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BIOMEDICAL SCIENCES
(GUO 28/77)

EFFECTS OF NONIONIZING ELECTROMAGNETIC RADIATION

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EFFECTS OF NONIONIZING ELECTROMAGNETIC RADIATION

CONTENTS PAGE

CONTENTS (Continued)

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ARTERIAL PRESSURE AS RELATED TO EXPOSURE TO LOW-INTENSITY MICROWAVES AND HIGH TEMPERATURE

Moscow GIGIYENA TRUDA I PROFESSIONAL'NYYE ZABOLEVANIYA in Russian No 2, 1977 pp 17-20

[Article by M. N. Sadchikova, K. V. Nikonova, Ye. A. Denisova, G. V. Snegova, E. N. L'vovskaya and V. A. Soldatova (Moscow), Institute of Industrial Hygiene and Occupational Diseases, USSR Academy of Medical Sciences, submitted 25 Feb 76]

[Text] It was reported in numerous works of the 1950's and 1960's (Ye. V. Gembitskiy; N. A. Osipov; A. A. Orlova; N. V. Uspenskaya) that there are hemodynamic changes of a vagotonic nature, usually evaluated as specific reactions of the organism to radiowaves. Vagotonic vegetovascular reactions were demonstrated primarily with exposure to superhigh frequency (SHF) electromagnetic fields of the order of hundreds of microwatts per sq cm to a few milliwatts per sq cm. Several authors (E. A. Drogichina and M. N. Sadchikova; N. V. Tyagin; P. I. Fofanov and others) observed asthenic (neurasthenic) manifestations, vegetovascular changes related to increased excitability of the sympathetic branch of the autonomic nervous system, and lability of arterial pressure with a tendency toward hypertensive or hypotensive reactions in individuals exposed to SHF (microwave) electromagnetic radiation for long periods of time. There are indications of possible development of neurocirculary disorders of the hypertensive type under the influence of microwaves of up to hundreds of microwatts per sq cm in publications of the last few years (G. G. Lysina; V. P. Medvedev; M. N. Sadchikova and K. V. Nikonova, and others).

The objective of the present work was to study vascular tonus in individuals whose work involved exposure to low intensity microwaves. A total of 885 workers in the radio and electronic industries were submitted to a polyclinical examination; 353 people (275 men and 78 women) were in contact with microwave sources and 532 people (411 men and 121 women) made up the control group. We analyzed the data of preliminary and periodic physicals on the basis of outpatient charts. A total of 68 people were submitted to a comprehensive workup in the hospital. The subjects ranged in age from 24 to 49 years. Their occupations were as follows: adjusters, engineers, technicians, testers and fitter-electricians. Two groups were distinguished, according to working conditions. The first group consisted of 182 men (73.1% under 40 years old) who worked in the finishing ["vypusknoy"] shops of radar stations (RS) and the sections of adjustment of SHF units at enterprises of the radio industry who were periodically exposed to microwaves ranging from a few to hundreds of microwatts per sq cm. Duration of exposure in the course of a work shift varied, depending on the type of product involved. According to time studies conducted by I. P. Sokolova, it did not exceed 2-3 hours per day. Work tenure of most subjects (63.2%) was up to 10 years. High air temperature (up to 37-39°) and noise, within the range of permissible levels, were additional deleterious factors during work in radar booths. The work was not associated with marked nervous and emotional tension.

The second group consisted of 93 men (69.9% up to 40 years of age) who worked in sectors of adjustment of radiorelay equipment in the radio industry, and 78 women (52.6% up to 40 years old) who serviced the sectors of adjustment and tuning of electronic instruments in enterprises of the electronics industry. In this group of workers, the level of exposure to microwaves did not exceed 10 μwatt/sq cm. Work tenure ranged from 3 to 20 years, constituing up to 10 years for most men (65.6%) and over 10 years for most women (66.7%). In both groups, primarily the hands, head and top half of the body were exposed to radiation.

The workers in the control group, consisting of 411 men (72.7% up to 40 years old) and 121 women (81% up to 40 years old) were not exposed to any deleterious industrial factors.

The general clinical examination of the first, second and control groups of workers showed most of them to be essentially healthy (72, 80 and 87.6%, respectively), while the others presented signs of vegetovascular dysfunction. In 4 workers of the 1st group (47-48 years old), who had worked for a long time with exposure to microwaves, there were neurocirculatory disorders with critical course, which were evaluated as an occupational disease. We are submitting the results of measuring arterial pressure, submitted to statistical processing as related to sex, age, work tenure and working conditions. Arterial pressure was measured by the auscultative method of Korotkov in three positions (seated, standing and lying down) with determination of the reactions to physical loads in men up to 40 years of age in the 1st and 2d groups. The range of fluctuations of arithmetic mean level ($M \pm 1.5\sigma$) obtained in the following control age groups: 20-29, 30-39, 40-49 years, was used as the norm for arterial pressure indices. In the control age groups, systolic and diastolic pressure did not exceed the range of conventional standards, 140/90 mm Hg (WHO criterion for individuals 20-60 years of age, 1962).

When we compared (Table 1) the mean indices of arterial pressure in the 1st, 2d and control groups, we were impressed by the statistically reliable elevation of systolic and diastolic pressure in men of the 1st group, regardless of age. Arterial hypertension was the most demonstrable under the influence of a physical load. In this group, we also obtained a high degree of statistical reliability of incidence of deviations from normal, in the direction of elevation of systolic ($P<0.001$ and $P<0.01$) and diastolic ($P<0.01$ and $P<0.001$) pressure. The arterial pressure elevation was often associated with mild or moderate constriction of retinal arteris; retinal angiopathy was observed in 16.5±2.8% of the cases, whereas in the 2d group no statistically reliable changes in arterial pressure in the direction of elevation were observed, with the exception of systolic pressure in women 40-49 years of age.

Table 1. Indices of arterial pressure in workers dealing with microwave sources and in the control group

Group	Statistical index	Arterial pressure, mm Hg					
		systolic, at age of			diastolic at age of		
		20–29 years	30–39 years	40–49 years	20–29 years	30–39 years	40–49 years
Men							
Control	n	100	199	112	100	199	112
	M	113,9	115,8	121,0	69,8	70,8	71,1
	±m	1,20	0,90	1,30	0,90	0,77	0,83
	σ	12,0	12,7	13,8	9,00	10,9	8,78
1	n	31	102	49	31	102	49
	M	120,8	124,8	135,5	76,1	79,6	87,0
	±m	2,18	1,67	2,07	1,59	1,18	1,28
	σ	12,0	16,9	14,5	8,38	11,9	8,87
	P	<0,01	<0,001	<0,001	<0,001	<0,001	<0,001
2	n	19	46	28	19	46	28
	M	114,5	115,3	118,4	68,9	72,4	76,1
	±m	4,16	1,83	3,35	1,28	1,66	2,15
	σ	17,6	12,3	17,4	5,43	11,1	11,2
	P	>0,05	>0,05	>0,05	>0,05	>0,05	>0,05
Women							
Control	n	54	44	23	54	44	23
	M	111,2	113,9	122,6	69,9	72,6	76,9
	±m	1,49	2,57	3,87	1,19	1,54	2,21
	σ	9,85	16,8	18,2	8,66	10,1	10,4
2	n	13	28	37	13	28	37
	M	110,4	116,6	140,8	68,1	69,8	79,0
	±m	4,31	2,39	2,67	2,16	1,43	1,72
	σ	15,0	12,4	20,6	7,47	7,44	10,3
	P	>0,05	>0,05	<0,001	>0,05	>0,05	>0,05

Analysis of arterial pressure indices in the 1st and 2d groups of men up to 40 years of age (Table 2) revealed reliable changes in systolic and diastolic pressure in the 1st group with work tenure of 5 or more years. Pulse pressure remained within the normal range. Pressure asymmetry (20-30 mm) was demonstrated only in a few men over 40 years of age and with tenure of 15-20 years, mainly during sympathoadrenal crises.

Table 2. Indices of arterial pressure as function of work tenure

Group	Tenure, years	No of cases	Arterial pressure, mm Hg: systolic, M±m	systolic, P	diastolic, M±m	diastolic, P
Control		299	116,5±0,70		70,8±0,60	
1	До 5 5—9 10—14	50 57 17	121,1±4,41 125,4±2,30 134,7±4,53	>0,05 <0,001 <0,001	75,8±1,26 78,7±1,58 84,7±3,13	<0,001 <0,001 <0,001
2	До 5 5—9 10—14	21 26 16	114,0±3,25 114,0±3,03 116,2±3,29	>0,05 >0,05 >0,05	69,3±2,37 70,0±2,02 74,7±2,93	>0,05 >0,05 >0,05

Table 3. Indices of arterial pressure as function of working conditions

Group	work sector	No of cases	Arterial pressure, mm Hg: systolic, M±m	systolic, P	diastolic, M±m	diastolic, P
Control		311	118,4±0,69		70,9±0,59	
1	a b	27 17	130,0±2,21 138,9±3,48	<0,02 <0,001	83,3±1,72 85,0±2,09	<0,001 <0,0[illegible]

Thus, changes in arterial pressure of the hypertensive type were found in the 1st group of men exposed to microwaves of up to hundreds of microwatts per sq cm, high ambient temperature and noise within the range of permissible levels for long periods of time (5 or more years) and in women with long tenure (10-20 years) of work involving exposure to up to 10 μwatt/sq cm microwaves.

In order to define the role of noise in onset of hypertensive states, we analyzed (Table 3) the indices of arterial pressure in the 1st group of men 30-49 years of age, who worked in either sector (sectors a and b), as related to working conditions. Individuals who worked in the finishing shops (sector a) were exposed to microwaves, high ambient temperature and noise; those engaged in adjusting SHF units (sector b) were exposed to microwaves and high air temperature. Their tenure constituted 10-14 years.

Analysis revealed statistically reliable differences in systolic and diastolic pressure levels of workers in both sectors, as compared to the control group. We failed to demonstrate differences in arterial pressure of individuals working in the two sectors, so that we could rule out the role of noise in onset of arterial hypertension.

The obtained data indicate that future measures to improve working conditions should be implemented with due consideration of both the microwave and other factors of the industrial environment, and they must be considered when evaluating the health status of workers.

Conclusions

1. Changes in arterial pressure of the hypertensive type develop in workers of finishing shops of RS and adjustment sectors of SHF units under the influence of microwaves of up to hundreds of microwatts per sq cm and high air temperature.

2. The hypertensive states observed are related to work tenure and, apparently, the combined effect of microwaves and heat.

3. When implementing protective measures and evaluating the health status of workers, attention should be given to both low intensity microwaves and other factors of the industrial environment.

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REACTIVITY OF BONE MARROW MEGAKARYOCYTES IN ALBINO RATS EXPOSED TO MICROWAVE LOW-INTENSIVE ELECTROMAGNETIC FIELD

Kiev TSITOLOGIYA I GENETIKA in Russian No 1, 1977 pp 27-29

/Article by E. I. Obukhan, Scientific and Technical Institute of General and Communal Hygiene/

/Text/ Upon exposing an organism to SHF fields several researchers discovered impairments of the blood coagulation system (1-4). In other works widespread or localized hemorrhages in various organs (5,6) and thrombocytopoiesis of the peripheral blood (7,8) were noted. The changes that were found were apparently brought on not only by the direct effects of microwaves on the blood, but also to a considerable degree by the morphological and functional condition of thrombocyte-producing cells, i.e. megakaryocytes. But for the meantime the peculiarities of differentiation of bone marrow megakaryocytes during irradiation of animals with electromagnetic energy of the VHF band have not been clarified in literature.

Materials and Method. In order to study the reactivity of megakaryocytes at various stages of differentiation, for which morphological and functional criteria were chosen as indicators (Thrombocytogenesis under the activity of centimetric microwaves with 12.6 cm wavelength), albino pubescent rats of the Wistar strain were irradiated by a 'Luch-58' generator with irradiation frequency of 2375 MHz. Two series of test were run: single continuous irradiation with SHF energy at power density of 500 uW/cm^2 with six hours of exposition and intermittent irradiation for 3, 7 and 10 days with microwaves with a power density of 50 group of animals was examined after 16 and 24 hours, and 7 and 16 days, the second group after 3, 4, 10 and 14 days. The tests were repeated seven times. The rats were killed by means of displacing the neck vertebrae. Bone marrow was aspirated from the thigh bones. Smears were prepared and stained by the Pannenheim method. Smears of bone marrow from normal animals were stained at the same time.

Results of the Research and Discussion. The most substantial deviations of morphological and functional features of megakaryocytes (as compared with the norm) were found in rats receiving a single irradiation of VHF energy

(500 uW/cm^2). Thus, within 16 and 24 hours after cessation of the irradiation the majority of mature megakaryocytes were in a state of thrombocytopoiesis (Fig 1, see inset 1). In the control these megakaryocytes were complete. Their nuclei, as a rule, were arranged eccentrically, the oxyphylic, sometimes polychromatophylic, cytoplasm was filled with thrombocytes, the wholeness of the cytoplasmic covering was destroyed, with thrombocytes frequently arranged next to the maternal megakaryocytes. Large islets of thrombocytes, territorially united by cytoplasm, were often found in the smears, which indicates they were formed by means of clasmatosis. Normally such islets are very rarely observed. Some of the mature megakaryocytes were broken down within 16 and 24 hours and cessation of the irradiation. The cytoplasm of the disintegrating cells becomes oxyphylic and swollen. The nuclei are pycnotized, arranged eccentrically and removed from the cytoplasm. All ensuing stages of enucleation we observed: 4, 3 and 2 anuclear megakaryocytes. Sometimes the nucleus' exit is accompanied by 'blistering' of the cytoplasm. Under the effect of microwaves with power density of 500 uW/cm^2 reinforced (intensive) thrombopoiesis apparently takes place, accompanied by cellular exhaustion and a loss of life capacity. A megakaryocyte at the limit of 'exhaustion' continues to produce thrombocytes pinched into the shape of strands (Fig 2, see inset 1). The cytoplasm, deprived of a nucleus, is oxyphylic with fine, basophile granular surface. In 7 and 16 days after irradiation the number of mature megakaryocytes that are producing thrombocytes is significantly reduced. Destructive forms were not found in 16 days. Megakaryocytes at various stages of differentiation do not differ morphologically from their counterparts in the control.

An interesting aspect of megakaryocytopoiesis under microwave activity (both series of tests) is heightened megakaryocyte phagocytosis, most frequently observed in the case of single irradiation (500 uW/cm^2). Lymphocytes, normoblasts, mature granulocytes and erythrocytes, often completely filling the cell, are subjected to phagocytosis. The causes and significance of megakaryocyte phagocytosis are unclear. It is possible that the microwaves increase the permeability of the megakaryocytes' cellular membrane, facilitating the influx of phagocytosis products. It is also possible that the contents of absorbed cells are re-utilized by the megakaryocytes so some extent. A possible inter-relationship can be surmised between such phenomena as enucleation of pycnotized nuclei that have exhausted their function, phagocytosis, re-utilization of the nuclear material of phagocytosis products, which a mature megakaryocyte in a state of functional activity (thrombocytopoiesis) can maintain for some time. It is known that 'phagocytosis is a stereotype reaction that is involved in the most diverse processes in the course of an illness' (9). It is entirely possible that under the effect of SHF some of the megakaryocytes acquire the characteristics of macrophages, engulfing the disintegrating bone marrow cells. In the majority of cases, however, the products of phagocytosis are completely normal cells. It follows that the 'megakaryocyte-macrophage' explanation is not exhaustive: the biological significance of megakaryophagocytosis is linked with more profound intracellular transformations.

