Session E. Occupational Exposure and Public Health Aspects of Microwave Radiation

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CLINICAL MANIFESTATIONS OF REACTIONS TO MICROWAVE IRRADIATION IN VARIOUS OCCUPATIONAL GROUPS

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Studies on the biological action of microwaves have been widely conducted in the USSR over the past 20 years. The investigations have been devoted mainly to hygienic, experimental, clinical and ecological aspects of the problem. Studies are being performed in the USA, Poland, Czechoslovakia, and in Western Europe (21, 22, 23, 24).

Results of our own clinical observations of many years, as well as literature data (2, 5, 6, 9, 12, 18, 22, 23) show that, as a consequence of prolonged work involving exposure to microwaves, changes take place in the functions of the nervous, cardiovascular and other systems of the organism leading to a characteristic complex of symptoms. A distinct form of occupational disease — microwave or radiowave sickness — has been identified as a nosologic entity.

However, up till now, numerous questions concerning the clinical course and pathogenesis of certain lesions have been insufficiently elucidated.

The present communication presents clinical observations on the health status in two groups of workers engaged in the regulation, tuning and testing of diverse radio-equipment emitting radiation in the microwave range.

Both groups were comparable with respect to sex and age, but differed in intensity of exposure and duration of work. Young men with a long (5—15 years) history of employment with microwave sources predominated in both groups. Those in the first group (1000) were subject to the influence of a power density of up to a few mW/cm². The second group (180) comprised people exposed to microwaves at lower

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intensities, which as a rule did not exceed several hundredths of a mW/cm². More significant exposure could have taken place during extremely short periods.

Some nervous tension during work could not be excluded. A group of people (200), matched with respect to sex, age and character of work processes which did not involve exposure to microwaves, served as a control.

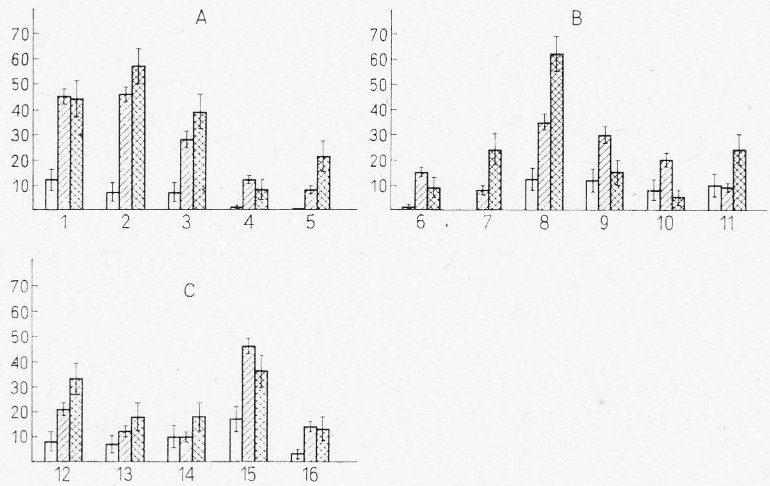

Fig. 1. Changes in the nervous and cardiovascular systems among workers exposed to microwaves and control subjects. Ordinate — frequency of changes in percentages; abscissa — main indicators: A — neurological, B — autonomic vascular and C — cardiac. White columns — control; oblique shading — persons of the first group, exposed previously to periodic action of microwaves of substantial intensities; double shading — persons of the second group working under conditions of exposure to microwaves of lower intensities. All indicators are presented with confidence limits. 1 — feeling of heaviness in the head, 2 — tiredness, 3 — irritability, 4 — sleepiness, 5 — partial loss of memory, 6 — inhibited dermographism, 7 — expressed dermographism, 8 — hyperhidrosis, 9 — bradycardia (upon counting), 10 — arterial hypotension, 11 — arterial hypertension, 12 — cardiac pain, 13 — dullness of the heart sounds, 14 — systolic murmur, 15 — bradycardia (according to ECG), 16 — lowering of deflections T I and T II.

Figures 1 and 2 show the frequency of the main subjective and objective changes in the subjects examined, as well as the relationship of these changes to duration of work under given conditions.

