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EFFECT OF RADIO WAVES OF A MILLIMETER FREQUENCY RANGE ON THE BODY OF MAN AND ANIMALS

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/Text/ We made observations of the state of health of 72 engineers and technicians aged 20 to 50 servicing ultra-high frequency generators of a millimeter frequency range from 1 to 10 years. The power flux density sometimes reached 1,000 $\mu W/cm^2$. A total of 30 people (average age, 35), who had no contact with ultra-high frequency energy in their practical activity, constituted the control group. All the examined people were under observation for 3 years and during winter months (December-February) underwent a periodic medical and biological examination.

Workers servicing ultra-high frequency generators complained of fatigue, drowsiness, headaches and loss of memory. The body temperature was normal throughout the period of examination. The changes in the pulse and arterial pressure did not exceed the limits of physiological fluctuations. During a study of the morphological composition of the peripheral blood in individuals servicing ultra-high frequency generators a decrease in the amount of hemoglobin and in the number of erythrocytes, a drop in the color blood index and a tendency toward hypercoagulation were observed. A variational-statistical processing of results showed a significant drop in these indices. An analysis of the white blood picture showed that under the effect of radio waves there was a significant change in the total number of leukocytes (from $4.71 \pm 0.33 \cdot 10^3$ to $4.10 \pm 0.60 \cdot 10^3$ per µl with $5.98 \pm 0.21 \cdot 10^3$ in control) and lymphocytes (from $30.3 \pm 1.20 \cdot 10^3$ to $37.8 \pm 1.13 \cdot 10^3$ per µl with $22.9 \pm 1.62 \cdot 10^3$ in control) and the number of segmentonuclear neutrophils decreased by 20%. At the same time, the number of reticulocytes and thrombocytes was reduced and the osmotic resistance of erythrocytes decreased by 18% and the acid resistance, by 26%. Thus, a pronounced reaction on the part of the blood appeared under the effect of radio waves of a millimeter frequency range, but the changes that appeared were noted for instability.

The immunobiological reactivity of the body as an integral index of the effect of a set of environmental factors is studied ever more extensively in hygienic investigations. It is well known that a decrease in natural immunobiological resistance can be the cause of a high morbidity. To clarify the effect of radio waves of a millimeter frequency range on immunobiological reactivity, the following were determined: barrier properties of the body--microflora of the mucous membrane of the oral cavity and the bactericidal action of the skin--as well as a number of indices reflecting humoral and cellular natural immunity, that is, lysozyme and complement titers and the phagocytic activity of blood neutrophils. These indices characterize the state of natural nonspecific resistance of the body. The results of investigations are presented in table 1.

Table 1. Indices of Nonspecific Resistance in Individuals Servicing Ultra-High Frequency Generators of a Millimeter Frequency Range (M±m)

(1) Показатель	(2) Контрольная группа	Лица, обслуживающие СВЧ-генераторы (3)	
		от (4) 1 года до 5 лет	от (5) 6 до 10 лет
(6) Флора слизистой оболочки полости рта	510±20	697±17	1437±50
P		<0,01	<0,01
(7) Бактерицидность кожи	79,9±4,1	65,2±2,3	63,0±1,9
P		<0,01	<0,01
(8) Титр лизоцима	320	160	160
Титр комплемента (9)	20	10	10
(10) Активность фагоцитоза	25,2±1,03	20,1±0,96	18,3±1,02
P		<0,01	<0,01
(11) Фагоцитарный индекс	1,0±0,02	0,60±0,02	0,7±0,01
P		<0,01	<0,01

Key:

1. Index
2. Control group
3. Individuals servicing ultra-high frequency generators
4. From 1 to 5 years
5. From 6 to 10 years
6. Flora of the mucous membrane of the oral cavity
7. Bactericidal action of the skin
8. Lysozyme titer
9. Complement titer
10. Phagocytosis activity
11. Phagocytic index

As a result of observations it was established that, as compared with the control group, in workers servicing ultra-high frequency generators the seeding of the oral cavity with autoflora microbes increased considerably, the bactericidal action of the skin decreased, lysozyme and complement titers in the blood serum were lowered by one-half and the phagocytic activity of neutrophils decreased.

In the process of observation (during 3 years) significant differences were not detected when the determined indices established during previous periods were compared ($P>0.05$), but during all the periods of observation these values were highly significant as compared with control ($P<0.01$). Thus, there

is reason to believe that some inhibition of the humoral and cellular factors of nonspecific immunity occurs in man under the effect of radio waves of a millimeter frequency range. These changes are not big, but statistically significant, which attests to disturbances in the immunity system.