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As a result of irradiation (500 uW/cm)against a background of intensification of thrombocytopoiesis and megakaryocytophagocytosis simultaneous intensification of the proliferative activity of megakaryoblasts and that of megakaryoblasts and promegakaryocytes occurs. The frequent appearance of 3 and 4 poled mitoses of megakaryoblasts (fig 3, see 2nd inset) and islets of promegakaryocytes (2-4) in each islet), closely touching the cellular membranes and chiefly distinguisehd by size (volume of cytoplasm, number of nuclei), is observed within 16 to 24 hours after the effect of the reactor. Megakaryocyte islets are rarely found in the bone marrow of healthy animals and as a rule consist of two, and only in isolated cases, three cells. It follows that the significant increase in the number of 2 and 3 cell groups and the frequent appearance of 4-cell associations in the marrow can only be explained by the multiplication of promegakaryocytes from their original forms under the direct influence of super high frequently vibrations. Inasmuch as mitosis in promegakaryocyte islets has not been found by us, it can be assumed that the basic method of multiplication is amitotic; the diverse size and structure of the cells in each islet confirms this.

Under the effect of a SHF field with intensity of 50 uW/cm^2 (3, 7, 10 sessions) the destructive changes of megakaryocytes are expressed to a lesser degree. Clasmatosis of the cytoplasm and lysis of nuclei were observed only in rats with hemmhoraging in the bone marrow. Intensification of the functional (thrombocytopoiesis) and proliferative activity of megakaryocytes as compared with the control correlates with the increase of sessions of irradiation. It follows that the morphological and functional characteristics of megakaryocytes under the effect of a SHF electromagnetic field of the indicated intensities bear witness to the significant reactivity of the cellular elements of megakaryocytopoiesis. Reinforced thrombocytopoiesis and intensification of the proliferative activity of megakaryoblasts and promegakaryocytes should be assumed to factors of compensatory significance; the reinforcement of megakaryocytophagocytosis is apparently associated with changes of the biophysical and chemical properties of the cells during the process of irradiation, this phenomenon can be compensatory and adaptive.

Conclusions. Under conditions of single (500 uW/cm^2) and intermittent (50 uW/cm^2; 3, 7, 10 sessions) application of SHF energy (6 hours exposition) some megakaryocytes are destroyed; functional activity (thrombocytopoiesis) is reinforced as compared with the control with the greates expression in the case of single application.

Reinforcement of megakaryocytophagocytosis occurs at one and four days after exposure to microwaves (all variations of the tests).

Intensification of the proliferative activity of megakaryoblasts and promegakaryocytes occurs at 1, 4, 7, 14, and 16 days after cessation of SHF applications, which is evidence of the compensatory and restorative processes in the megakaryocytopoiesis system.

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CONTRACTION FUNCTION OF THE MYOCARDIUM IN PATIENTS SUFFERING FROM RHEUMATOID ARTHRITIS WITH MICROWAVE THERAPY (ACCORDING TO POLYCARDIOGRAPHY DATA)

Moscow VOPROSY KURORTOLOGII FIZIOTERAPII I LECHEBNOY FIZICHESKOY KUL'TURY in Russian No 1, 1977 received by editors 11 May 75 pp 65-68

/Article by P. I. Pokutsa, Dobromil'skiy Rayon Hospital, L'vovskaya Oblast/

/Text/ The fact of the heart's involvement in the pathological process in rheumatoid arthritis does not evoke any doubt now (Ye. M. Tareyev; A. I. Nesterov and Ya. I. Sigidin; M. G. Astapenko et al.).

Microwave therapy occupies an important place among the physiotherapeutic effects used in the treatment of patients suffering from rheumatoid arthritis. However, the mechanism of action of microwaves has not yet been clarified definitively.

According to the data in the literature, the contraction function of the myocardium improves under the effect of this factor (M. Yu. Alimova). At the same time, microwaves have a negative effect on the cardiovascular system, especially in individuals with heart pathology (A. N. Obrosov and coauthors; F. D. Vasilenko).

We attempted to clarify the effect of microwaves in patients suffering from rheumatoid arthritis on the contraction function of the myocardium by means of an analysis of the phase structure of the systole of the left ventricle.

A total of 65 patients (12 men and 53 women) were under observation. There were 8 patients aged 15 to 19, 29 patients aged 20 to 29, and 28 patients aged 30 to 40. A. N. Nesterov's and M. G. Astapenko's classifications were used during the diagnosis.

The articular form of rheumatoid arthritis predominated in 51 patients and the articular-cardiac form, in 14 patients. The exudative form was detected in 13 patients, the exudative-proliferative form, in 47 patients and the fibrous form, in 5 patients. First degree process activity occurred in 18 patients, second degree, in 37 patients and third degree, in 10 patients.

The disease lasted from 1 to 5 years in 29 patients, from 6 to 10 years, in 24 patients and more than 10 years, in 12 patients. Patients complained about stiffness in joints in the morning (48), unpleasant sensations in the heart area (31), dull, sharply constricting pains behind the breastbone (27) and difficult breathing and heart beating (19). In 51 patients the joints were swollen slightly and in 49, disfigured. Trophic changes in the skin were detected in 25 patients and muscle hypotrophy, in 32 patients.

On X-ray photographs of joints osteoporosis of bony epiphyses pronounced to a varying degree was observed in 61 patients, stricture of joint fissures in 48 patients, usuration of joint surfaces in 27 patients, subluxations in 2 joints and more in 8 patients, and joint ankylosis in 10 patients. In 17 patients the heart was dilated to the left up to 1.5 cm and in 22 patients the heart sounds were thudding. A systolic apex murmur was detected in 19 patients and an accentuated second sound on a pulmonary artery, in 13 patients.

In 29 patients ECG data indicated a disturbance in the intra-atrial and intraventricular conduction and in 21 patients, a change in the end part of the ventricular complex, primarily in the form of flattening and inversion of the T wave.

A change in the protein formula of blood serum in the form of α_2 and γ-globulin was noted in 52 patients, rise in the diphenylamine test indices, in 46 patients, rise in the antistreptolysin O titer, in 22 patients and the existence of C-reactive protein, in 53 patients.

To clarify the effect of microwaves on the contractility of the myocardium, the patients were divided into 3 groups almost identical in the stage of disease and process activity. The first group included 22 patients, who along with drugs (pyrazolone and quinoline preparations and salicylates) received the effect of 20-40 watt microwaves. The second group included 20 patients who received the same treatment, but the power of the microwave effect was 50-70 watts. The third group included 23 patients who received only drugs. The foci of chronic infection were disinfected in all the patients and all received therapeutic physical training.

The Luch-58 apparatus was used for microwave therapy. In the presence of a lesion of interdigital joints a cylindrical radiator of a 110 mm diameter was used and 2 to 5 joints were affected simultaneously. In the presence of a symmetrical lesion in large joints a rectangular radiator (300X90X90 cm) was used. Procedures with a gap of 7 to 8 cm lasting 10 to 20 min were performed in a day. The course of treatment consisted of 10 to 14 procedures.

Polycardiograms were recorded before the beginning and after the end of treatment. The phase analysis of the systole of the left ventricle was conducted according to Blumberg's method in V. L. Karpman's modification (1965).

For a comparison of the changes in the phase structure of the systole of the left ventricle under the effect of combined treatment 22 essentially healthy people no older than 40, in whose anamnesis there were no indications of previous diseases of the cardiovascular system, were examined.

When the average length of the phases of the systole of the left ventricle and interphase indices were compared, the following differences from the group of healthy individuals were detected in all the groups of patients before the treatment: lengthening of the period of tension due to both its constituent phases, shortening of the phase of expulsion and lowering of Blumberg's mechanical coefficient, the intrasystolic index, the initial rate of increase in intraventricular pressure and the average rate of ventricular emptying (see table). At the same time, a direct relationship between the activity of rheumatoid arthritis and phase changes in the heart activity was noted.

After treatment a positive dynamics of ECG indicators was observed--primarily in the form of improvement in the intra-atrial and intraventricular conduction and increase in the voltage of the T wave (in 14 patients of the first group, in 4 patients of the second group and in 10 patients of the third group). Deterioration of ECG data was noted in 6 patients of the second group: depression of the T wave and reduction in the voltage of the QRS complex.

During an analysis of the phase structure of the systole of the left ventricle shortening of the period of tension was noted in 17 patients of the first group and in 11 patients of the third group, lengthening of the period of expulsion in 19 and 9 patients respectively and increase in the mechanical coefficient and intrasystolic index in 17 and 13 patients respectively. These changes indicate a favorable effect of low power microwaves on the contractility of the myocardium. At the same time, lengthening of the period of tension in 18 patients and shortening of the period of expulsion in 16 patients (as compared with initial values) was noted in the second group after microwave therapy, which indicates a reduction in the contractility of the myocardium.

The initial rate of increase in intraventricular pressure and the average rate of ventricular emptying are of great importance for judging the contractility of the myocardium (V. L. Karpman, 1970). Under the effect of treatment these indices reached normal values in patients of the first and third group. In patients of the second group they were lowered, which indirectly indicates an unfavorable effect of high-power microwaves on the cardiac muscle.

Thus, disturbances in the contractility of the myocardium in patients were leveled under the effect of combined therapy with an inclusion of low power microwaves. This should be taken into consideration when prescribing microwave therapy, especially to patients with a visceral form of rheumatoid arthritis with a predominant heart lesion.

Change in the Phase Structure of the Systole of the Left Ventricle in Patients Suffering From Rheumatoid Arthritis (M±m)

(1) Показатель	(2) Группа больных									Здоровые (6)
	1-я (3)			2-я (4)			3-я (5)			
	до лечения (7)	после лечения (8)	P	до лечения (7)	после лечения (8)	P	до лечения (7)	после лечения (8)	P	
Сердечный цикл (9)	0,77 ± 0,027	0,93 ± 0,028	<0,001	0,79 ± 0,035	0,74 ± 0,056	<0,2	0,74 ± 0,032	0,81 ± 0,031	<0,2	0,83 ± 0,015
Фаза асинхронного сокращения (10)	0,07 ± 0,002	0,05 ± 0,002	<0,001	0,07 ± 0,003	0,08 ± 0,006	<0,2	0,06 ± 0,002	0,05 ± 0,002	<0,001	0,04 ± 0,002
Фаза изометрического сокращения (11)	0,06 ± 0,004	0,04 ± 0,003	<0,001	0,06 ± 0,004	0,06 ± 0,005	>0,5	0,05 ± 0,003	0,03 ± 0,002	<0,001	0,03 ± 0,003
Период напряжения (12) (17) с	0,13 ± 0,002	0,09 ± 0,002	<0,001	0,13 ± 0,005	0,14 ± 0,007	<0,2	0,11 ± 0,003	0,08 ± 0,003	<0,001	0,07 ± 0,007
» изгнания (13)	0,22 ± 0,004 (0,24 ± 0,003)	0,26 ± 0,005 (0,26 ± 0,004)	<0,001	0,23 ± 0,005 (0,24 ± 0,0061)	0,22 ± 0,004 (0,24 ± 0,004)	<0,1	0,23 ± 0,005 (0,24 ± 0,0061)	0,25 ± 0,009 (0,24 ± 0,0031)	<0,05	0,25 ± 0,003 0,25 ± 0,003
Механическая систола (14)	0,28 ± 0,005 (0,27 ± 0,007)	0,30 ± 0,007 (0,29 ± 0,005)	<0,01	0,29 ± 0,008 (0,27 ± 0,005)	0,28 ± 0,005 (0,27 ± 0,008)	>0,5	0,28 ± 0,007 (0,27 ± 0,009)	0,28 ± 0,009 (0,27 ± 0,007)	>0,5	0,27 ± 0,005 0,28 ± 0,004
Общая » (15)	0,35 ± 0,006 (0,32 ± 0,006)	0,35 ± 0,007 (0,34 ± 0,005)	<0,5	0,[illegible]6 ± 0,007 (0,[illegible]3 ± 0,004)	0,36 ± 0,005 (0,32 ± 0,006)	>0,2	0,34 ± 0,007 (0,32 ± 0,004)	0,33 ± 0,005 (0,33 ± 0,004)	<0,2	0,32 ± 0,006 0,32 ± 0,007
Диастола (16)	0,43 ± 0,037	0,52 ± 0,037	<0,5	0,[illegible]3 ± 0,028	0,38 ± 0,034	<0,1	0,40 ± 0,007	0,47 ± 0,003	<0,2	0,41 ± 0,025
Механический коэффициент Блюмбергера (18)	1,63 ± 0,066	3,00 ± 0,088	<0,001	1,64 ± 0,068	1,79 ± 0,114	<0,2	2,20 ± 0,006	2,91 ± 0,128	<0,1	3,19 ± 0,266
Внутрисистолический показатель, % (19)	78,57 ± 0,623	86,02 ± 1,529	<0,01	75,17 ± 2,152	78,57 ± 0,926	<0,1	82,17 ± 1,057	89,28 ± 0,979	<0,001	90,16 ± 1,247
Индекс напряжения миокарда, % (20)	36,50 ± 0,664	25,45 ± 0,588	<0,001	36,51 ± 0,875	38,88 ± 1,934	<0,5	32,91 ± 0,627	25,69 ± 0,128	<0,001	24,52 ± 1,110
Начальная скорость повышения внутрижелудочкового давления, мм рт. ст./с (21)	1269,46 ± 95,702	2180,0 ± 99,871	<0,01	1203,34 ± 102,165	1133,40 ± 96,864	<0,5	1577,00 ± 81,281	2342,50 ± 105,125	<0,001	1800,07 ± 117,434
Средняя скорость опорожнения желудочка, мл/с (22)	245,56 ± 2,781	284,92 ± 2,794	<0,1	264,40 ± 4,420	250,41 ± 6,256	<0,1	257,25 ± 3,513	264,87 ± 4,710	<0,5	292,67 ± 3,814
Время изгнания минутного объема, с (23)	16,43 ± 0,363	19,80 ± 1,205	<0,05	18,33 ± 6,233	18,21 ± 0,767	>0,5	17,52 ± 0,840	18,50 ± 0,655	<0,5	19,66 ± 0,508

Note. The proper magnitudes of phase indicators are presented in parentheses

/Key on following page/

Declassified and Approved For Release 2012/05/10 : CIA-RDP88B01125R000300120005-6

Key:

1. Indicator
2. Group of patients
3. First
4. Second
5. Third
6. Healthy
7. Before treatment
8. After treatment
9. Cardiac cycle
10. Phase of asynchronous contraction
11. Phase of isometric contraction
12. Period of tension
13. Period of expulsion
14. Mechanical systole
15. General systole
16. Diastole
17. Seconds
18. Blumberg's mechanical coefficient
19. Intrasystolic index, %
20. Index of myocardial tension, %
21. Initial rate of increase in intraventricular pressure, mm Hg/s
22. Average rate of ventricular emptying, ml/s
23. Time of expulsion of minute volume, s

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EFFECT OF DIFFERENT SHF ENERGY LEVELS ON THE FUNCTIONAL STATE OF THE BODY

Moscow VRACHEBNOYE DELO in Russian No 12, 1976 pp 113-116

[Article by Prof M. G. Shandala and Cand Med Sci M. I. Rudnev and S. I. Nozdrachev, Kiev Institute of General and Communal Hygiene imeni A. N. Marzeyev]

[Text] Research by hygienists showed that insignificant quantitative expression of a certain unfavorable factor that does not produce clinical manifestations of disease often promotes development of so-called nonspecific reactions. The reason research is urgently needed on various aspects of the biological action of low intensity stimuli is that effects such as these are especially typical of modern environmental conditions.

