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## BIOLOGICAL EFFECT OF MICROWAVES OF LOW INTENSITY\*

Z. V. GORDON, Ye. A. LOBANOVA, I. A. KITSOVSKAYA and M. S. TOLGSKAYA

Institute of Work Hygiene and Occupational Diseases, U.S.S.R. Academy of Medical Sciences, Moscow

**Abstract**—Russian work on the effects of microwaves on rats is summarized. The intensities used were in the range 1 to 100 mW/cm<sup>2</sup>, and the wave lengths used were between a few mm and 10 cm. The effects measured were temperature changes, lethal effects, changes in swimming endurance, changes in blood pressure, changes in higher nervous activity, and morphological effects. In general, as the wave length was reduced, the changes diminished in degree. Effects were observed even when the intensity was as low as 1 mW/cm<sup>2</sup>.

### 1. INTRODUCTION

RESEARCH on the effects of centimetre waves on the animal organism has been going on for a number of years in the institutes of this country and abroad. These investigations have afforded evidence of the development of a number of functional and morphological changes in the experimental animals. Investigations of special importance are those dealing with the effects of irradiation with centimetre wave intensities below the heat-effect producing level (GORDON and LOBANOVA, 1960; KITSOVSKAYA, 1960; LOBANOVA and TOLGOSKAYA, 1960; NIKOGOSYAN, 1960; TOLGOSKAYA and GORDON, 1960; TOLGOSKAYA, GORDON and LOBANOVA, 1960).

The subject of this communication is the comparative evaluation of the biological effects of mm and cm waves.

### 2. TEMPERATURE CHANGES

We know that cm wave irradiation intensities of up to 10 mW/cm<sup>2</sup> do not produce any increase in the body temperature of animals (GORDON and LOBANOVA, 1960). Investigations on the temperature reactions of animals irradiated with mm impulse waves have shown that an intensity of 10 mW/cm<sup>2</sup> increased the body (rectal) temperature by 0.4°C.

It should also be noted that with mm waves, just as with cm waves, the maximum temperature increase was reached in the initial period of

irradiation after 10 to 20 min, and the temperature then persisted at this level for the rest of a 60-min irradiation.

### 3. SURVIVAL AND ENDURANCE TESTS

It has been established that 50 per cent of the animals (albino rats) survived 3-hr irradiation of intensity 100 mW/cm<sup>2</sup> with mm waves. With cm waves the same survival percentage could only be observed after irradiation of the animals for 10 or, at most, 15 min.

A single irradiation with either mm or cm waves led to a reduction in the animals' tolerance for physical exertion—swimming. The swimming endurance was greater after irradiation with mm waves (Table 1, column 3). When the irradiation intensity was increased, and even though there was a corresponding reduction in the time of exposure, the animals' swimming endurance was reduced but was still greater than in the case of irradiation with cm waves (Table 1, column 2).

### 4. EFFECTS ON BLOOD PRESSURE

Experimental investigations on animals subjected to long periods of irradiation with cm and mm waves have revealed the development of hypotensive effects after varying periods, depending on irradiation intensity and wave length.

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Without dwelling in detail on the changes produced by high-intensity irradiation (40 and 100 mW/cm<sup>2</sup>), we would merely note that the reactions with these intensities were essentially

Table 1. Average duration of swimming

Waves	Intensity of irradiation		Control
	40 mW/cm <sup>2</sup> · 10 mW/cm <sup>2</sup>		
	Duration of irradiation		
	30 min	90 min	
mm	10' 32"	18' 24"	57' 38"
cm	8' 08"	10' 20"	62' 02"

similar in character, an initial period of increase of blood pressure being followed by gradual decline.

When the irradiation was of low intensity—up to 1 mW/cm<sup>2</sup>—reactions of this type were only observed with 10 cm waves.

Hypotensive effects of any marked degree developed later in animals given low-intensity, the irradiation was with mm waves. Also, the recovery period was longer after irradiation with 10-cm waves.

### 5. EFFECTS ON HIGHER NERVOUS ACTIVITY

The acoustic method, as improved by L. V. KRUSHINSKII, was used to demonstrate the effect of the irradiation on the animals' higher nervous activity. Albino rats, sensitive to acoustic stimulation (responding to a bell by a specific motor reaction or by convulsive attacks of varying intensity), were used in the investigation.

Reduced sensitivity to the acoustic stimulus (absence of reactions or reduction in the number of convulsive attacks) was observed in 100 per cent of cases during chronic 10 cm wave irradiation of intensity up to 10 mW/cm<sup>2</sup>. When the irradiation was of the same intensity with 3 cm waves, changes in the reactions to the acoustic stimulus were noted in only 58.5 per cent of cases, and the changes were much less pronounced and developed much later than in the animals irradiated with 10 cm waves. Fluctua-

tions in the reactions of animals irradiated with mm waves of the same intensity could be observed during the first 2 months of irradiation. Persistently reduced reactions and increased latent periods were only observed in 50 per cent of cases after irradiation for 7 or 8 months.

