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HYGIENIC PROBLEMS OF THE EFFECT OF MICROWAVE ELECTROMAGNETIC FIELDS ON THE BODY

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HYGIENIC PROBLEMS OF THE EFFECT OF MICROWAVE ELECTROMAGNETIC FIELDS ON THE BODY

[Article by Candidate of Medical Sciences M.P. Troyanskiy; Moscow, Gigiyena i Sanitariya, Russian, No 8, 1972, submitted 28 March 1972, pp 87-92]

The vigorous development of radioelectronics and its introduction into the various branches of the national economy has led to the result that virtually all the earth's population has to some degree become subjected to the effect of radio waves.

Radio-frequency electromagnetic waves are now widely used in radio communication, broadcasting, television, medicine, radar, radio navigation, radio astronomy, nuclear physics, metallurgical and machine-building industry (for welding, tempering, melting, and vibroforging metallic goods), gluing plastics and wood products, and so on.

Problems have arisen concerning the determination of the injury level in the human body produced by radio waves, establishment of maximum permissible human exposure levels, and development of preventative and protective measures. At present, the classification of radio frequencies presented in Table 1 has been adopted by the hygienic practice.

Table 1

Classification of Radio Frequencies

Frequencies	High (HF) 100 kHz-30 MHz			Ultrahigh (UHF) 30-300 MHz	Superhigh (SHF [Microwave]) 300-300,000 MHz		
Wavelengths	Long 3-1 km	Medium 1 km-100 m	Short 100-10 m	Ultrashort 10-1 m	Decimeter 1 m-10 cm	Centimeter 10-1 cm	Millimeter 1 cm-1 mm

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The sources of HF, UHF, and SHF electromagnetic fields can be various types of generators, inductors, transmitter blocks, feeder lines, capacitors, antenna systems, and others. The persons operating the generators and the transmission system for radio-frequency electromagnetic oscillations can be subjected to the effect of different HF, UHF, and SHF ranges. When designing, testing, tuning, and operating the stations and individual units generating electromagnetic energy, waves can be radiated into the working area. This occurs with poor shielding of the transmitter blocks and waveguide channels, irrational location of antenna feeder systems, and so on, as well as from neglect of accident prevention. The personnel and population not professionally linked with the transmitting apparatus can sometimes be exposed to the effect of radio waves from powerful antenna systems.

Radio waves in the superhigh frequency range are the most widely used. SHF generators of various ratings, from several tens of milliwatts up to megawatts per pulse, are being utilized in nearly every branch of the national economy. It has been established that the biological effect of an SHF field has a number of properties which differ from those of a UHF field. The widespread distribution of microwave generators, ever increasing number of persons exposed to microwaves, and great difficulties in protecting them from the effect of the powerful antenna fields of radar stations has advanced the problem of the biological effect of microwaves to major prominance. Contemporary superpower RLS [radar stations] can create radiation levels exceeding the maximum permissible level by hundreds of times at a distance of 2-3 km. At present, more than 1,000 studies by domestic and foreign authors have been devoted to the biological effect of microwaves.

Investigations into the effect of a microwave field on the human body and animals primarily confirm the fact that microwave radiations possess a high biological effectiveness over a wide range of wavelengths. The nature and expressiveness of the microwave field's effect on the body depend mainly on the wavelength, intensity, duration, and irradiation character (pulsed, continuous, in a fixed beam or rotating antenna mode, and so on). The greatest interest as well as the most practical value lies in data on nonthermal -- specific -- microwave field effects*. In its most general form, the specific effect of a microwave field appears in functional changes in the nervous, cardiovascular, and other systems. This is confirmed in an experiment on animals using conditioned reflex procedures, electroencephalography, electrocardiography, blood pressure changes, and so on, and also by biochemical, morphological, and biophysical data (Z. V. Gordon; A. S. Presman, 1963, 1968).

Data obtained by studying volunteers is of great value. An analysis of the body changes under the influence of microwave irradiation indicates that the damage pattern is primarily determined by the changes in the nervous system. It is therefore natural that the attention of researchers, particularly Soviet, is being devoted to investigation of the nervous system

*It is customary to consider that the nonthermal effect occurs during the effect on the body of a power flux density of 10 milliwatts and less.

reaction to microwave effects. It has been established that weak effects stimulate the central nervous system, while strong effects depress it, where parabiotic stages can be observed in the latter case (I. P. Bychkov).

A distinguishing feature of the changes produced in the body by nonthermal microwave effects is their reversibility. This implies one of the major hygienic measures, that is, discontinuing contact with the microwave field for a definite time. It should also be remembered, however, that the concept of "reversibility" is most often used in its clinical sense, while there are very few studies devoted to a deep investigation of the restoration processes after microwave exposure.