The goal of the present paper is to reveal specific features in reactions of the body depending on SHF [superhigh frequency] energy power flux density (PFD) and dose distribution with respect to time. In addition we were also interested in determining the intensity of the body's reactions in animals irradiated by different SHF field PFD while experiencing a functional load in an altitude chamber.

Selecting the research methods with a consideration for published data (3) and the probable mechanism of action of SHF energy, we tried to study indices which reflect the functional state of the body--bioelectric activity of the brain and heart, respiration frequency, intratissue circulation rate, intratissue temperature, tissue oxygen tension, and some water-salt metabolism data. A LUCh-58 generator was the source of centimeter-band SHF energy.

Moreover, considering that the reactions of a healthy and an ill body to the same effect have important significance to evaluation of harmful environmental factors, in our research we modeled the most frequently encountered pathological state--hypertension--in rats, and we took account of the indices of two animal age groups--sexually mature and sexually immature.

A functional load--hypoxic hypoxia, created in an altitude chamber--was used to reveal latent effects of the action of SHF energy on the body.

The animals were "raised" to an altitude of 8 km and maintained "there" for 20 minutes. Readings were taken prior to "ascent," at 3, 6, and 8 km altitudes, and then after 5, 10, 15, and 20 minutes at this altitude; readings were subsequently taken during "descent," at 6, 3, and 0 km, and upon recovery, after 5 and 10 minutes.

The experiments were conducted on rats and rabbits. The rabbits were divided into seven groups: 1--Control (intact animals), 2--animals irradiated by SHF energy with a PFD of 500 $\mu w/cm^2$ for 7 hours, and groups 3, 4, 5, and 7--animals irradiated by an SHF field with a PFD of 50 $\mu w/cm^2$ for 10 days, 7 hours per day. Among these, group 3 contained mature animals and group 4 contained immature animals; group 5 was subjected to analysis 1 month after irradiation was terminated; group 7 contained animals in which renal hypertension was reproduced; group 6 contained animals with renal hypertension not subjected to irradiation.

There were two groups of rabbits. Group 1--control (intact), and group 2--irradiated by SHF energy with a PFD of 500 $\mu w/cm^2$ for 7 hours.

Each group contained 10 animals. Weights were 220-250 gm for adult rats, 80-100 gm for immature rats, and 2.8-3.0 kg for rabbits.

Cerebral biopotentials were recorded from rats by needle electrodes implanted subcutaneously above the visual and motor areas of the brain with a spacing of 1 cm between them. Cerebral biocurrents were recorded from rabbits in the same way as from rats, except that the spacing between electrodes was 2 cm. The electroencephalograms were recorded by a 4EEG-3 ink-recording encephalograph. This instrument also recorded electrocardiograms and respiration frequency.

Intratissue circulation rate was determined with differential thermocouples. Oxygen tension in the tissues was recorded polarographically with exposed platinum electrodes. A TPEM-1 electronic thermometer was used to determine animal tissue temperature.

Among indices of water-salt metabolism, we considered daily diuresis, specific weight, concentration of hydrogen ions, titrational acidity, sugar, protein, chloride concentration, and the total chloride quantity in urine.

The research established that different body functions reacted in different ways to the selected factors. Imposition of a hypoxic load upon the animals permitted us to obtain additional data indicating specific features in the changes in functional indices during the period of recovery after irradiation.

We recorded differences in the functional parameters of the animals depending on the PFD of the SHF energy and the exposure time. Thus the experimental results indicate that body reactions exhibit changes of greater significance in response to single irradiation (PFD of 500 μw/cm^2 for 7 hours) than in response to fractional irradiation (PFD of 50 μw/cm^2, 7 hours a day for 10 days). These changes manifested themselves as more highly pronounced inhibition of hemodynamics, water-salt metabolism, and cerebral bioelectric activity.

An analysis of the research showed that the most significant changes in intratissue temperature were recorded from animals irradiated by an SHF field with a PFD of 500 μw/cm^2 for 7 hours (up to 33.0°C, $P<0.05$), and from animals with reproduced renal hypertension irradiated by a PFD of 50 μw/cm^2 for 10 days, 7 hours per day, while experiencing the dynamics of a hypoxic load (34.3°C, $P<0.05$). The reductions in the intratissue temperature of the animals indicate a corresponding change in the body's energy processes.

The most highly pronounced changes in frequency of respiratory movements in response to an SHF field were noted among animals with renal hypertension; after being irradiated by a PFD of 50 μw/cm^2 for 10 days their respiration frequency increased by 1.5 times over the control level ($P<0.05$). Simultaneously we observed faster respiration by animals after irradiation by a PFD of 500 μw/cm^2 for 7 hours and by a PFD of 50 μw/cm^2 for 10 days, 7 hours per day (group 3).

As a way of compensation, the frequency of cardiac contractions in rats experiencing a hypoxic load increased until an altitude of 6 km was reached, after which the frequency was observed to decline. The most drastic changes in cardiac contraction frequency were noted among animals irradiated by an SHF field with a PFD of 500 μw/cm^2 for 7 hours, and among irradiated animals suffering reproduced renal hypertension.

Published data also indicate a dependence of the extent to which cardiac activity changes are pronounced on the wave band and irradiation conditions (1,2).

Oxygen tension in the tissues of experimental animals subjected to irradiation by SHF energy increased over the control level. Thus when rats were irradiated by a PFD of 500 μw/cm^2 for 7 hours (group 2) the oxygen tension in the tissues was 68.2 mm Hg, which exceeded the pO_2 of intact animals by a factor of two ($P<0.05$). After animals were irradiated by an SHF field with a PFD of 50 μw/cm^2 for 10 days, 7 hours per day (group 3), once again the pO_2 increased to 61.3 mm Hg, significantly above the control level ($P<0.05$).

The tissue oxygen tension of rats normalizes 30 days after irradiation (group 5).

Oxygen tension in animals with experimental hypertension (group 6) was 46 mm Hg, which was significantly different from control. When rats suffering hypertension were irradiated by a dose of 50 μw/cm^2 for 10 days, 7 hours per day (group 7), the pO_2 increased even more ($P<0.05$). These data indicate differences in the reactions of an ill body and a healthy body to SHF field exposure.

The rate of intratissue circulation changes in response to SHF energy exposure, but significant differences were noted only in group 7. We should note that when hypoxia induced by an altitude chamber is employed, the intratissue circulation rate decreases more slowly in irradiated animals than in control animals.

Changes in relation to control were noted in the QRS complex of electrocardiograms recorded from animals in groups 2, 3, 4, and 7.

On analyzing cerebral bioelectric activity we revealed the most significant changes in animals of groups 2, 3, 4, and 7 ($P<0.05$). Cerebral biopotential amplitude increased somewhat in response to an SHF field, while frequency decreased. These deviations from control exhibited in the electroencephalograms of experimental rats were revealed during a functional load in the presence of hypoxic hypoxia (8 km, 20 minutes). They were most highly pronounced among animals in group 2 (500 $\mu w/cm^2$, 7 hours).

Data obtained on the effect of an SHF electromagnetic field on kidney function and water-salt metabolism indicated that daily diuresis, chloride elimination, and the acid-base balance are the most sensitive. The SHF energy PFD we worked with (50 and 500 $\mu w/cm^2$) have an inhibitory effect upon the water and salt eliminating function of the kidneys and upon excretion of free hydrogen ions. In addition to quantitative changes in these indices, we noted certain qualitative differences (arisal of moderate albuminuria) as the dose was increased. The quantitative and some qualitative changes in kidney function and water-salt metabolism are directly dependent upon the intensity of SHF radiation: The higher the PFD, the more highly pronounced are the functional changes.

All changes in the condition of the kidneys and in water-salt metabolism in response to an SHF field were reversible in our experiments, normalization occurring 30 days after irradiation was terminated.

On analyzing the effect of an SHF field on functional indices of the bodies of rabbits we found that these changes were unidirectional, similar to the situation we revealed in rats. However, the extent to which the changes were pronounced and the extent of their recovery were somewhat different depending on the animal species. The acquired data indicate general biological laws governing reactions of the bodies of different animal species to the effect of SHF energy. This provides the grounds for hypothesizing that the mechanism of action of SHF energy is comparable in different animal species.

The results of research on animals exposed to SHF energy permits the assertion that there is a significant decline in intratissue temperature, a decrease in the frequency of cerebral biopotential oscillations, an increase in tissue oxygen tension, and a rise in respiration frequency.

Application of a functional load--hypoxia--permitted us to additionally reveal functional changes in the body in response to dynamic external factors.

Tracing the changes in body indices depending on dose and time of exposure to SHF energy appeared interesting. In our research we compared these indices among animals irradiated by PFD of 50 and 500 $\mu w/cm^2$. Comparison of these data established that significant changes occur in indices describing intratissue temperature, the frequency of cardiac contractions and respiratory movements, tissue oxygen tension, and cerebral bioelectric activity when a functional load is employed. Changes of greater significance were revealed in animals subjected to a single exposure of SHF energy with a PFD of 500 $\mu w/cm^2$ (group 2), as compared to changes experienced in response to irradiation by a PFD of 50 $\mu w/cm^2$ 10 times (group 3).

On comparing data obtained from intact animals with data from animals in which renal hypertension was modeled, we revealed significant differences in the frequency of respiratory movements and cardiac contractions, tissue oxygen tension, and cerebral bioelectric activity.

Analysis of the recovery period following exposure to SHF energy demonstrated that the principal indices of the irradiated animals returned to control levels 30 days after irradiation (PFD of 50 $\mu w/cm^2$); when a functional load was employed we also recorded some differences in these indices, which indirectly attests to incomplete recovery of physiological functions during this period.

And so, the biological effect of the action of SHF energy was recorded in some indices describing hemodynamics, cerebral bioelectric activity, the cardiovascular system, the respiratory organs, thermoregulation, and water-salt metabolism. We were able to establish specific features in the reactions of a healthy body and an ill body dependent upon age, and to reveal the general laws governing biological action of SHF energy upon different animal species.

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EFFECTS ON THE ORGANISM OF BRIEF DAILY EXPOSURE TO LOW-FREQUENCY ELECTROMAGNETIC FIELDS

Moscow GIGIYENA I SANITARIYA in Russian No 4, 1977 pp 18-21

[Article by I. P. Kozyarin, Prof R. D. Gabovich and V. M. Popovich, submitted 7 Sep 76]

[Text] Experimental studies were conducted at the Kiev Scientific Research Institute of General and Municipal Hygiene for the purpose of hygienic evaluation of electromagnetic fields of industrial frequency (EMFIF) in populated areas; it was found that the threshold level of EMFIF is 2 kV/m in the case of constant 24-hour operation over a 4-month period, and it is 0.5 kV/m when inactive. At the same time our interviews revealed that different groups of people, who either perform different types of work in the area where there are power lines [or transmission] or who travel under them, can be exposed daily to rather intensive EMFIF but more briefly, usually from 10-15 min to 2 h per day.

In view of the foregoing, we made an experimental study on animals of the distinctive features of biological effects of EMFIF varying in voltage, in the case of brief daily exposure. We submit here the results of studies conducted with 2-h exposure.

This study was pursued on 200 white male rats, which were put in special cages with a simulated electric field of 50 Hz frequency generated by NOM-10 transformers. The first group of animals served as a control. The rats in the 2d group were exposed to fields of 1 kV/m for 2 h daily for 4 months; the 3d group to fields of 2 kV/m, 3d to 4 kV/m, 5th to 7 kV/m and 6th to 15 kV/m daily, for the same period of time.

The Table summarizes the results of studies conducted at the end of the experiment; we have submitted mainly indices with respect to which a marked and reliable difference was demonstrated between the control and experimental groups of animals. In the course of the experiments, we failed to record signs of deviations in behavioral reactions of experimental groups of animals as compared to the control, but toward the end of the experiment, we observed some change in color of pelage, which also developed small areas of alopecia, in the fifth and sixth groups of animals, as well as a reliable decrease in weight gain and efficiency (shorter time of swimming with a load corresponding to 10% of body weight).

Indices of animals' condition toward the end of the experiment

Index	Statistical index	Animal groups: 1st control	2d 1 kV/m	3d 2 kV/m	4th 4 kV/m	5th 7 kV/m	6th 15 kV/m
Animals weight, g	M	295,2	285,3	270,3	283,3	261,6	253,9*
	±m	10,7	11,5	14,0	11,1	10,1	10,7
Swimming test, min	M	6,8	6,5	7,3	6,6	3,9*	4,4*
	±m	0,4	0,9	0,9	1,2	0,3	0,9
Correlation between chronaxia of antagonist muscles (extensors to flexors)	M	1,9	1,6	1,6	1,6	0,5*	0,4*
	±m	0,2	0,2	0,2	0,1	0,08	0,04
Threshold summation index, V	M	11,7	11,2	11,7	12,0	17,3*	19,1*
	±m	0,5	0,3	0,5	0,4	0,2	0,1
Blood cholinesterase activity, μg/ml/min	M	130,8	127,3	128,6	128,6	134,5	150,2*
	±m	3,3	6,0	5,8	5,8	4,1	6,5
Maximum radioiodine uptake by thyroid, %	M	59,4	52,7	55,2	52,4	40,8*	47,2*
	±m	3,6	2,2	2,6	2,8	1,9	3,7
Blood glucose level, mg%	M	77,5	81,3	83,3	80,7	85,5*	86,7*
	±m	1,8	4,4	4,0	2,9	1,3	2,9
Blood residual nitrogen level, mg%	M	24,8	25,3	26,7	26,2	28,2*	30,3*
	±m	0,9	1,6	1,2	1,0	0,9	1,2
Blood urea, mg%	M	29,7	30,7	33,4	32,5	39,8*	40,5*
	±m	1,8	1,8	2,4	2,1	1,6	2,1

$^{*}P<0.05$.

Studies of physical condition of personnel servicing high-tension substations, pursued at the All-Union Scientific Research Institute of Labor Safety, revealed that individuals whose work involved exposure to EMFIF presented, first of all, changes referable to functional state of the nervous system, to which we devoted special attention.

With reference to indices of functional state of the nervous system, the earliest changes (in the 5th and 6th groups of rats, after the end of the 1st month of exposure) were referable to the threshold summation index and latency period of the reflex. The same animals presented a reliable decrease of the ratio between chronaxia of antagonis muscles of the crus (see Table). These changes were demonstrable after the end of the 2d month (6th group) and 3d month (5th group) of exposure, and they progressed thereafter. At first, the decline of ratio between muscular chronaxia was referable mainly to an increase in chronaxia of flexors. Then, along with increased chronaxia of flexors, we recorded a decrease thereof in extensors, which resulted in lowering the ratio index. In the opinion of Lapicque (the author of chronaxia theory), the differences in levels of antagonist chronaxia observed under normal conditions are determined by the influence of the nuclei rubri of the brain, the "subordination centers." For this reason, it may be assumed that the changes we demonstrated in chronaxia, in the 5th and 6th groups of rats, are related to weakening of subordinating influence of the central nervous system on the periphery.

On the whole, the nervous system changes described in experimental animals are indicative of impairment of dynamic equilibrium between excitatory and inhibitory processes in the cerebral cortex, with predominance of the latter.

