomagnetic field. We succeeded in showing experimentally that the artificially created weak subsonics of frequency 0.1 and 16 Hz reduces the level of the drosophila reaction to the electrical field on the average by 40%.

9035
CSO: 1870

UDC 612.014.43/46

SPECIAL CHARACTERISTICS OF THE INTERACTION OF ELECTROMAGNETIC FIELDS WITH BIOLOGICAL ENTITIES

Moscow OSOBENNOSTI VZAIMODEYSTVIYA ELEKTROMAGNITNYKH POLEY S BIOOB'YEKTAMI (Special Characteristics of the Interaction of Electromagnetic Fields with Biological Entities) in Russian 1978, pp 5-9

[Foreword by the editors, Professors B. M. Savin and G. A. Stepanskiy, and table of contents from book by V. M. Shtemler and S. V. Kolesnikov]

[Text] The problem of the biological effects of radio-frequency electromagnetic fields has become particularly urgent in recent years. As a result of the rapid development of radio communications, radar, and television, a considerable part of the earth's population is constantly exposed to electromagnetic radiation of the radio-wave range. The wide use of electromagnetic energy in the national economy, science, and medicine is accompanied by further increase in the number of persons exposed to hygienically significant levels of electromagnetic radiation with various characteristics: from quasistatic radiation to radiation of the optical band.

Devices which are sources of radio waves are extremely useful to man, however, when used without proper control, they create extremely high levels of radiation and can be hazardous to human health. This determines the special significance of problems of hygienic normalization of radio-wave radiation in solving problems of ensuring safe working conditions and environmental protection.

It should be noted that the Soviet Union is the first country in the world where the levels of radio-frequency effects were regulated by the government.

In recent years, international attention to the problems of the biological effects of electromagnetic radio-frequency radiation and its hygienic normalization has increased considerably. The formation of the International Committee on Nonionizing Radiation within the framework of IRPA (International Commission on Radiological Protection) is significant in this respect. The tasks of the committee include the analysis of the biological effects of various types of nonionizing radiation, as well as the development of recommendations for the maximum permissible levels of radiation and normative documents of international nature. Just since 1973, the time of the first large-scale international symposium "Biological Effects of Microwaves and Health Hazards," 15 international forums were held on various aspects of this problem.

The problem of the biological effects of electromagnetic radiation of the radio-wave range is one of the main divisions of the radiobiology of non-ionizing radiation, which is an independent area of scientific knowledge. It includes a number of scientific directions connected with the establishing of regularities in the responses of live systems to the effects of radio waves at various levels of their organization: subcellular, cellular, systemic, and the organism level.

Being engendered primarily by practical needs -- the necessity of preventing the unfavorable effects of this type of radiation on the human organism, as well as the interests of clinical medicine (particularly, physiotherapy) -- in recent years, it has been increasingly acquiring a heuristic importance, contributing to the discovery of the most intimate vital activity processes of the organism.

Although the first studies on the biological effects (therapeutic) of electromagnetic radiation of the radio-frequency range were done as early as the end of the last century, a systematic development of this problem was started only at the end of the forties.

At the present time, the bibliography on the problems connected with the biological effects of electromagnetic radio-frequency fields has several thousand titles. Nevertheless, a considerable part of them are descriptive in nature and deal chiefly with phenomenology. Only in recent years there has developed a definite tendency toward increasing the number of publications treating special characteristics of the absorption and distribution of the energy of electromagnetic fields in biological entities, and the investigation of the intimate mechanisms of their action, as well as the improvement of research methods and experimental techniques.

This collection was prepared by the members of the laboratory of electromagnetic radio-frequency waves of the Institute of Labor Hygiene and Occupational Diseases of the USSR Academy of Medical Sciences.

The surveys contained in it are dealing with three key aspects of the problem: its clinicohygienic aspects, effects of radio-wave radiation on the central nervous system, and biophysical aspects of the interaction of electromagnetic fields with biological entities.

The correct estimation of the hazards of radio-frequency radiation and extrapolation of the data of experimental studies conducted on animals in application to the human organism are possible only on the basis of the establishment of a strict interrelation between the incident energy and the energy absorbed by the biological entity, between the electromagnetic fields which are really acting (induced in the biological entity) and the biological effects occurring at that time. These problems are discussed in the first survey of the collection.

Until recently, very little was known about these problems. It is very recently that considerable progress has been made in this area, which has created the prerequisites for a more correct evaluation of the results of experimental studies. There is no doubt that the authors of this survey had a difficult task of making the problems of the interaction of the electromagnetic field with a biological entity accessible for broad sections of medicobiological specialists without resorting to the comparatively complex mathematical apparatus. The authors limited themselves to a minimal number of formulas which, at the same time, make it possible to perform practical computations extremely important in planning the experiments and analyzing the results of the studies.

The next survey analyzes the works dealing with the effects of radio waves on the activity of the central nervous system. It should be mentioned that the largest number of works published in recent years are dealing with this problem. This is quite understandable because the accumulated data indicate that the central nervous system is one of the systems of the organism which is the most sensitive to the effect of electromagnetic fields of the radio-frequency range, and changes in the indexes of its functional state are considered to be of decisive importance in substantiating the thresholds of harmful factors.

As has been mentioned above, the problems of hygienic normalization of radio-wave radiation have become particularly urgent in recent years. In this connection, the concluding survey, along with the discussion of the published data on the clinical manifestations of radio-frequency effects, gives information on the exposure standards adopted in various countries, modern approaches to the hygienic evaluation of factors, measurement methods, and levels of radiation to which people are exposed under industrial conditions and in everyday life. It should be mentioned that, in spite of the great importance of these problems, the number of publications treating them is rather limited, and most of them belong to Soviet authors.

It is notable that the number of works by foreign authors on the methodology of hygienic standardization is extremely limited in spite of the fact that it is in this problem that there are substantial differences both in the treatment of clinical changes connected with the effects of this factor, and in the exposure levels permitted by the standards of various countries.

This collection is intended primarily for scientists engaged in research on the problem of nonionizing radiation. However, it is believed that the materials contained in it will also be of interest for broader sections of medical and radio engineering specialists.

Contents

10,233
CSO: 8144

END