Indications of a variation in the influence of the microwave effect in the course of frequent repeated exposures are frequently encountered in the literature. These changes can be expressed either in decreased shifts proportional to the repeated exposures, or in the intensity of the shifts. Processes of adaptation and accumulation were obviously expressed in a similar type of changes. In particular studies, it was discovered that in the course of systematic irradiations of experimental animals by microwave fields of different frequency ranges, a relatively light body adaptation to the microwave field effect was observed. It was expressed in the fact that in the majority of animals, the change in conditioned reflexes, as well as the changes in circulation, digestion, urination, and interchange of gases, were adjusted in proportion to the exposure repetition. The adaptation rate of the various functions was not identical. The cortex of the large cerebral hemispheres adapted most rapidly to SHF effects, while the other body systems, particularly digestion, adapted appreciably slower.

The adaptation phenomena are supported by the stabilization of biochemical changes in proportion to the increased amount of exposure and less expressiveness of morphological and histological changes for extended exposures than for more frequent exposures having a flux density of the same power (PPM).

Adaptation processes have also been observed when examining people. In the first weeks and months of work under conditions of microwave field influence, a characteristic reaction appeared in a significant fraction (up to 70 percent) of persons, expressed by a poor state of health, breakdown, increased fatigue, general weakness, and headaches. In the subsequent months, the state of health improves, which is related to the adaptation phenomena.

Next, in proportion to the duration of work under conditions of the microwave field effect, the health of the people again worsens (E. A. Drogichina and coauthor(s), D. A. Ginzburg, and M. N. Sadchikova).

Changes in olfactory sensitivity are more distinct in the initial period of work under microwave exposure conditions (up to 1 year). After this, the olfactory sensitiveness begins to normalize, being replaced in proportion to the microwave field effect duration by pronounced changes

(Z. V. Gordon and Ye. A. Loginova). Thus, the development of adaptation changes under the chronic effects of a microwave field can be considered as a principle. However, an estimate of these phenomena requires great caution. First of all, attention is devoted to the development following adaptations of the functional state's deterioration, which confirms the fact that adaptation is only possible up to a certain limit before which the reparation processes cease to neutralize the altering changes. It is clear that the nervous and endocrine systems play a large role in the adaptation mechanisms (I. R. Petrov, A. G. Subbota, and Ye. A. Lobanova).

With chronic microwave field exposure, the accumulation effects in the body can be observed along with the adaptation processes. The fact that there is accumulation in itself indicates that the full recovery time after a previous effect exceeds the interval between the effects being repeated. This implies that the matter of reversibility of changes due to the SHF effect, particularly of the full recovery periods, are of major importance in understanding the accumulation effects and in developing measures to prevent cumulative shifts. Nevertheless, this matter has as yet far from been studied sufficiently. Apparantly, the cumulative phenomena are related to the functional state deteriorations which appear following the adaptations (for example, the development of beyond-threshold retardation after the stimulation phase of the conditioned reflexes and the appearance of neurotic states in dogs after normalization of the conditioned reflex activities).

The following fact deserves mention in this connection. When persons were exposed to centimeter waves with a PPM of up to 20 microwatts per square centimeter, the skin temperature reaction was insignificant for people not previously exposed to a microwave field, whereas a pronounced skin temperature rise proportional to the professional status was observed for persons earlier subjected to microwave effects (Yu. A. Osipov). Under these conditions, particular interest lies in the fact that the person absorbs a microwave field conditional stimulus of very low intensity.

The adaptation and accumulation processes occur in complex interrelations. Both a transition from adaptation to accumulation and a parallel development of the accumulation and adaptation phenomena can be observed. In specific studies of the adaptation and accumulation phenomena, it was observed that adaptation to the effect of microwave thermal and nonthermal intensity can have a retardation, stimulation, and phase character. The retardation type of adaptation develops through the fact that following the most pronounced depression of the functions in question at the moment of the first exposures, ever less distinct changes appear during the subsequent effects. The stimulation type of adaptation develops during the initial intensification of the reaction effects, replacing them with depression. In phase adaptation, the initial effects produce a depression of the functions, and then the stimulation effects gradually develop (Howland and coauthor(s)).

The role of the intervals between effects for the direction of the shifts has been shown (A. G. Subbota, 1957). Cumulative effects were observed for small intervals between the reactions, and the adaptation phenomena developed with an increase of the intervals. Under conditions of the simultaneous influence on the body of a microwave field and unfavorable environmental factors (heat, noise, intense light, and so on), complex relationships developed between these adapted reactions in the form of a mutual intensification or reduction. The simultaneous effect on the body of two superhigh frequency ranges led to an attenuation of the adaptation. This data is of appreciable theoretical value and should be considered for normalization of microwave radiations and also when carrying out specific hygienic and general health measures.

The pathogenesis of microwave affection is still basically unclear at the present. This concerns both the intimate physical and chemical changes, and also the basic pathophysiological mechanisms lying at the basis of development of the chronic microwave affection syndrome.