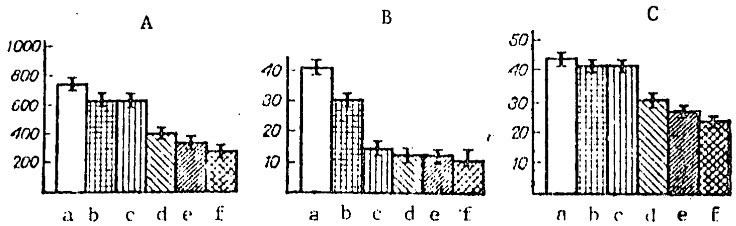
The increased blood cholinesterase activity in animals of the 5th and 6th groups may be indicative of impaired biochemical homeostasis, which implements stability of nervous processes.

A study of thyroid function revealed that, starting in the 3d experimental month, there was some depression of thyroid function in the 5th and 6th groups of animals, as indicated by decline of maximum uptake of ^{131}I (see Table). Consequently, neuroendocrine regulation of the organism also undergoes changes under the prolonged influence of EMFIF. This also affected metabolic processes to some extent. In particular, we observed elevation of residual nitrogen, urea and glucose levels in the blood of animals exposed to 7 and 15 kV/m EMFIF.

The increased activity of blood lactate and succinate dehydrogenases and elevation of parameters of respiration and phosphorylation of liver mitochondria, which was observed with 7 and 15 kV/m fields, is indicative of the effect of the factor under study on energy metabolism. It was also noted that the respiratory chain of liver mitochondria phosphorulated less ADP than in the control, in the case of utilization of succinate and α-ketoglutarate. Evidently, EMFIF have the capacity to injure the mitochondrial and endoplasmic membranes. In peripheral blood, only a reliable decrease in reticulocytes was demonstrable in the 6th group of animals after the 2d and 3d month of exposure to EMFIF, after which there was gradual normalization. We failed to demonstrate appreciable changes in indices of nonspecific immunity in experimental groups of animals.

At the end of the experiment, the 6th group of animals presented a reliable increase in ascorbic acid level of the adrenals, as well as in relative weight of the testes, which revealed dystrophic and destructive changes in cells of the spermatogenic epithelium and interstitial tissue.

The Figure illustrates levels of some trace elements in the liver (the most important reservoir of trace elements). We see that even exposure to 4 kV/m leads to a reliable depletion of iron, copper and molybdenum, the metabolism of which is closely interrelated. A reliable decrease in iron level in the liver, as well as a number of other organs (brain, bones, etc.) was demonstrated even in the 2d group of animals exposed to 1 kV/m fields; however, in this instance we failed to observe changes in iron level of blood, which was indicative of possible preservation of homeostasis under these conditions.



Trace element content of liver after 4-month exposure of animals to EMFIF

A) copper (μg%)	a) control	d) 4 kV/m
B) iron (mg%)	b) 1 kV/m	e) 7 kV/m
C) molybdenum (μg%)	c) 2 kV/m	f) 15 kV/m

All of the described changes were reversible and they disappeared within 30-45 days after discontinuing irradiation.

The results of these experimental studies on animals indicate that, according to most parameters, the threshold level of field voltage is 7 kV/m and subliminal level is 3-7 kV/m. For this reason, we supplemented this study with observations of 10 volunteers who remained in a 5 kV/m electric field for 2 h daily for 1 month; the field was generated by a superhigh-voltage 330 kV power line under natural conditions. These dynamic observations (lability of nervous processes of the central nervous system studied on the basis of volume of operational memory and capacity for concentration, bioelectric activity of the cerebral cortex, dynamometry, examination of autonomic nervous system, cardiovascular system according to EKG with measured physical load; study of some aspects of metabolic processes by assaying blood glucose, residual nitrogen and urea; study of indices of nonspecific immunity by assaying titer of complement and lysozyme; overall bactericidal properties of blood serum) failed to demonstrate appreciable changes, as compared to background data. The volunteers made no complaints throughout the observation period.

Conclusions

1. Superhigh tension power lines of 330, 500, 750 kV or more are linear sources of low-frequency electromagnetic fields in populated areas, around which the EMFIF reaches a level of 12-17 kV/m, and there are some groups of people who could be exposed to it for 10-15 min to 2 h.

2. Daily (2 h) expose to EMFIF for 4 months, with fields of 7 and 15 kV/m, elicits adverse changes in experimental rats, which are referable to body weight, efficiency, threshold summation index, latency period of reflex, ratio between chronaxia of antagonist muscles, blood cholinesterase activity, blood urea, residual nitrogen and glucose content, thyroid function, composition of peripheral blood, state of energy metabolism, balance and interorganic distribution of trace elements and morphology of internal organs.

3. Exposure of white rats to EMFIF leads to a significant change in balance and distribution of trace elements in the organs, and their levels rise with increase in field tension, so that this is a rather sensitive criterion of the effects of this factor.

4. The results of our experimental investigations revealed that 7 kV/m is the threshold voltage (according to most indices) in the case of 2-h exposure and 4 kV/m is the subliminal level. Observations of volunteers revealed that exposure to 5 kV/m elicits no changes. By virtue of all of the foregoing, a field level of 5 kV/m can be recommended as the maximum permissible voltage of brief (not more than 2 h) exposure of people in the range of action of electric fields of 50 Hz frequency.

10,657
CSO: 1870

UDC 621.315.17:621.784.3

THE INFLUENCE OF THE ELECTRICAL FIELD OF AN ELECTRICAL POWER TRANSMISSION LINE ON COMMUNICATIONS LINES SERVICE PERSONNEL

Moscow ELEKTROSVYAZ' in Russian No 3, 1977 pp 30-34

[Article by V.F. Kalyuzhnyy and M.I. Mikhaylov]

[Text] A three-phase, alternating current, electrical power transmission line (LEP) at a voltage of up to 220 KV, when intersecting or coming close to an open wire communications line (LS) can have a dangerous effect on the service personnel of the communications line only if a person comes in direct contact with the communications wire which is located in the electrical field of the LEP.

When communications lines come close to or intersect electrical power transmission lines with voltages of 330, 500, 750 KV and above, as has been established by special research, the electromagnetic field of these lines also becomes dangerous to the line service personnel even if a person does not touch the communications wires, but is located underneath the LEP conductors or at a communications line support pole running parallel and close to the ultrahigh voltage line, or intersecting this line.

Medical research [1, 2] has established the fact that a harmful influence is exerted on the human organism not primarily by the magnetic field, but by the electrical field of a three-phase LEP with a line voltage of from 330 KV and above. The Industrial Safety Institute of the USSR Public Health Ministry, in conjunction with the Power Engineering Ministry of the USSR have established norms for the permissible amount of time spent by service personnel in the electrical field an LEP, depending on its voltage, based on the research which has been carried out [3] (Table 1).

TABLE 1.

Electrical Field Intensity KV/m	5	10	15	20	25
Time allowed for a person to stay in the electrical field	Unlimited time	Up to 3 hours	Up to 1.5 hours	No more than 10 minutes	No more than 5 minutes

It follows from the data of the table that open wire communications lines have to positioned at distances from electrical power transmission lines such that the electrical field intensity of the LEP around the communications line does not exceed 5 KV/m.

In accordance with the table, we shall determine the boundaries of the dangerous zones around electrical power transmission lines with voltages of 330, 500, 750 and 1,200 KV. By means of solving Maxwell's equations, we shall compute the potentials and the intensities of the electrical fields of three-phase electrical power transmission lines at different line voltages. Shown in Figure 1 are a section through a three-phase LEP, positioned above the ground, and the mirror image of the conductors. Indicated in the drawing are all the quantities included in the equation for the determination of the potentials and intensities at the point P(x,y): b_1, b_2 and b_3 are the heights at which the conductors are suspended; s is the distance between the phases above the surface of the ground; a_{1P}, a_{2P}, a_{3P}, a'_{1P}, a'_{2P} and a'_{3P} are the distances from the LEP conductors and their mirror images to P(x,y). Zone I corresponds to points P(x,y) located above the ground between the center and outside phase; Zone II corresponds to the points P(x,y) located beyond the projections of the outside phases.

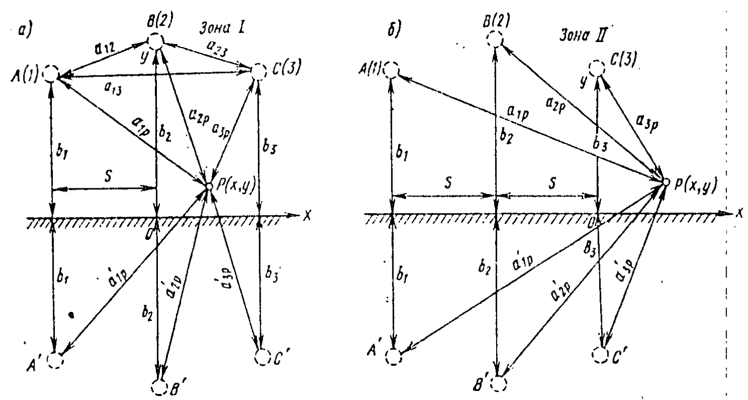


Figure 1.

The electrical field potential at any point P(x,y) is found as the sum of the potentials produced by each conductor of the electrical power transmission line individually, i.e.

$$U_P(x,y) = \dot{U}_{1P} + \dot{U}_{2P} + \dot{U}_{3P}\,. \qquad (1)$$

It is known from the theory for the electrical influence of a three-phase electrical power transmission line on a communications line [4] that the potential induced in an insulated conductor strung parallel to a three-phase electrical powered transmission line, determined from the equation:

$$U_p = \frac{U_\Phi \left[-\alpha_{p1} + \frac{1}{2}(\alpha_{p2} + \alpha_{p3}) + i\frac{\sqrt{3}}{2}(\alpha_{p2} - \alpha_{p3}) \right]}{\alpha_{11} - \alpha_{12}} + \\ + \frac{U_0(\alpha_{p1} + \alpha_{p2} + \alpha_{p3})}{\alpha_{11} + 2\alpha_{12}}. \tag{2}$$

It is obvious that this same formula also applies for the determination of the potential at the point P(x,y) in the air space located at the suspension level of the insulated communications line conductor. The symbols included in the formula mean the following: U_Φ is the phase voltage of the three-phase electrical transmission line: U_0 is the residual voltage of the three-phase electrical power transmission line system with respect to ground; α_{p1}, α_{p2}, α_{p3}, α_{11}, and α_{12} are potential coefficients (for example, $\alpha_{11} =$ $= K \ln \frac{2b_1}{r}$; r is the equivalent radius of a seperate phase of the electrical power transmission line).

Assuming that $U_0 = 0$, the absolute value of the complex electrical field intensity underneath the conductor and close to the LEP conductors at the point P(x,y) can be defined as:

$$E_p(x, y) = \frac{CU_\Phi}{2\pi\epsilon} \sqrt{\left|\frac{\partial U_p(x, y)}{\partial x}\right|^2 + \left|\frac{\partial U_p(x, y)}{\partial y}\right|^2}, \tag{3}$$

Where $\frac{\partial U_p(x, y)}{\partial x}, \frac{\partial U_p(x, y)}{\partial y}$ are partial derivatives of the expression for finding the potential at the point P(x,y); C is the capacitance of the "phase to ground" per unit length of line, in F/m.

We will write the expressions for the potential at the point P(x,y) and its derivatives for the first and second zones (beneath the conductors and close to the conductors of the electrical power transmission line respectively) with a horizontal arrangement of the conductors. In this case, $b_1 = b_2 = b_3$. For the first zone (Figure 1a):

$$U_p(x, y) = \frac{CU_\Phi}{2\pi\epsilon} \left[\ln\sqrt{(b_1 + y)^2 + (s + x)^2} - \ln\sqrt{(b_1 - y)^2 + (s + x)^2} + \right. \\ + (0{,}5 + i\,0{,}866)\left(\ln\sqrt{(b_1 - y)^2 + x^2} - \ln\sqrt{(b_1 + y)^2 + x^2} + \right. \\ \left. + (0{,}5 - i\,0{,}866)\left(\ln\sqrt{(b_1 - y)^2 + (s - x)^2} - \ln\sqrt{(b_1 + y)^2 + (s - x)^2}\right)\right].$$

$$-\frac{\partial U_p(x, y)}{\partial x} = -\frac{CU_\Phi}{2\pi\epsilon}\left[(s + x)\left(\frac{1}{(b_1 + y)^2 + (s + x)^2} - \frac{1}{(b_1 - y)^2 + (s + x)^2} + \right.\right. \tag{4}$$

$$+(0,5+i\,0,866)\,x\left(\frac{1}{(b_1-y)^2+x^2}-\frac{1}{(b_1+y)^2+x^2}\right)-$$
$$-(0,5-i\,0,866)(s-x)\left(\frac{1}{(b_1-y)^2+(s-x)^2}-\frac{1}{(b_1+y)^2+(s-x)^2}\right)\Bigg]. \qquad (5)$$

$$-\frac{\partial U_P(x,y)}{\partial y}=-\frac{CU_\Phi}{2\pi\varepsilon}\Bigg[\frac{b_1+y}{(b_1+y)^2+(s+x)^2}+\frac{b_1-y}{(b_1-y)^2+(s+x)^2}-$$
$$-(0,5+i\,0,866)\left(\frac{b_1-y}{(b_1-y)^2+x^2}+\frac{b_1+y}{(b_1+y)^2+x^2}\right)-$$
$$-(0,5-i\,0,866)\left(\frac{b_1-y}{(b_1-y)^2+(s-x)^2}+\frac{b_1+y}{(b_1+y)^2+(s-x)^2}\right)\Bigg]. \qquad (6)$$

For the second zone (Fig. 1b)

$$U_p(x,y)=\frac{CU_\Phi}{2\pi\varepsilon}\Big[\ln\sqrt{(b_1+y)^2+(2s+x)^2}-\ln\sqrt{(b_1-y)^2+(2s+x)^2}+$$
$$+(0,5+i\,0,866)\left(\ln\sqrt{(b_1-y)^2+(s+x)^2}-\ln\sqrt{(b_1+y)^2+(s+x)^2}\right)+$$
$$+(0,5-i\,0,866)\left(\ln\sqrt{(b_1-y)^2+x^2}-\ln\sqrt{(b_1+y)^2+x^2}\right)\Big]. \qquad (7)$$

$$-\frac{\partial U_p(x,y)}{\partial x}=-\frac{CU_\Phi}{2\pi\varepsilon}\Bigg[(2s+x)\left(\frac{1}{(b_1+y)^2+(2s+x)^2}-\frac{1}{(b_1-y)^2+(2s+x)^2}\right)+$$
$$+(0,5+i\,0,866)(s+x)\left(\frac{1}{(b_1-y)^2+(s+x)^2}-\frac{1}{(b_1+y)^2+(s+x)^2}\right)+$$
$$+(0,5-i\,0,866)\,x\left(\frac{1}{(b_1-y)^2+x^2}-\frac{1}{(b_1+y)^2+x^2}\right)\Bigg]. \qquad (8)$$

$$-\frac{\partial U_p(x,y)}{\partial y}=-\frac{CU_\Phi}{2\pi\varepsilon}\Bigg[\frac{b_1+y}{(b_1+y)^2+(2s+x)^2}+\frac{b_1-y}{(b_1-y)^2+(2s+x)^2}-$$
$$-(0,5+i\,0,866)\left(\frac{b_1-y}{(b_1-y)^2+(s+x)^2}+\frac{b_1+y}{(b_1+y)^2+(s+x)^2}\right)-$$
$$-(0,5-i\,0,866)\left(\frac{b_1-y}{(b_1-y)^2+x^2}+\frac{b_1+y}{(b_1+y)^2+x^2}\right)\Bigg]. \qquad (9)$$

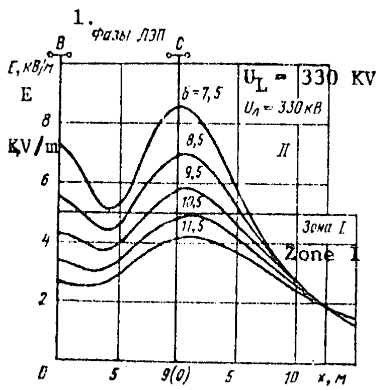
In calculating the magnitudes of the electrical field intensity at various points above the surface of the ground and below the conductors of the LEP, and to the side from it at different distances, we will use Table 2, where the LEP parameters are given for various line voltages. The magnitudes of the field intensity were computed for a point positioned at a height of $y = 1,8$ m above the surface of the ground for electrical power transmission lines and voltages of 330, 500, 750, and 1200 KV with a span length of 400 m by means of substituting the data from the table in the formulas.