Reduced sensitivity to the acoustic stimulus was not confined to animals given irradiation of intensity 10 mW/cm<sup>2</sup>. Changes were observed in the reactions of 81.6 per cent of animals subjected to 10-cm wave irradiation of intensity 1 mW/cm<sup>2</sup>.

Irradiation with microwaves in the different ranges thus led to similar types of change in higher nervous activity—reduced sensitivity to an acoustic stimulus and increase of the latent period. The reactions were, however, more intense and developed more rapidly with 10-cm than with mm waves.

### 6. MORPHOLOGICAL EFFECTS

Morphological examination of the organs of animals subjected to high-intensity microwave irradiation revealed considerable vascular disturbances in all viscera and in the nervous system, associated with degenerative changes in the nerve cells and in the cells of parenchymatous organs. These morphological changes were equally pronounced over the range of microwaves from 10 cm downwards and were apparently due to significant overheating of the body.

Low-intensity microwave irradiation produced only slight morphological changes in the axon-soma and axon-dendrite interneuron connections of the cerebral cortex and in the receptor and interoceptor apparatuses in various receptor zones (skin, intestinal wall, the wall of the urinary bladder, myocardium, aorta etc.). The changes were particularly marked in the receptor apparatus of the skin. These changes were reversible and disappeared 3 to 4 weeks after the end of irradiation.

In addition to these changes, low-intensity irradiation led to histochemical shifts, in the form of reduction in the nucleoprotein contents of various cells and tissues, most pronounced in

the skin and its derivatives. These histochemical changes developed before the usual morphological changes and were reversible.

The degree, and sometimes also the character of the changes in interneuron connexions and in receptor and interoceptor apparatuses and of the histochemical changes depended on the microwave range. It should be emphasized that the changes in the receptor apparatus of the skin were particularly marked with mm waves.

### 7. DISCUSSION

One thus gained the impression that, with low-intensity irradiations, the degree and sometimes even the nature of the functional and morphological changes depended on the wavelength. As the wavelength became shorter (from 10 cm downwards), certain functional and morphological changes in the bodies of the irradiated animals diminished in degree.

A feature of the reaction of animals to microwaves was the more pronounced change in the receptor apparatus of the skin and the slight increase of (rectal) temperature in animals submitted to low-intensity mm wave irradiation.

Apparently a reflex increase of body temperature took place as a result of the stimulation of a large number of thermoreceptors in the skin by the mm waves, which are mainly absorbed in the superficial layers of the skin.

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\*It is regretted that it has not been possible to obtain full references for this paper.

### EFFETS BIOLOGIQUES DE MICRO-ONDES D'INTENSITÉ BASSE

Résumé—Il s'agit d'une vue d'ensemble de travaux soviétiques au sujet des effets de micro-ondes sur les rats. On a employé des intensités de 1 à 100 mW/cm<sup>2</sup>, et des longueurs d'ondes de quelques mm à 10 cm. Ont été mesurés les effets que voici: changements de température, effets léthaux, variations de l'endurance à la nage, variations de la pression sanguine, changements de l'activité nerveuse supérieure, effets morphologiques. En règle générale, les changements vont décroissant lorsqu'on réduit la longueur d'onde. On a observé des effets même à l'intensité de 1 mW/cm<sup>2</sup>.

### DIE BIOLOGISCHE WIRKUNG VON MIKROWELLEN GERINGER STÄRKE

Zusammenfassung—Sowjetische Arbeiten über die Wirkungen von Mikrowellen auf Ratten werden hier zusammengefaßt. Die Intensität lag im Bereich von 1 bis 100 mW/cm<sup>2</sup>, und die Wellenlängen lagen zwischen wenigen mm und 10 cm. Gemessen wurden Temperaturschwankungen, letale Effekte, Veränderungen in der Schwimmfähigkeitsdauer, Wechsel des Blutdrucks, Veränderungen der höheren Nerventätigkeit und morphologische Effekte. Im allgemeinen ließen die Veränderungen gradmäßig nach, wenn die Wellenlänge reduziert wurde. Selbst bei einer Stärke von 1 mW/cm<sup>2</sup> wurden noch Effekte beobachtet.

### Биологический эффект микроволн низкой интенсивности

Резюме — Дается сводка работы советских ученых о воздействии микроволн на крыс. Применялись интенсивности в пределах 1–100 м.в.т./см<sup>2</sup> и волны длиной от нескольких мм до 10 см. Измеряемые эффекты включали изменения в температуре, смертоносные воздействия, изменения в испытаниях на выносливость в плавании, изменения в давлении крови, в повышенной нервной деятельности и морфологические эффекты. В общем, по мере того как сокращалась длина волн, степень изменений понижалась. Наблюдение эффектов производилось даже тогда, когда заниженность интенсивности доходила до 1 м.в.т./см<sup>2</sup>.

GORDON