A more profound clarification of the effect of radio waves on the immunocompetent system and its specific functions was the object of the experiments on animals. The experiments were conducted on 350 mice of the CBA line (250 irradiated and 100 control). The animals were irradiated 15 minutes every day for 20 days in the integrating chamber of an experimental unit operating on the basis of a generator of the type of backward wave tube (OV-12). The wave length was 6.50 mm and the power flux density, 1,000 $\mu W/cm^2$. The use of this intensity stemmed from the data in the literature attesting to the occurring functional changes. Intensities of such an order occur at work places.

The results of experiments showed (table 2) that in the irradiated animals the number of leukocytes in the peripheral blood decreased and the indices characterizing the nonspecific resistance of the body changed. Lysozyme and complement titers, as well as the phagocytic activity of neutrophils, were lowered by one-half and the bactericidal properties of the skin were inhibited. The data obtained indicate that multiple irradiation of animals with radio waves of a millimeter frequency range affects the state of nonspecific reactivity and confirm the results of examination of individuals working with ultra-high frequency generators.

Table 2. Change in Indices of Nonspecific Reactivity in Animals Irradiated With Radio Waves of a Millimeter Frequency Range (M±m)

(1) Показатель	Контрольная группа (2)	Облученные (3)	P
(4) Число лейкоцитов в 1 мкл	$7,2 \cdot 10^3$	$6,1 \cdot 10^3$	<0,05
(5) Фагоцитарная активность, %	32,3±1,07	19,6±1,22	<0,001
Фагоцитарный индекс (6)	1,0±0,1	0,56±0,04	<0,001
(7) Титр лизоцима	100±4,6	40±1,4	>0,05
(8) Титр комплемента	25±1,0	10±2,0	<0,05
(9) Бактерицидность кожи, %	98±1,39	57±2,12	<0,01

Key:

1. Index
2. Control group
3. Irradiated
4. Number of leukocytes per µl
5. Phagocytic activity, %
6. Phagocytic index
7. Lysozyme titer
8. Complement titer
9. Bactericidal action of the skin

A histological investigation of internal organs disclosed changes in the thymus, spleen and lymph nodes. In the cortical substance of the thymus the number of mature lymphocytes decreased and cells with pyknotic nuclei appeared. Dilatation and plethora of sinuses were noted in the red pulp

of the spleen and the number of immature lymphoid cells decreased in the center of follicle reproduction. In regional lymph nodes and the spleen the number of plasma cells decreased by 20 to 30% ($P<0.01$). The total mass of the spleen, thymus and regional lymph nodes was lowered considerably in irradiated animals, as compared with control animals. The disclosed morphological changes can be considered a sign of nonspecific irritation of the lymphoid tissue in animals.

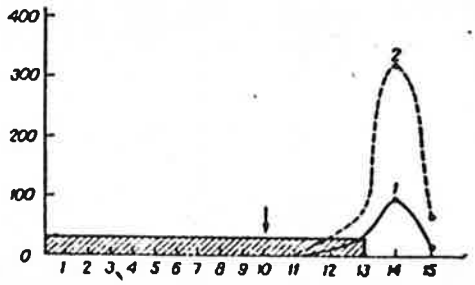
Evaluation of the resistance of the body to induced infections is an informative criterion in the study of the effect of microradio waves. Under the effect of irradiation with radio waves of a millimeter frequency range resistance to infection induced with a typhoid culture was lowered by 40% in animals. The difference was manifested with special clarity when mice were infected with small doses of the causative agent (on the order of 2 to 4 LD_{50}), with which mortality in the control group did not exceed 10%. When preirradiated animals were infected with a typhoid culture, the number of antibodies in their blood serum was lowered by one-half or one-third as compared with control. During reinfection with this culture 3 weeks after irradiation changes in the antibody level in the blood of animals were not detected, but their susceptibility to infection increased by 20% and more. Decrease in the function of immunological mechanisms may be one of the causes of the more severe course of microbial infections in case of irradiation with radio waves.

Specific immunity in animals was attained by immunization with a typhoid vaccine or a tetanic anatoxin. In animals irradiated simultaneously with immunization, when infected with the causative agent of typhoid fever or a tetanic anatoxin, mortality increased by 30 to 40%, the number of leukocytes decreased and the antibody level and lysozyme and complement titers in the blood serum were lowered. The data obtained indicate that radio waves of a millimeter frequency range affect specific immunity and contribute to the generalization of the infectious process.

To clarify the cause of activation of the development of infection and increase in the death of mice, the effect of radio waves on the characteristics of formation of specific immunity was investigated. Animals were irradiated for 10 days and then immunized with ram erythrocytes (0.2 ml 50% suspension). Irradiation was continued and on the 4th day of immunization the number of antibody forming cells in the spleen was calculated by the Yerne method. The intensity of antibody formation was lowered in irradiated animals (see figure). On the fourth day after immunization the number of antibody forming cells in the spleen of irradiated mice was reduced by one-third as compared with control ($P<0.001$) and the titers of humoral antibodies were also lower, that is, 256 in experiments and 726 in control. In secondary immunization activation of antibody formation was noted. However, the average number of antibodies and antibody forming cells remained below the control number.