TABLE 2.

Electrical Power Transmission Line Parameters	Line Voltage, KV			
	330	500	750	1200
Phase voltage U_ϕ KV	190	289	434	694
Spacing between the phase conductors s, in m	9.1/18.2	12.5/25	17.5/35	26.1/52.2
Number of conductors per phase	2	3	4	8
Equivalent phase radius, r, in m ..	0.074	0.13	0.27	0.42
Suspension height of the conductor, b, in m	22	22	23	24
Line clearance at the center of a span, H, in m	7.5	8	9	11
Equivalent capacitance of the "phase to ground" circuit, C, in F/m.......	$12.3 \cdot 10^{-12}$	$12.1 \cdot 10^{-12}$	$13.4 \cdot 10^{-12}$	$14.1 \cdot 10^{-12}$

The computations were performed on a computer; the resulting values of the intensity along the span at the points positioned at different distances "x" from the axis of the electrical power transmission lines, as well as in a direction perpendicular to it, are represented in the form of curves for $E = \phi(x)$, which are depicted in Figures 2-5. Additionally, indicated in these figures at intervals of 5 KV/m are the zones of dangerous influence of the electrical power transmission lines.

Figure 2.



Key: 1. Electrical power transmission line phases.

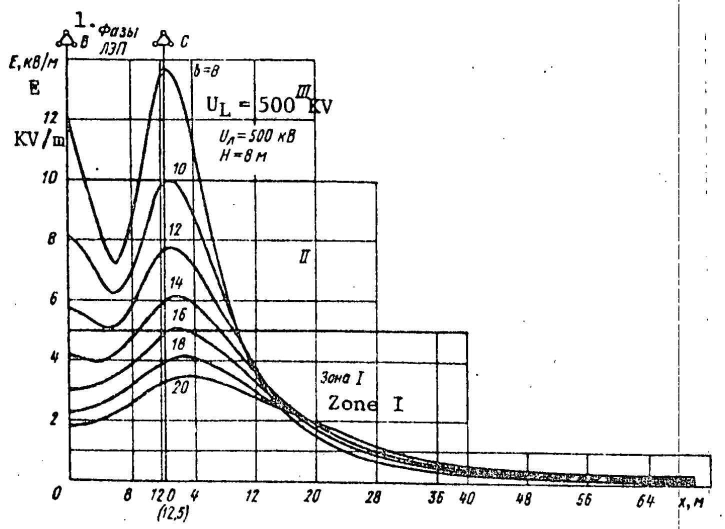


Figure 3
1. Electrical power transmission line phases.

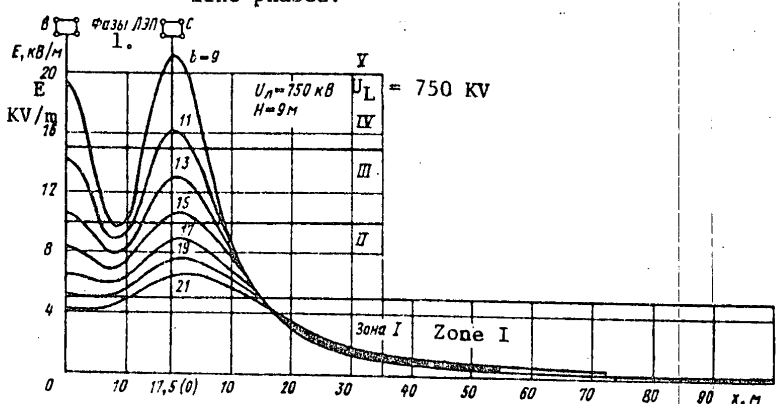


Figure 4

1. Electrical power transmission line phases.

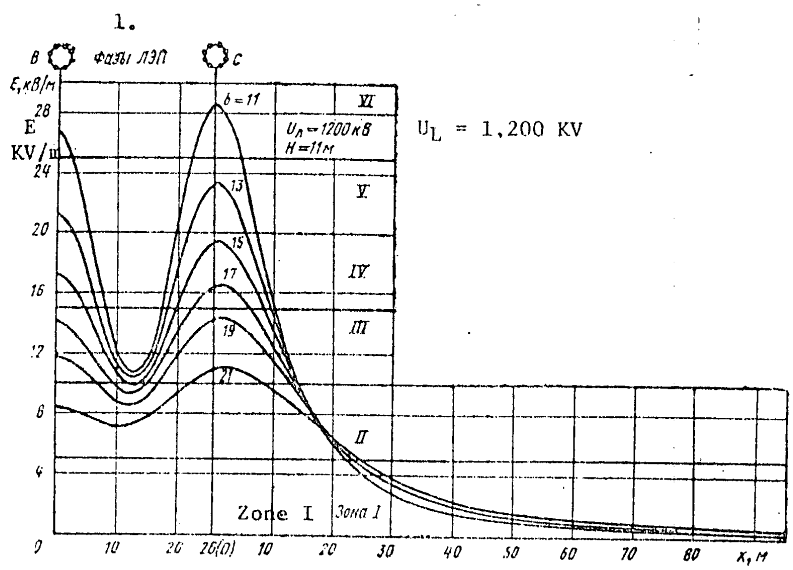


Figure 5

1. Electrical power transmission line phases.

It can be seen from an analysis of the curves that it is most dangerous for a person to be located in the center of the span, where the LEP conductor is positioned at the minimum height, and it is least dangerous close to the support, where the conductors are at a maximum distance from the ground.

If values of E = 5 KV/m and less are adopted as the permissible values which are not dangerous to human health [3], then for a 330 KV LEP, the safe zone is the one located 5 - 6 meters beyond the projection of the end conductor onto the surface of the ground at the center of the span, and for 500, 750, and 1200 KV LEPs, beyond limits of 10, 15, and 25 meters respectively.

For the purpose of protecting the line service personnel of open wire communications lines against the harmful effects of the electrical field of LEPs when carrying out structural and repair operations, on sections which are close or intersect, it is necessary to replace the open wire line by cable inserts, the length of which are given in Table 3.

TABLE 3

U_L, KV	330	500	750	1200
l, m	43	57	77	115

Note: The above table is compiled for an intersection angle of $\alpha = 90°$. If the intersection occurs at an angle of $\alpha < 90°$, then the length of the cable inserts are $l_x = l/\sin\alpha$.

On sections which run parallel and are close, when the distances between the closest conductor of the LEP and the communications line are equal or less than the critical amount obtained by calculation, the open air lines should be replaced by a cable insert over the entire adjacent section.

If there are cable inserts on sections where open wire communications line intersect an LEP and have a length less than that indicated in Table 3, the work positions on the cable supports should be equipped with special grounded shielded nets which reduce the electrical field intensity down to the established norms. Where cable inserts are lacking, work on the supports of open air communications lines which are located in the zone of influence of a LEP electrical field, should be carried out only when using an individual shielding set, included in which are: a protective suit (a jacket and pants or one-piece suit), shielding head gear, and special electrically conductive foot wear [5,6].

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8225
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ELECTRIC AND MAGNETIC PROPERTIES OF BIOLOGICAL MEMBRANES

Moscow PRIRODA in Russian No 3, 1977 pp 68-75

/Article by Doctor of Chemical Sciences S. Ye. Bresler/

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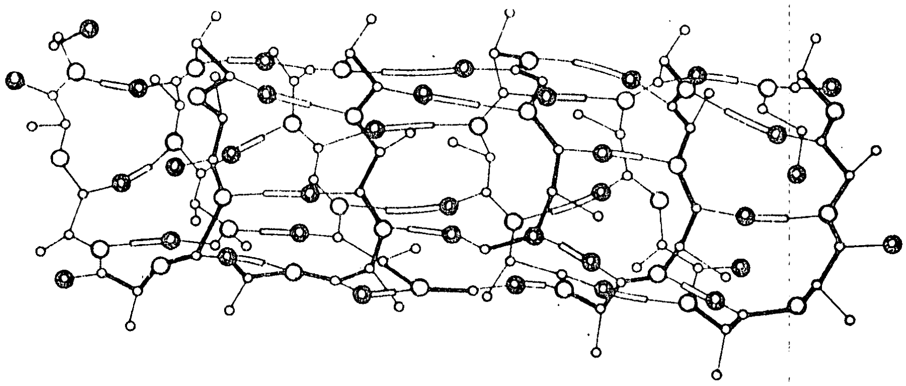
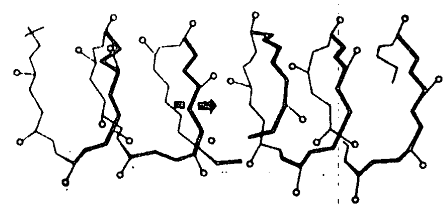
Electric phenomena play an important part in biology. As far back as 1791 in his first experiments in electrophysiology L. Galvani discovered muscular contraction in a severed leg of a frog when potentials of a small difference were applied to it. Sea animals (for example, the electric ray) capable of killing their catch with high-voltage electric discharges have been known for a long time. At first glance all this seems paradoxical. The intracellular fluid--cytoplasm--conducts electricity well. In conductivity its ionic medium corresponds approximately to a 0.15-molar solution of sodium chloride. In what way can marked differences in potentials be created in such a conducting medium? It is easy to answer this question if it is taken into consideration that all cellular membranes, as well as intracellular organelles (for example, mitochondria), consist of membranes formed by insulating lipids. Although the thickness of individual membranes is only 50-100 Å, potential differences on the order of 0.1 V are formed on each of them, which produces intramembrane fields on the order of 100,000 V/sm. As a result of summation sets of millions of membranes can produce the high voltages mentioned above.

The reason for the formation of membrane potential lies in the selective conductivity of membranes for some ions. For example, a membrane can be permeable to potassium, but not to sodium. Anions usually do not pass through the lipid layer. If on both sides of such a membrane potassium salt concentrations are different, potassium ions will diffuse through the membrane and create a potential difference on it (because anions cannot follow them), which will exactly balance the tendency of potassium toward diffusion. The so-called Nernst diffusion potential is formed. Now it has been firmly established that the potential jump on a membrane is exceptionally important. In particular, according to the modern theory of transmembrane transport (Mitchell's theory) the electric field inside a membrane creates flows of the necessary substances from the environment into the cell or from the cell to the environment.

Today the structure and functions of membranes have been studied quite well. Laboratory models of biomembranes are even made. A layer made of a mixture of lipids is applied to a hole in a hydrophobic plate (made of polyethylene or teflon) under water. By measuring the capacity or electric conductivity, it is possible to observe how the lipid film becomes thinner. Finally, the thickness of the layer reaches ~100 Å and a so-called "black spot" is formed (the name emphasizes its invisibility). In such a form a membrane can exist for many hours. Some substances, for example, ionophores, which transfer ions through a nonaqueous medium, can be introduced into the lipid. Then the lipid film becomes conducting for certain ions, which can be easily measured if a potential difference on the order of 0.1 V is applied to it. The electric properties of membranes greatly depend on the nature of the ionophore introduced into them. For example, the antibiotics alamethicin or gramicidin create pores or canals in the lipid film, through which single-charged cations penetrate selectively. It is interesting that, if the lipid film is frozen by cooling, the canals remain and the passage of ions through them does not stop.



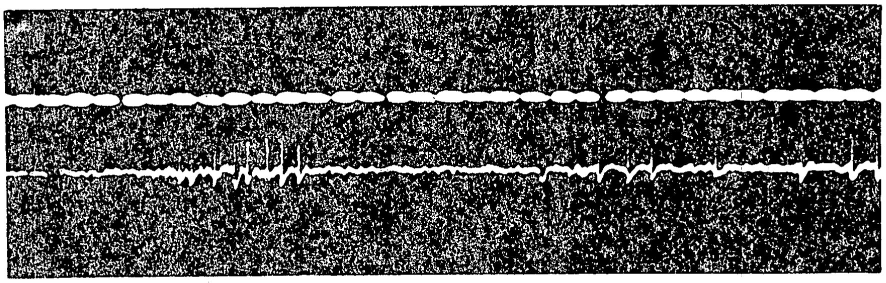
A schematic spatial model of a complex consisting of two spiral gramicidin molecules. Below, the same complex without the side groups of the polypeptide chain (its size is 25-30 Å). The arrow points to the location of sodium or potassium cations inside the spiral.

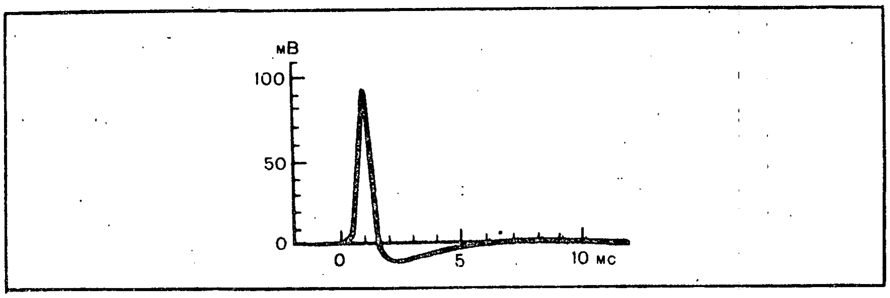


What is the molecular structure of the canals for the passage of ions? In most real membranes these canals are of a protein nature and their structure has not yet been studied. However, for the model membrane with gramicidin there are now hypotheses on the mechanism of its action.[1] Gramicidin is a polypeptide consisting of 15 amino acid radicals. Several gramicidin molecules form a complex convoluted into a spiral tubule and located perpendicularly to the membrane plane.

By measuring the electric conductivity of the film and knowing that at low concentrations of gramicidin it depends on its concentration approximately to the sixth-ninth power, it can be concluded that this complex consists of six-nine molecules. Since gramicidin spirals contain water repellent, hydrophobic groups on the outside and polar, hydrophylic groups inside, outside they are solvated (that is, moistened) with the lipid and inside they retain a canal for the passage of ions. Incidentally, similar so-called "canal complexes" have been known to physical chemistry for a long time.

When the electric properties of model membranes are studied, abrupt changes in electric conductivity with a change in the applied potential difference are observed, that is, nothing like the manifestation of the ordinary Ohm law. At the same time, some ionophores behave so that, as the voltage on the film is reduced, the current does not drop, but increases abruptly. As is known from oscillation physics, such an electric element with a "drooping characteristic" is capable of generating electric oscillations. In fact, the model membrane reveals such properties. These phenomena shown on a relatively primitive "black spot" model have a direct bearing on one of the most important processes in biology--the formation of the electric nerve signal.





Key:
1. Mv 2. Ms (Color)

Above, an oscillogram of the electric activity of a neuron from the optical region of the cerebral cortex of a rabbit. A flash of light lasting 0.5 ms was produced before the animal's eyes at the moment indicated by the color. The neuron responded to the brief excitation of the sense organ with bundles of spikes. The time mark is recorded in the upper part of the diagram. Every oval spot denotes an interval of 10 ms (0.01 s). According to present ideas the information on the event (flash of light) transmitted to the brain is coded in these bundles of signals.