The clinical observations and experimental data testify to the fact that one of the major links in the development of a unified pathological process for microwave irradiation in the body is the disruption of the function of the central nervous system, in particular, the function of the middle brain. Up to the present, the large role of the hypothalamus in regulating the body temperature, metabolism, sexual functioning, blood pressure, functions of the gastroenteretic tract, and also in regulating sleep and alertness has been demonstrated. Affection of the hypothalamus manifests itself in changes in the enumerated functions. Of course, in disrupting the hypothalamus functions, a considerable role is played by changes under the influence of microwave cortical effects. However, it should be remembered that the hypothalamic region is highly and directly sensitive to beam effects.

The microwave effect syndrome is comprised of a number of reactions each of which, taken separately, is not specific for such a reaction. The asthenic states, so characteristic of the microwave affection syndrome, can be observed under the most diverse effects. This is also true for shifts on the side of the cardiovascular system, blood, and so on. In the large, then, all these reactions appear as a definite whole, which permits the authors to refer to the microwave affection syndrome (N. V. Tyagin). The syndrome is characterized by functional changes in the nervous system, particularly its vegetative section, which develop in the phenomena of asthenia and disruptions of cardiovascular regulation with an inclination toward vagotonia reactions (bradycardia, hypotonia, and EKG changes).

The biochemical shifts appearing in the body during microwave irradiation have not been studied sufficiently. In particular, there is very little data on changes in the vitamin balance and mineral exchange. Meanwhile, data of this type would allow a corresponding change in the character of the diet for preventative purposes.

An explanation of the dependence between the various parameters of the microwave effect and the body reaction character is complex but needed for the problem's urgent solution. The nonthermal effect of microwaves should by considered proven beyond doubt, where certain effects are observed for very small influence intensities (units and tens of microwatts per square centimeter).

This gives rise to the problem of a most careful investigation of threshold reactions to microwave effects and accumulation processes for such small intensities. This problem becomes particularly acute in relation to the fact that both the personnel maintaining the generators and the surrounding population can be subjected to systematic microwave exposure.

Convincing evidence has been obtained on the unequal biological effectiveness of different wave ranges, diverse RLS operating modes, and so on. It has been established that decimeter waves are the most dangerous for the body, while the meter and centimeter waves are less dangerous. Field modulation proves to be an appreciable influence on the nature of the body reactions. The growth of RLS ratings will pose a question concerning the determination of maximum permissible magnitudes of not only the average, but also the pulsed PPM.

The pulse duration and space factor should also be considered, since for a sufficiently high pulse power, the irreversible changes in tissues can arise during a very short time (M. P. Troyanskiy and Yu. V. Sebrant).

The protection of persons from the effect of external radio fields is assuming vast hygienic meaning. The biologists, hygienists, clinical pathologists, physicists, and engineers face a complex problem: how to provide complete safety for the personnel and population falling within the active zone of radio fields under the conditions of modern activity to force the growth of generator installation ratings, antenna system outputs, and so on in the presence of a significant quantity of inhabited centers. In this connection, it is extremely important to develop a unified basic system of protection from the reradiation of radio fields, particularly external fields. A primary role in solving the problem of possible exposure is to derive a computational method (prognosis) for radio fields.

Unfortunately, the existing procedures are complex and cumbersome and not always acceptable. There are no legalized methods for calculating fields in near and intermediate zones.

Another trend in the system of protection and health measures is to upgrade the shielding properties of various construction materials by including additives which will dampen electromagnetic energy. The presence of a whole series of materials which reflect and absorb electromagnetic energy still cannot totally provide guaranteed safety.

In order to provide protection from the reradiation of radio fields, Sanitation Norms and Rules for Work With Sources of Electromagnetic Fields of High, Ultrahigh, and Superhigh Frequencies No 878-70 have been directed and confirmed as of 30 March 1970 by the Deputy to the Main Sanitary Inspector of the USSR. These norms and rules have established the following maximum permissible intensities for the 300-30,000 MHz microwave range: for exposure during an entire working day -- 10 microwatts/cm^2, for exposure of no more than 2 hours in a working day -- 100 microwatts/cm^2, and for 15-20 minutes exposure in a working day -- 1,000 microwatts/cm^2 (with the compulsory use of safety glasses).

According to these norms, the irradiation intensity should not exceed 1 microwatt/cm^2 for persons not professionally connected with the irradiation and the population.

The adopted standards are based on sizable experimental material and are oriented toward protecting the health of workers, but, all the same, the use of time standards for the permissible levels is cumbersome in certain situations. In particular, it is not clear how to evaluate the simultaneous effect of several radiation sources from different directions, how to treat pulsed, continuous, and intermittent (scanning) radiation, and so on. These and other questions have been discussed at conferences and symposiums, but, unfortunately, they have yet to be solved in practice.

The study of the biological effect of microwave fields and protective measures is an urgent problem. The need has arrived of widely acquainting doctors, including radiologists, hygienists, clinical pathologists, and others, with the fundamentals of the biological effect of radio-frequency electromagnetic fields and the principles of organizing protective and preventative measures.

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