The data obtained attest to the inhibiting effect of radio waves of a millimeter frequency range on the immunocompetent system. The established decrease in immunobiological reactivity may be largely due to the changes in the hematopoietic system, the neuroendocrine system and so forth. In connection with

this it seemed advisable to investigate the state of the hypophysial-adrenal system according to the content of 17-OCS in the blood (N. A. Yudayev and Yu. A. Pankov) and the functional state of the sympathico-adrenal system according to the number of catecholamines in the blood and tissues (V. V. Men'shikov).



Inhibition of Antibody Synthesis in Animals Irradiated With Radio Waves of a Millimeter Range

X-axis (cross-hatched)--day of irradiation; Y-axis--number of antibody forming cells per 10^6 spleen cells (arrows--time of antigen administration); 1--irradiated animals; 2--control animals.

It can be seen from the data presented in table 3 that an increase in the amount of 17-OCS in the blood of animals after irradiation was combined with a decrease in the content of ascorbic acid in the adrenal cortex as compared with control indices. Thus, systematic irradiation with millimeter waves produces marked changes in animals in the hypothalamus-hypophysis-adrenal cortex, which, as is well known, performs a special role in triggering and regulating the adaptive reactions of the body in response to disturbing effects.

Since catecholamines have the property of rapidly joining in ensuring the adaptive reactions of the body, a question arose as to the characteristics of the changes of catecholamines in animals subjected to multiple irradiation with waves of a millimeter frequency range. As a result of irradiation changes of different directions in the content of adrenalin and noradrenalin both in brain tissues and in the blood occurred. It is noteworthy that, along with a decrease in the noradrenalin level in the hypothalamus, adrenalin concentration in the blood and adrenal glands increased, that is, changes characteristic of a state of stress appeared (E. Sh. Matlina). At the same time, the change in the activity of hypothalamic-hypophysial and sympathico-adrenal systems attests to the presence of a reaction of a nonspecific nature appearing in response to an unfavorable effect and developing according to the mechanisms of bodily reactions to stress situations. Apparently, the mechanism of action of radio waves of a millimeter frequency range is based on the onset of a state of stress having a direct effect on the body by means of the hypothalamic-hypophysial-adrenal system.

Table 3. Change in the Content of 17-OCS, Ascorbic Acid and Catecholamines in the Blood and Tissues of Animals Irradiated With Radio Waves of a Millimeter Frequency Range (Mtm)

(1) Показатель	Контрольная группа (2)	Облученные (3)
(4) 17-ОКС, мкг в 100 мл плазмы	13,78±1,57	22,21±2,03
P		<0,01
(5) Аскорбиновая кислота, мг на 100 г ткани	27,63±0,91	18,47±0,72
P		<0,05
(6) Адреналин, мкг/г:		
(8) в крови (7)	1,22±0,11	1,60±0,13
(8) в гипоталамусе	0,23±0,02	0,45±0,04
в надпочечниках (9)	3,50±0,27	5,17±0,60
P		<0,05
(10) Норадреналин, мкг/г:		
(8) в крови (7)	2,21±0,15	3,97±0,20
(8) в гипоталамусе	0,50±0,06	0,32±0,01
в надпочечниках (9)	2,63±0,17	3,11±0,26
P		<0,05

Key:

1. Index
2. Control group
3. Irradiated
4. 17-OCS, µg per 100 ml of plasma
5. Ascorbic acid, mg per 100 g of tissue
6. Adrenalin, µg/g
7. In the blood
8. In the hypothalamus
9. In adrenal glands
10. Noradrenalin, µg/g

Conclusions

1. During an examination of individuals servicing ultra-high frequency generators of a millimeter frequency range for 5 to 15 years tendencies toward a fluctuation in the content of red and white blood elements, increase in the seeding of the oral cavity with autoflora microbes, decrease in the bactericidal action of the skin and in lysozyme and complement titers in the blood serum and reduction in the phagocytic activity of neutrophils are observed.

2. During systematic irradiation of animals with radio waves of a millimeter frequency range and a power flux density of 1,000 $\mu W/cm^2$ significant differences in the indices of nonspecific reactivity, drop in the total mass of lymphoid organs and morphological changes in the thymus, spleen and lymph nodes were established. The number of plasma cells decreased in regional lymph nodes and the spleen.

3. Under the effect of irradiation in animals resistance to infections induced with a typhoid culture or a tetanic toxin decreases and specific immunity developed by immunization with a typhoid vaccine or a tetanic anatoxin is inhibited.

4. Systematic irradiation produces in animals a change in the activity of hypophysial-adrenal and sympathico-adrenal systems.

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