Below, the calculated single spike obtained according to Hodgkin's-Huxley's phenomenological theory. The characteristics of this phenomenon can be seen on it. The potential difference at a certain axon point is plotted along the ordinates and the time is indicated along the abscissas.

The potential jump on the external membrane of nerve cells (neurons) causes the formation of sharp electric signals running along the neurons, which, as modern physiology believes, serve as the material mechanism for the transfer of information in the nervous system of man and animal. It is possible to artificially obtain the basic element of this mechanism--spike (a single nerve signal)--if, for example, the potential jump is lowered several times on a small section of the membrane of the nerve cell, applying the external potential difference of the reverse sign. When the potential jump at a certain point of the membrane is suddenly reduced from 0.1 to 0.02 V, then the electric properties of the dielectric filling the membrane change abruptly. It begins to conduct electricity and, in particular, becomes permeable to sodium ions, which rush from the external medium inside the cells, because the membrane is charged positively on the outside. The ion current causes a reduction in the field in neighboring membrane points, where again conductivity occurs and thus a wave of an electric current running along the charged capacitor, nerve fiber or axon is formed. The oscillograph shows that a single impulse has a width of 0.5-1 ms and the rate of its propagation is equal to 10-50 m/s. When the impulse has run through the membrane, its electric properties change again. It no longer passes sodium ions, but conducts only potassium ions, potassium concentration within the cell being 30 times greater than outside the cell. Potassium ions diffuse into the external medium and again create a potential jump. Then the membrane is again ready for a spike. This preparation requires time on the order of only a 100th fraction of a second. The spike was thoroughly studied by A. L. Hodgkin, A. F. Huxley[2] and other researchers. By measuring the electric properties of an axon (an extension of a nerve cell), that is, the internal and external electric conductivity, as well as the membrane capacity, it was theoretically possible to predict the form of the signal and the rate of propagation by means of the solution of the so-called Kelvin's telegraph equation.

One of our figures shows an oscillographic recording of signals from a single neuron of a rabbit's cerebral cortex following the excitation of the optical nerve with a short flash of light. In this experiment attention should be drawn to the fine equipment. The electric signal is taken from a single brain cell, for which a metal electrode 2 microns thick is packed into it. Physiologists also implant such microelectrodes in people.

The calculated form of the spike computed according to Hodgkin's-Huxley's theory shows that, phenomenologically, the phenomenon is described correctly.

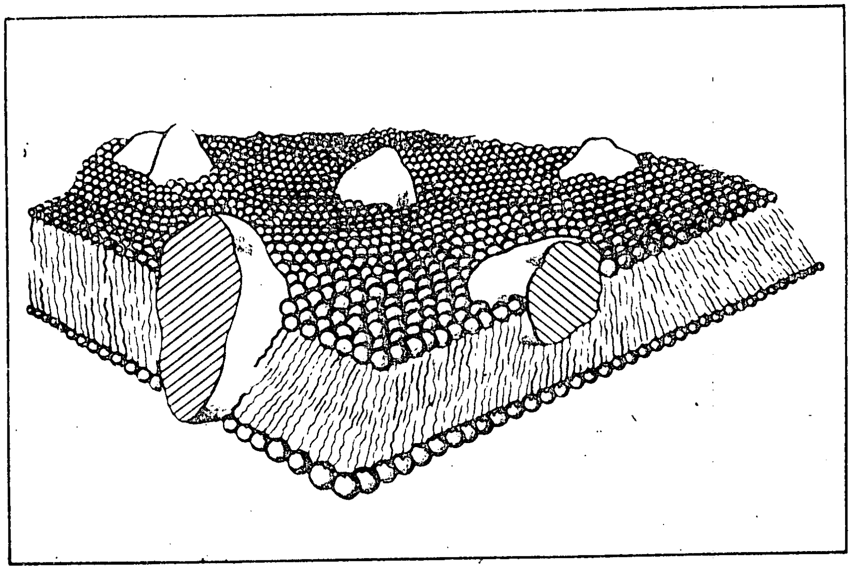
However, the main secret remained unraveled. The reason for such amazing changes in the electric properties of the membrane--occurrence of conductivity for sodium ions and liquidation for potassium ions at the moment of the spike start and return to the initial state after the membrane discharge--was unclear.

It was established that inside the membrane there are special protein canals, separate for sodium and for potassium. This was shown by means of specific toxins. One of them, tetrodotoxin, blocks the canals for the passage of sodium, and the other, tetraethyl ammonium, the canals for potassium. It is not yet known how the canals open and close. First it seemed that the formation of spikes was the special privilege of nerve cells. Then it turned out that they could be observed on the most various objects. For example, they are observed on the paramecium (slipper limpet) in which they serve to transfer information on the change in the ionic composition of the environment and in filamentous nitella algae in which their physiological role is unclear. Then spike formation could be observed on artificial models--"black spots." It is believed that, when the voltage is lowered, the canals conducting ions change from one state of equilibrium to another. Reproduction of this phenomenon on a nonbiological model shows that a special physical mechanism operates here.

Whereas electric processes in living matter do not evoke any doubt, the role of magnetic fields in biology is still being debated. Unfortunately, the presently existing whole area of research called magnetobiology has compromised itself with a large number of errors, lack of control and sometimes direct falsification as well. The experiments pertaining to the effect of weak fields are especially suspicious. I shall recall the story with the "magnetic bracelets" manufactured by Japanese firms for the treatment of numerous diseases and prohibited by the Japanese Government as an outright deception. As a result, skeptical attitude has taken root among scientific workers and articles completely denying magnetobiology have appeared.

From our point of view, first of all, it is necessary to understand the physical mechanism of action of the magnetic field on cells. The period of study of biological objects, when it was believed that any miracles are possible in them, is already past. Biological objects are complex systems and at the system level they sometimes manifest unexpected regularities. However, all the elements of biological systems, moreover, they as a whole, are subjected to general physical laws. Its constituent molecules have now been studied well and one can approach them with the ordinary criteria of molecular physics.

The following question arises: In principle, is it possible to observe the effect of the magnetic field on biological molecules? At first glance the answer will be negative. In fact, all biologically important substances, for all practical purposes, are diamagnetic. A weak magnetic moment $\mu=\chi H$, where χ is the magnetic susceptibility and H is the field, is induced in their molecules. Therefore, the energy that they can acquire in the magnetic field equal to μH is very small. This energy must be compared with the energy of the thermal movement kT, where k is Boltzmann's constant and T, the absolute temperature. From the comparison it follows that the relation $\mu H/kT$ is equal to $\sim 10^{-7}$ and even quite a large field (H=10,000 Oe) and the energy acquired in the magnetic field are negligibly small. In electric fields molecule orientation is determined by the criterion $\varepsilon E/kT$, where ε is the dipole moment and E is the electric field. For fields on the order of 10^5 V/sm this criterion is $\varepsilon E/kT \cong 10^{-2}$, that is, just as small as compared with a unit.



A model of the so-called liquid mosaic structure of a membrane. Lipid molecules form double layers--the membrane basis. The chains in individual crystal domains are parallel, but the spatial orientation of various domains is different, although, on the average, the angles of slope are the same. The polar groups of lipids are shown in the form of small circles, and proteins, in the form of small islands partially penetrating the membrane. The lipid layer is liquid and the protein macromolecules retain their mobility along the membrane (lateral mobility). Their position in the membrane is determined by the lipid wetting them.

However, this simple consideration does not exhaust the problem. The point is that many organic molecules (up to 5 percent of all the presently known organic compounds) form so-called liquid crystals in a certain temperature region. This means that their molecules are packed into ordered formations, that is, domains containing millions of molecules. The forces of interaction among neighboring spatial asymmetrical molecules are the reason for this. At the same time, the substance remains liquid, mobile and deprived of elasticity with regard to shift, because the degree of order inside the domains is still relative, not comparable with such true crystals.

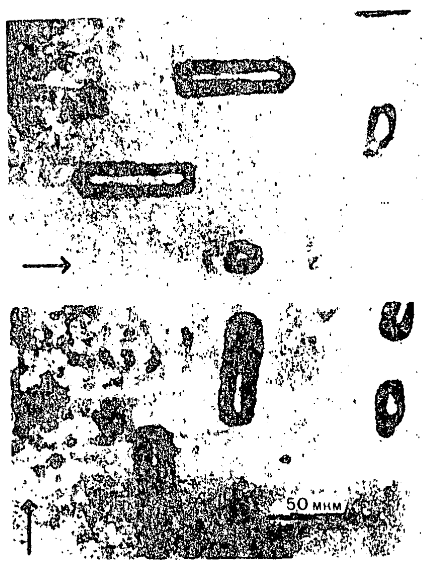
When liquid crystals are placed in an electric or a magnetic field, strong (depending on the field intensity) orientation effects, studied by physicists for a long time, occur in them. The point is that in a magnetic field the domains are anisotropic. If they consist of prolate chain molecules, in the field the domains should be reconstructed (as though recrystallized) so that the long axis of the molecule coincides with the direction of the magnetic field. At the same time, the change in energy will be $n\ \mu H/kT$, where n is the average number of molecules in a domain and this criterion can attain a magnitude on the order of a unit in fields accessible for an experiment.

Now the following question arises: Are there liquid crystal domains in biological objects? It turns out that the lipids of which membranes are made are typical liquid crystals of the so-called smectic type forming layers parallel to the oriented chain molecules. This means that the orientation of lipid domains in electric and magnetic fields is not only possible, but also inevitable. Protein particles, which serve as canals for the ions, are located inside a lipid membrane and are oriented according to the orientation of lipids, because with their hydrophobic side surface they are closely linked with lipid molecules. Therefore, from the point of view of physics, the effect of the magnetic field on membranes and on membrane permeability is quite natural.

Here mention should be made of another observation during which the effect of a moderate magnetic field (on the order of 100-1,000 Oe) on the kinetics of processes was revealed. It concerns the effect of a magnetic field on the photoconductivity of organic substances, on luminescence and on some photochemical reactions in which paramagnetic molecules, for example, oxygen, participate. Physically, this phenomenon is quite clear.[3] It is difficult to say now whether it has any bearing on biology. It is not ruled out that photochemical and photoelectric processes in living nature (photosynthesis and the work of the organs of vision) can prove to be a target for the effect of magnetic fields in this mechanism.

Let us examine the orientation in a magnetic field (10,000 Oe) of a suspension of rods taken from the retina of a frog's eye. The rods consist of lipid molecules oriented by their long axis along the rod axis. The French researchers R. Chagneux and A. Chalazonitis[4] showed that a magnetic field turns the rods as compass needles, although they do not contain paramagnetic or, moreover, ferromagnetic substances. Physically, it is clear that the anisotropy of magnetic susceptibility of chain lipid molecules is the source of orientation.

We studied[5] (in cooperation with V. M. Bresler, E. N. Kazbekov and N. N. Vasil'yeva) the effect of magnetic fields from 10,000 to 50,000 Oe in a superconducting solenoid on the transport of various substances through the membrane of renal canals. Having placed the kidney of a frog in a magnetic field, we observed how the renal canals pumped the heavily fluorescent substance fluorescein from the environment. For quantitative measurements we used a microscope combined with a fluorimeter (an instrument measuring fluorescence by a photoelectric method). Finally, in order to avoid organic disturbances, we worked on a whole, undamaged organ. For this a special contact objective was slightly immersed in the kidney, which made it possible to focus the microscope on a renal canal without the preparation of sections or other damaging operations. We were able to follow the pumping of the luminescent mark from the environment into an individual canal. The result obtained was clear--the magnetic field hampered the transport of the substance by approximately one order of magnitude. The rate of transport depended on the field: near 30,000 Oe the effect reached saturation--the speed was reduced five or six times as compared with control. Of course, the experiments were repeated many times and convincing statistics were obtained.



1)

A photomicrograph of rods from the eye of a frog suspended in a physiological solution and placed in a magnetic field of an intensity of 10,000 Oe. A good orientation of the rods along the field (indicated by an arrow) is seen.

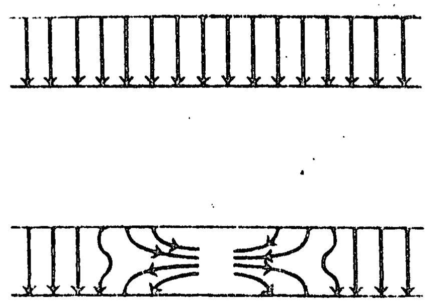
Key:
1. 50 microns

However, the kidney proved to be not quite a convenient object, because the different canals in it have a different spatial orientation. Therefore, in subsequent experiments we used a choroid plexus from a rabbit's brain. This is a special organ in the form of a fine, transparent strip, which sucks from the cerebral fluid ballast substances into capillary blood vessels. This plexus is a membrane consisting of one plicate layer of epithelial cells. On the average, the membrane plane coincides with the plexus plane, which makes it possible to create a certain orientation of the membrane with regard to the field.

The picture of the effect of the magnetic field on the membrane proved to be quite complex. In an ordinary medium containing sodium, potassium and calcium salts the magnetic field accelerated the transport of the fluorescent dye approximately twice. At the same time, the effect was observed only when the membrane plane was perpendicular to the direction of the field and during a parallel orientation the effect was absent. It is known that lipid molecules are by no means always perpendicular to the membrane plane. An X-ray structural analysis shows that, usually, they are inclined approximately at an angle of 60°. Probably, the carriers of organic ions are also inclined and this inclination is not optimal for transport. The inclusion of the magnetic field should rectify the molecules of lipids and, accordingly, of the carriers, which, apparently, accelerates the transport.

A different situation is created if calcium concentration in the medium is greatly reduced. Calcium ions play an important part in the structure of the lipid layer, because they strongly interact with the phosphate groups of phospholipids. The lack of calcium reduces the bond among lipid molecules. In this case the magnetic field operates in a reverse direction, that is, it slows down the transport of the indicator fluorescein ion approximately 2.5 times. Such a strong effect (exceeding the statistical variance by an order of magnitude) is observed only in sufficiently large fields and is saturated in the vicinity of 20,000 to 30,000 Oe. Apparently, a reduction in calcium concentration sharply changes the structure and orientation of fluid crystal domains. For the time being, we cannot say anything more definite. Additional structural changes on the membrane are needed. This problem can be solved on a transparent choroid plexus, because lipid layers have a double refraction, but, technically, this is not easy to carry out, taking into consideration the small thickness of biomembranes.

Let us now go back to the electric phenomena in the membrane. Since protein canals are capable of changing their orientation and, therefore, permeability when fields are changed, as a result of the reconstruction of the lipid layer, the change in potassium and sodium conductance, that is, the opening and closing of canals for sodium and potassium during a change in the potential jump, is fully explainable. Before the spike we have in the membrane a seemingly charged capacitor, in which the power lines are perpendicular to the membrane surface. At the spike moment the charge at a certain point of the membrane becomes equal to zero and remains the previous in the neighboring areas of the membrane. At the same time, the vector of the electric field near the "short circuit" turns 90° and is directed along the membrane surface. In the end the field disappears, because the charge on the capacitor is neutralized.



The electric field in the membrane before the beginning of the discharge (above) and at the moment when the discharge began at a certain point of the membrane (below). It is possible to initiate the discharge by applying a reciprocal potential difference at a given point. In the synapses of neurons (at the points where they contact with each other) the discharge is initiated with an ultramicroscopic droplet of a mediator, for example, acetylcholine.

It is clear that these situations can correspond to different orientations of lipid domains. In practice, this leads to the fact that before a spike the membrane conducts only potassium ions, at the moment of discharge only sodium ions pass through the membrane and after the discharge potassium conductance again returns to the membrane. This means that, in fact, protein canals are capable of changing owing to the reconstruction of lipid domains in changing electric fields. Such a reconstruction should be accompanied by a change in the optic properties of the membrane at the same points where the spike runs. In fact, the change in the optic properties of the membrane, in particular, in the double refraction at the spike moment, was discovered experimentally by R. Keynes,[6] I. Tasaki[7] and other researchers.[8] Another significant observation--liquidation of spikes when the axon membrane is placed in a strong magnetic field (16,000 Oe) as a result of a certain orientation of domains imposed by the magnetic field--was made in the experiments of a number of physiologists.[9]

Summing up, it can be stated that orientation phenomena in a lipid membrane are fundamentally important for many biological processes, in particular, the transmembrane migration of ions and everything that follows this. The point of application for the effect of electric and magnetic fields to biological structures is precisely here.

FOOTNOTES

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ELECTROMAGNETIC ECOLOGY AND COMPATIBILITY

Prague CESKOSLOVENSKA STANDARDIZACE in Czech No 9, 1976 pp 355-358

[Article by Engr Vaclav Prosr, State Standardization Center for Electrotechnical Engineering in Prague]

[Text] Relations between noise elements in electrotechnical engineering, the lack of knowledge of which causes considerable losses. This entire problem must be also reflected in the future in the area of standardization.

Modern utilization of electric power is always related by virtue of natural laws to the formation of electrostatic, magnetic, and electromagnetic fields. This omnipresent, useful, and today indispensable part of modern life has specific negative effects in many sectors of the production-consumption chain, effects which ruin the pleasure from the contribution of progress not only in industry, but also for example in culture, health services, and elsewhere.

The consumption, conversion, distribution, transmission, and production of electric power constitutes classic schemes of heavy-current problems. With the start of industrial (as well as heavy) electronics, it seems that the differences as compared to the previous clear-cut weak current area of utilization of electric power are disappearing, that is, with regard to the application of small amounts of power or low voltages.

As examples which can perhaps illustrate best the type and method of applying unpleasant features [sic] which accompany modern application of electric power,we select further the application of electric power for transmission of information for purposes of control and regulation. From this there are derived generalizing conclusions, which can be applied also outside of these selected applications, with orientation to international connections in the scientific-technical development and in problems of standardization.

Useful application of electricity is accompanied by the effects of electromagnetic fields, which may disrupt other processes or phenomena taking place in their proximity. The concept of proximity is understood in this context mostly as spatial (geometric) and electric (related) proximity of two phenomena. At the same time, the second phenomenon under observation (in addition to the useful application) may be -- but does not have to be -- participating directly in the first phenomenon (process). A sort of deception exists in the spatial or time incidence of the occurrence of the conditions which lead to the undesirable disruptive connection. The interference is often related to the mediating effect through parts, members, or phenomena which otherwise do not participate in the process. Maximum possible combinations are represented by cases when an interference field is formed and is manifested by its effects in terms of space and time in such a valuable way, that it is beyond the experience of the team of expert construction engineers, research workers, and testing technicians. Under closer scrutiny, it is found that even a slight oversight is enough for the fine mechanism of the interference chain to fall apart before one succeeds in finding out and identifying its parts. In contrast, interfering "arrangement" which is very striking is not taken in consideration precisely because it is so obvious. All this must be prevented by taking suitable measures. However, in order to restore these measures, it is necessary in some cases to have a good amount of fantasy and experience.

In this connection, professional circles in the world are beginning to consider the interference purity of the environment ("ether") in the same way as the purity of the air and water.

Disturbing influences literally flood increasingly larger areas, mainly places with a high concentration of industry and dense urban agglomeration. Which means an ecological problem "par excellent" [sic, should read "par excellence"] and at the same time to the extent that originally purely technical questions become economic problems and pertain to the life of not only an individual, but of the entire society.

How did this qualitative jump occur, and how is it occurring now? Up to a certain time, interference voltage influenced by its negative effects only the so-called weak-current applications of electricity. It is characteristic that fields which presented little interference -- mostly dispersion fields -- as a rule did not affect heavy-current applications of electric power. That is why at the beginning the fields which dealt with these problems were those which have been affected by them most: broadcasting, communications, and railways. The method of solving the problem is also illuminating: preparation of technical norms which created conditions for uninterrupted (and therefore also safe) operations in the given area. Specific measures were as a rule one-sided, and economical management of investments in other branches of the national economy was not always taken in consideration. From the point of view of standardization, a similar approach is used on the international scale, especially because broadcasting, communications, and railroads represent areas of broad international interest, where there was and is urgent need for recommendations and norms. Within the framework of the IEC, these questions have been handled since 1933 for example at the cost of a different organizational structure of the appropriate specialized organ (International Special Committee for Radio Interference -- CISPR) and at the cost of a different way of publishing sectional results of its activities. It is true that subsequent solutions of these questions within the framework of the SKN [expansion unknown] of CEMA involves a uniform type of CEMA recommendations, but substantially it deals [sic, should read does not deal] with uniform methods of solving the problem.

Modern utilization of electric power for data processing and in the automation of processes (mainly technological processes) is characterized on the one hand by the application of low voltages, and on the other hand by the beginning of the use of nonlinear semiconducting parts both in industrial electronics as well as in the electrification system itself. In particular, the application of tyristors in high output installations results in a great increase of outputs of higher harmonic frequencies not only in the installations of the users themselves, but in the entire power distribution network. Interference voltage also began to be affected negatively by heavy-current application of electricity. At the same time, it is equally characteristic that at the present time strong interference fields in the form of interference voltages or currents are not restricted to individual equipment or installation in a given facility, but are often dragged to great distances.

The "medium" of this interference connection consists as a rule not only of disrupting dispersion fields in the area around the given facility, as it happened before, but direct electric connections in the heavy-current power lines themselves. The seemingly little sensitive huge organism of power systems is being attacked by low-current interference throughout its entire field of activity and at the most sensitive places: at the place of production (electric power plant) and consumption (households) -- not excluding distribution network and power lines.

With the introduction of computer technology in the control of industrial processes, exceptionally great difficulties occur with regard to interference voltages on a large scale. The sources of power themselves, namely electric power plants, are not remaining aside and are not spared of the positive as well as negative aspects of this process.

The measuring central organ at the inlet of the computer is connected with the technological process by means of hundreds to thousands of sensors, which are connected with a complicated bundle of measuring cables several hundred meters to several kilometers long. These sensitive "nerve terminals", which operate with very low voltages, are exposed throughout their entire course by the effects of all kinds of interference fields. In the case of the classic direct method of evaluation of the incoming signals, which carry information about magnitudes measured by measuring instruments of the dial type, alternate interference voltages do not affect the measurements, even when they are several times stronger than the useful signal: frequency characteristics and low impedance of the dial instrument guarantee that the evaluation is made correctly even in the presence of interference. As the number of the covered measuring points increases and the system switches from analog to digital processing (digitalization) for input in the control computer, the original information which is required may be suppressed entirely by the interference voltages. Reversely, the computer may receive a false signal, which did not originate at the measuring place of the technological process, but somewhere along the course of the measuring cable. One can use in this case direct analogy with the so-called sequential automatic machines, which use at the inlet very low voltages (and therefore only slight amounts of power) for the control of the input logical circuits, which in addition operate at a high impedance. An incorrect interference by the control and regulatory equipment, which is not protected against the effects of interference impulses or voltages, may result in a minimal economic loss.

At the opposite end of the distribution network of electric power, there is for example our household, and an electric meter at one of its power inlets. This watt-hour counter is both a measuring instrument for the consumption of electric power from the distribution network, and at the same time it is an indicator of the extent to which we ourselves create at home an artificial environment. Naturally, this costs some money. It costs money both to the society (the distributor) considered as the supplier on the one hand, and ourselves as consumers on the other hand. Both partners in this direct monetary ratio rely on the idea that the electrometer does the measuring correctly. That is why it is also tested officially. The catch is that the conditions for which the electrometer has been designed, manufactured, tested, and finally used, are changing at the present time. The use of mostly induction electrometers for measuring the active output of electric current under conditions of non-sinusoidal course of the curve of the current represents today a method of measurement which is demonstrably less appropriate. When appliances with semiconducting parts are switched on, the originally single-wave course of the current (50 cycles per second) turns into multi-wave currents. These multi-wave currents are integrated by the electrometer, and this causes much greater errors. And these errors are by no means within the tolerance of the tested grade of accuracy. Which means that there is no error in the design, manufacture, or testing, but rather an error due to changes of the conditions for which the induction watt-hour electrometers were designed -- an increase of the content of higher harmonic components of the basic frequency in the distribution itself of the electric power.

But the worst cases of interference voltage are those where there is danger to the service personnel or danger to various installations, particularly telecommunication installations in cases of short circuits on high-voltage power lines. The amplitude of the interference voltage induced in parallel communication cables, metal pipes and constructions grounded in close proximity of the short circuit on a high-voltage power line reaches as much as thousands of volts. It is true that the entire phenomenon occurs within a limited time interval, but on the other hand the induced voltage is dragged through underground installations at distances of several kilometers from the place of origin. With the exception of power lines of exceptionally high voltage, this does not pose a new, unknown problem. These situations on high voltage and very high voltage power lines are defined in electrotechnical regulations with a relatively degree of accuracy, and there are also measures prescribed which must be observed for reasons of safety and possible secondary danger in the construction of power lines and their operation.

However, from the general point of view, it is worth while to consider the question as to what should be done when modern measuring, control, and regulatory installations cannot be fully effective because of interference voltages, when these installations increase the productivity of human labor in a literally revolutionary way, or when on the other hand output semiconductors can make savings of the received power without unnecessary losses. And while generally speaking interference can result in danger to material values and human life, there is no other way but to spend money to eliminate interference fields, voltages, currents and to fight against their indirect effects. In contrast to this active approach, it may also be possible to wait and depend on larger amounts to liquidate the subsequent material losses, but that certainly is not a solution. In addition, losses in terms of human health cannot be measured by these values. Naturally, there also exist economic sanctions based on the application and validity of norms which have been agreed to at the state level or international level, norms which force potential "producers" of interference voltages and fields to study in greater detail and especially to study systematically the theory and practice of the formulation of such interference and of the elimination of its effects. In view of the nature of the effects of interference, one cannot very well calculate today the costs of its elimination and to include it in operational costs, thereby avoiding the problem of pollution of the environment, as it is still done sometimes when dealing with the problems of air and water pollution. A contributory factor in this is the deceptive effect of interference fields and voltages, which was mentioned previously and which in many cases turns immediately against its "creator" and strikes him at the sensitive points of his "blood circulation", if we can use for comparison purposes the well-known comparison of the function of electric power in the economic organism. Underground operations and constructions such as mines and subways are not exempt from these problems, either. What represents a separate chapter, which sometimes borders on science-fiction, are interferences in electronic equipment used in medicine and their mutual interraction, in the same way as mutual interferences of television sets connected inappropriately by a pole-type interchangeable connector with a joint power network outlet.

Effective use of means allocated for finding the causes of the formation of interference voltages or on liquidation of the consequences of their effects is today beginning to exceed the framework of one single national economy and represents a suitable and up-to-date subject for international cooperation in the broadest sense of the word. As exchange of electric power continues to increase between power systems, for example on the European scale, and above all within the framework of the uniform power system of the countries of the socialist camp, there will be necessarily problems of interference which will have to be dealt with in connection with studies of the quality of the exchanged electric power. On the other hand, for example the present advantage of deliveries of whole investment units to foreign countries ("with key") may be only a temporary advantage as compared to subdeliveries of technological lines and installations precisely because of the problem of interference.

Also, what has to be considered as an effective step is the development of bilateral cooperation within the framework of the CEMA countries. The goal of this cooperation should be a gradual transition to multilateral cooperation. What applies today to the area of scientific-technical cooperation continues to be applicable in the future with regard to standardization. At the same time, the gathering of experience and the corresponding exchange cannot stop before reaching also a broader international forum, such as for example the IEC.

The results achieved in Czechoslovakia also confirm the fact that it truely pays off to proceed in a complex manner, as provided for in the corresponding state program. In this respect, the handling of seemingly general problems such as electromagnetic compatibility or electromagnetic ecology bring specific results. Let us mention at random the production of a screened measuring table, independent destination of reduction factors on the side of communication and power lines (supplement to the Czechoslovak Norm CSN 34 2030), or progress in uniform evaluation of the effects of both components of an electromagnetic field by the method of evaluation of interferences by connecting channels.

In the fight for preservation of bearable living conditions, when all available natural sources of power are being mobilized, man is making great efforts to develop technology and especially to make further progress in it. This progress cannot be stopped, and at the same time one cannot conceive it without an active role of the human factor. However, with regard to the results achieved one must also accept the negative results of such behavior and not wait until some bright idea may occur, which is not defined in greater detail and may occur let us say at the end of this century. At the same time, until the end of the century there is relatively enough time to reject the view that these negative effects of industrial progress in particular may be somewhat objective, even though they are not at all acceptable. They are considered as if they came somewhere from the outside, instead of being understood as the result of rational considerations concerning the need for proper control of all activities which stimulate progress and broader application of scientific-technical discoveries. This in spite of the fact that in some cases there predominates the feeling of being sorry about the fact that those whose duty it is to inform the public do not do so, because they see only one side of the intricated problems -- the external side of them.

At the first sight, it looks like a paradox: if technicians (and therefore also electrotechnical engineers in the case of interference) want to demonstrate their own technical capability, they must by themselves find a solution of the dilemma that either

-- they do not know how to explain anything and cannot be suspected of technocratism, or
-- they are able to explain everything and may be suspected of being prejudiced.

In reality, it means that they must be able to demonstrate that they can find a solution outside of their own profession and draw the proper conclusions from it for themselves. This is a difficult task. At the beginning, they will agree with the others that protection of our -- your, their -- living environment appears to them -- who are technicians -- as being an ecological problem. Electrotechnicians add a word -- electromagnetic ecology -- and draw conclusions for themselves:

The discovery and use of electric power results in creation of artifical environments, in hunting for distant natural conditions, by which man deliberately surrounds himself more and more. At the same time, he creates problems of mutually similar type.

Depending on what aspect will be followed in the future, we shall talk about the corresponding type of ecology.

And so electrotechnical engineers will define later on electromagnetic ecology and immediately after that electromagnetic compatibility. This applies especially to electrotechnical and electronic products or distribution networks. They will see the difference in the fact that the aspect under study, that is the interference (interference field, voltage, current) affects directly only the users of the equipment or appliances themselves, or it affects also other individuals, the public, the community, or the society as a whole.

The problem of solving these questions calls directly for adaptation, streamlining, and codification of norms or regulations. This should be done as soon as possible in international documents, so that a few years from now one would not hear comments that ... and so on. Standardizers, acting in harmonious cooperation with electrotechnical engineers, have a new content to deal with. This content is certainly not easy in terms of formulation, but it is also complex in terms of applying the results in practice.

It is relatively easy to determine that in addition to the given human aspects of the present need for dealing with certain general ecological questions, there exists a certain "driving motor" which results in the need for dealing with the problems of interference. This is almost certainly the fact that manufacturers and especially distributors of electric power are -- in contrast to the past -- confronted with their consumers. And the consumers are beginning to demand a certain quality of energy which is being delivered to them. However, at the same time, the "nonlinear" properties of the use of electric power on the part of the consumers is -- to put it simply -- having a bad effect on the efforts of the suppliers. In fact, this effect is such that they cause more difficulties sometimes to the suppliers than to themselves. Distribution systems represent on the one hand a binding factor between the two partners, but on the other hand a suitable environment which within a short time may become infected unbearably by a defect in the form of interference -- if they let things develop as they have been developing up to now.

The demand for standardization at the international level was accepted, and so the IEC decided in 1973 at its session in Munich to create a Technical Commission No 77 -- Electromagentic Compatibility Between Electric Instruments, Including Networks. For the time being, the area of interest of the TC 77 concentrates on ... "preparation of international recommendations pertaining to electromagnetic compatibility of electric or electronic instruments with regard to each other and with regard to electric distribution networks." At the same time, the program of the operations of the Technical Commission No 77 will be coordinated with other technical commissions of the IEC, which are interested in these problems, but outside of the framework of the CISPR.

The preceding sentence is also an expression of the fact that in addition to a broader study of the problems of electromagnetic compatibility, that is problems of electromagnetic ecology, it will be necessary to take in consideration the results of the studies made by the CISPR, particularly in terms of the working methods, standardization of the methods of measurement, and determination of the limits of interference effects, and especially in the creation of terminology. Also, specialized international organizations are being invited to participate in this on a broad scale. This applies for example to the CCIR -- International Consulting Committee for Radio, CCIT -- International Consulting Committee for Telephone and Telegraph, UIE -- International Union for Electric Heat, CIGRE -- International Conference on Electric Systems of Very High Voltage, CIRED -- International Conference on Distribution of Electricity, UNIPEDE -- International Union of Producers and Distributors of Energy, and others.

While the TC 77 deals with problems of electromagnetic compatibility, the Action Committee of the IEC retains the control and framework handling of the problems of electromagnetic ecology. Its special work team of five members, whose activities have been reported previously in the press, has proposed a definition of both main concepts for purposes of various technical commissions and subcommissions of the IEC;

Electromagnetic ecology -- a study of relationship between electrically live elements and the resulting electromagnetic environment (natural environment as well as artifical environment).

Note: We are dealing with an analogy and definition of ecology, which deals with the study of relations between living creatures and the natural environment.

Electromagnetic compatibility -- an element of electromagnetic environment is compatible, if its mutual reaction with other elements of this environment is acceptable.

This led to the creation of a conceptual basis for studies of other tasks, which include specifically the preparation of a survey of technical problems in the area of electromagnetic compatibility, with delimitation of studies carried out so far and other needs involving the use of the results or continued to be dealt with in cooperation with other technical commissions of the IEC. This includes analysis of available information obtained from the CISPR and TC 77, which will lead to a proposal of measures to be taken by the Action Committee of the IEC. In view of the need for standardization coverage of the problem, this involves also proposals of suitable internal and external relations of the IEC by means of mixed working groups consisting of representatives of the interested organizations. Last but not least, it is a preparation of proposals for the Action Committee to standardize specific functional characteristics of instruments in view of electromagnetic compatibility.

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BIOLOGICAL EFFECT OF MILLIMETER RADIOWAVES

Kiev VRACHEBNOYE DELO in Russian No 3, 1977 pp 116-119

[Article by N. P. Zalyubovskaya, Khar'kov Scientific Research Institute of Microbiology, Vaccines and Sera imeni Mechnikov]

[Text] Morphological, functional and biochemical studies conducted in humans and animals revealed that millimeter waves caused changes in the body manifested in structural alterations in the skin and internal organs, qualitative and quantitative changes of the blood and bone marrow composition and changes of the conditioned reflex activity, tissue respiration, activity of enzymes participating in the processes of tissue respiration and nucleic metabolism. The degree of unfavorable effect of millimeter waves depended on the duration of the radiation and individual characteristics of the organism.

The ubiquitous propagation of radiowaves, radio broadcasting and television is contributing to the appearance of a new physical factor -- electromagnetic waves of the radio-frequency range. In recent years it has been established that radiowaves of different ranges have an unfavorable influence on the organism. The literature data (A. G. Subbota, 1970; N. V. Tyagin, 1971; B. A. Chukhlovin, 1973; M. I. Yakovleva, 1973; Yu. D. Dumanskiy et al, 1975) testify that long stay in conditions of the effect of radiowaves (the dm and cm ranges) leads to change of the functions of the nervous, cardiovascular and other systems of the organism, with the development of a characteristic complex of symptoms which permit speaking of a special nosological form of disease -- radiowave disease (M. N. Sadchikova, 1973). However, in the literature there is almost no information about the biological effect of radio frequencies of the millimeter range, although that range is widely used in technology and the question of its biological activity has acquired special urgency.

The goal of the present investigations consisted in study of the physiological and biochemical processes lying at the basis of the changes which occur in animals as a result of the effect of radiowaves in the range of 5-8 mm, at a density of the flow of power of 1 milliwatt/cm^2. The investigations were conducted on rats of the Wistar line and mice of the CBA line, irradiated for 15 minutes daily in the course of 60 days in the volume resonator of an experimental installation working on the basis of a type OV-12 generator.

Study of the morphological, functional and biochemical indicators, which play an essential role in the formation of reactions of the organism, disclosed various disorders in the experimental animals.

As is known, the energy of millimeter waves, because of its weak penetrating ability, is absorbed primarily and mainly by the skin. Our investigations have shown that in the skin of irradiated animals deformation of the receptor apparatus and well-expressed changes of a reactive character were observed. In the skin layer properly speaking appeared bunches of nerve fibers with hypertrophy of a portion of the fiber and sections with demyelinization. In the dermis, among the collagen fibers were small trunks of various thickness, the neural conductors of which were fragmented in separate cases, and phenomena of demyelinization were observed in the surface layers.

As the results of histomorphological analysis showed, in the functionally active structures of tissue of the myocardium, liver, kidneys and spleen disorders of the hemodynamics were established, with disruption of the permeability of the vesicular membranes, the appearance of micronecroses and subsequent tissue dystrophy. Moreover, qualitative and quantitative shifts were revealed in the erythrocytic and leukocytic composition of the blood of irradiated animals, indicating suppression of the hemopoietic function of the bone marrow and lymphatic system. Noted in the composition of the red blood was eosinophilia, neutrophilia and lymphopenia, and lowering of the hemoglobin level and reduction of the number of erythrocytes were observed, which was determined to a considerable degree by the retention of erythrocytes in the bone marrow. In the latter occurred an increase of the number of erythroblastic cells and decrease of cells of the leukoblastic series.

Under the effect of millimeter waves of low intensity the degree of affection depends on the general condition of the organism and evidently is not so great, as the observed disorders are in the main reversible.

A characteristic feature of the biological effect of radiowaves was changes of the state of various sections of the central and vegetative nervous systems which involve directly or indirectly disorders of the principal functions of the organisms (M. I. Yakovlev, 1973).

As a result of investigations conducted by us on animals irradiated with millimeter waves, disorders of conditioned reflex activity have been established: weakening of the stimulatory process, reduction of the size of the latent period in response to different conditioned stimuli (light, noise or pain) and disinhibition of differentiation reactions. Disorders of the stimulatory and inhibitory processes displayed in animals during the repeated effects of millimeter radiowaves can be considered suppression of the function of the central nervous system, although the developed inhibition can be linked with protective-compensatory reaction of the organism in response to irradiation.

In the blood plasma of irradiated animals the content of 17-oxycorticosteroids increased (22.64 ± 2.18 mkg per 100 ml of plasma of the irradiated and 14.98 ± 2.01 mkg of the unirradiated. Along with that, in the adrenal cortex of rats irradiated by millimeter waves the ascorbic acid level dropped 32%. The functional changes established in the content of 17-ocs in the blood plasma and of ascorbic acid in the adrenal cortex of irradiated animals indicate the influence of millimeter radiowaves on the central components of the hypothalamus-hypophysis system -- the adrenal glands with involvement of a number of humoral components.

The conducted investigations showed that in animals subjected to the effect of millimeter radiowaves there was a variation of the content and ratio of catecholamines: in the blood the concentration increased, in the hypothalamus the adrenaline content increased and the noradrenaline level dropped, in the cerebral cortex there was a slight redistribution of catecholamines, in the adrenal glands the adrenaline content doubled and the noradrenaline level dropped by 11% in comparison with that in unirradiated animals. The adrenaline concentration in the adrenal glands remained elevated by 60% 10 days after the irradiation ceased. The obtained results indicate well-expressed changes of metabolism of catecholamines under the influence of millimeter waves both in the hormonal and in the sympathetic components of the sympathetic-adrenal system and also reflect changes of the functional activity of its hormonal and mediator components.

The main mass of the energy in tissues and organs of animal organisms, as is known, is released during the biological oxidation of organic substances, in which case the greater part of it is accumulated in the form of macroergs. The processes of bioenergetics, occurring mainly in the mitochondria with the direct participation of respiratory enzymes which accomplish the terminal stage of biological oxidation, are of universal importance and assure the functional activity of organs and tissues, the synthesis of proteins and nucleic acids, the formation of some intermediate products of exchange, etc.

The conducted investigations showed that the irradiation of animals by millimeter waves caused changes of the processes of oxidative phosphorylation in the liver, kidneys, heart and brain of the animals. The irradiation inhibited the oxygen consumption rate by the mitochondria of those organs in the active phosphorylating state and slowed down the rate of respiration upon exhaustion of the ATP. In the liver and kidneys of irradiated animals the intensity of phosphorylation decreased by 64%, the values of the respiratory controls decreased by 26 and 28% respectively and the changes were less expressed in the heart and brain.

The established disorders of the process of conjugate oxidative phosphorylation in the mitochondria of irradiated animals testify to suppression of energy exchange and can be a result of changes occurring in the electron transport chain. The expressed hypothesis was confirmed by the results of investigations of the activity of enzymes participating in the processes of tissue respiration. In the mitochondria of the livers of irradiated animals the succinate dehydrogenase activity increased by 34% and the cytochromoxidase activity decreased by 37%. Those data testify to destruction of the cytochrome chain.

Very essential in the system of enzymes of cell energy supply is the role of the ATPases regulating the processes of formation and use of the energy of macroergs (V. P. Skulachev, 1969). The conducted investigations revealed in the mitochondria of the livers of irradiated animals an increase of ATPase activity by 63% as compared with similar indicators for the unirradiated. In that case in the liver and spleen of animals irradiated many times by millimeter waves there was a decrease of the content of adenylnucleotides by 61 and 68% respectively.

Investigation of the influence of millimeter waves on the state of nucleic exchange showed that in the liver, spleen, kidneys, lungs and heart there was a reduction of the content of nucleic acids and suppression of the rate of ^{14}C-thymidine in DNA and ^{14}C-uridine in RNA. In a comparison of the results of quantitative determination of nucleic acids it was established that the rate of inclusion of the predecessor in RNA and its content in the organs changes less than the DNA. The change of the nucleic acids concentration was more expressed in the liver, spleen and kidneys than in the heart and lungs. Together with reduction of the nucleic acids content, the quantity of acid-soluble products in the liver and spleen of irradiated animals increased by 35 and 43% and the activity of ribonuclease and DNAase increased 50%.

Under the influence of radiowaves the protein spectrum of the blood serum changed (the albumin content decreased and the number of globulins increased, which led to decrease of the value of the albumin-globulin coefficient) and the number of free amino acids decreased by 22%. An indicator of the reduced level of protein synthesis in the irradiated animals also was the established reduction of the rate of inclusion of ^{14}C-methionine in proteins of the liver, spleen, lymph nodes and thymus. The presented data testify to substantial changes in the protein metabolism which occur under the influence of multiple irradiation of animals by millimeter radiowaves. Evidently the reduction of of the general energy level occurring in the organism under the influence of millimeter radiowaves had an effect on the formation of macroergs and caused a suppression of all functions of the organism, including suppression of synthetic processes but especially of nucleoprotein metabolism, which is very energy-consuming.

The conducted experimental investigations were compared with observations of the state of health of 97 persons working with generators of the millimeter range on the basis of systematic conducting of biochemical analyses. The obtained data confirmed the existence of an influence of radiowaves on the state of metabolic processes in the organism, in particular, changes of the indicators of protein and carbohydrate metabolism were revealed and disturbances of the indicators of immuno-biological reactivity and of the blood system were established.

Thus the conducted investigations indicate high biological activity and an unfavorable influence of millimeter radiowaves on the organism. The expressness of the biological reactions increased with increase of the period of irradiation and depended on individual characteristics of the organism.

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EFFECT OF THE EARTH'S MAGNETIC FIELD ON SOME REGULATORY FUNCTIONS IN HEALTHY PERSONS

Moscow REFERATIVNYY ZHURNAL, MEDITSINSKAYA GEOGRAFIYA in Russian No 3, 1976 Abstract No 3.36.36 by K. Murav'yeva

/Text/ A physiological-mathematical model and correlation analysis combine with a determination of general parameters were used to evaluate the effect of external physical factors on the physiological indices in healthy persons and to evaluate meteotropic reactions. The changes in regulatory functions of man in the course of adaptation to conditions in the European North are especially great in winter. A close, nonlinear correlation was detected between changes in the earth's magnetic field and fluctuations in the excretion of 17-ketosteroids and weighted mean skin temperature. Table.

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HELIOGEOMAGNETIC AND METEOROLOGICAL FACTORS IN THE PROCESS OF ADAPTATION

Moscow REFERATIVNYY ZHURNAL, MEDITSINSKAYA GEOGRAFIYA in Russian No 3, 1976 Abstract No 3.36.35 by K. Murav'yeva

/Text/ The authors propose a program of research--entitled "Adaptation and the Life-Support System"--on human adaptation to unfavorable natural conditions in the area where the Baykal-Amur Railway is under construction. The external factors that act on the body are subdivided into adequate, corresponding to the phenogenotypic properties of the body, and inadequate. Adaptive reactions arise in response to external factors: adaptation syndrome and breakdown of adaptation with different outcomes. It is suggested that mathematical models of the functioning of the body as a whole or of its individual systems be regarded as a standard. The heliogeo-meteorological factors are among the constituents of the life-support system of the region. Climatic conditions in the area of the Baykal-Amur Railway are inadequate for people coming from the European USSR. The characteristics of the constituents of the meteorological regime include calculation of the means, their errors, standard deviations, and coefficient of variation. The weather complex is judged either by Osokin's formula or by the Fedorov-Chubukov method. A comparison of weather evaluations with the physiological functions of individual groups of people is used to construct physiological-mathematical models that could help to predict the health of the people living in the given region. It is suggested that the following be determined in order to define the role of individual factors in altering the physiological functions of the body: (i) "threshold" of force of a stimulus, i.e., the minimum value of a factor that causes a functional deviation, and (ii) time during which the functional deviation takes place after change in the external factor. Complete correlation analysis with algorith 18 (according to Plokhinskiy) is used for the former. For the latter, i.e., to determine the relationship between the physical and physiological factors, mutual correlative functions are determined between the quantities regarded as 2 ergodic processes. Use of the physiological-mathematical model made it possible to establish the threshold values of each factor and the time intervals of its action. Analysis revealed the physiological parameters that clearly respond to change in the physical factors: wighted mean skin temperature, rate of blood flow, and urinary excretion of 17-ketosteroids.

The most sensitive to fluctuations of the meteorological factors are humoral regulation, mental and emotional sphere, cardiovascular system, water-salt homeostasis, and respiratory system. Use of the proposed methods will be of value in predicting the health status of populations in relation to the climate in particular regions.

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