Inspection of Figure 1 shows that people of the first and second group significantly differed from the control in frequency of such complaints as heaviness in the head, tiredness, irritability, drowsiness during the day, anxiety and light sleep at night and partial loss of memory. In both groups attention was drawn to various autonomic vascular changes: inhibited or expressed dermographism, hyperhidrosis of the hands, instability of pulse and arterial pressure increasing during functional loading (ortho-clinostatic test, Aschner's test, graded physical loading), tendency to bradycardia (pulse rate of up to 60 per min) and arterial hypotension (systolic pressure of up to 100 mm Hg) or hypertension (systolic pressure of more than 135 mm Hg) appearing against the background of normal arterial pressure and accompanied by narrowing of retinal arteries (1).

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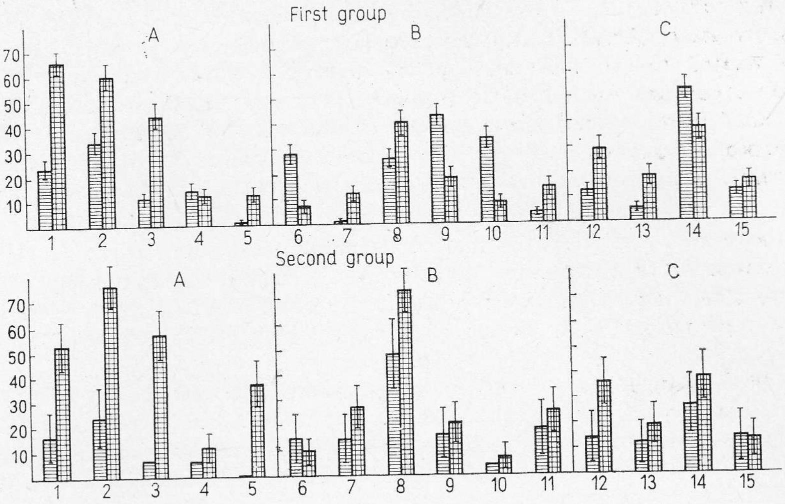

Fig. 2. Changes in the nervous and cardiovascular systems among those under 40 with varying duration of work involving exposure to microwave irradiation. Ordinate — frequency of changes in percentages, abscissa — main indicators: A — neurological, B — autonomic vascular and C — cardiac. Horizontal shading — duration of employment of less than 5 years; double shading — duration of employment of 5—10 years. First group — persons exposed previously to periodic exposure to microwaves of substantial intensities; second group — those working under conditions of exposure to microwaves of lower intensities. All indicators are presented with confidence limits. 1 — feeling of heaviness in the head, 2 — tiredness, 3 — irritability, 4 — sleepiness, 5 — partial loss of memory, 6 — inhibited dermographism, 7 — expressed dermographism, 8 — hyperhidrosis, 9 — bradycardia (upon counting), 10 — arterial hypotension, 11 — arterial hypertension, 12 — cardiac pain, 13 — dullness of the heart sounds, 14 — bradycardia (according to the ECG), 15 — lowering of deflections T I and T II.

Functional thyroid changes with increase of its activity occurred not infrequently (15).

Predominant complaints concerned cardiac pain of a lancinating or boring, and less frequently constricting, character radiating to the scapula and arm. The heart sounds were dull and functional systolic murmur over the heart apex was present.

Electrocardiographic examination revealed minor disturbances of intraventricular conduction (conduction of the initial part of the ventricular complex amounted to 0.10 s or 0.11 s and more), sinus bradycardia and moderate lowering of T deflection in standard leads. In some cases more pronounced changes of T deflection were observed (lowered, smoothed or negative T deflection) in left chest leads, accompanied by minor downward displacement of the S—T segment without conspicuous changes in its shape, and by increased duration of electric ventricular systole. In a number of cases these changes in T deflection were combined with bradycardia and deceleration of intraventricular conduction which, taken together with complaints of heart pain and hypertensive reactions, led to their being taken for myocardial lesions or manifestations of coronary spasm (4, 12).

Autonomic vascular changes in persons of the first group exposed periodically in the past to microwaves of high intensities had vagotonic, as well as sympathicotonic, character, while in the second group they were predominantly sympathicotonic.

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In both groups (Fig. 2) the frequency of asthenic and autonomic vascular disturbances of a hyperreactive character (expressed dermographism, hyperhidrosis, arterial hypertension) related to age and employment depended directly on the duration of professional contact. Among those working for 5—10 years reactions of this type predominated in the second group, but they were more pronounced in the first one. As to vagotonic reactions (inhibited dermographism, bradycardia, arterial hypotension), they occurred mainly in the first group in the initial period of work with microwave sources.

The above data showed that microwave action was characterized by autonomic vascular symptoms of a vagotonic character. At the same time the symptoms of dystonia of the hypertonic type, related to nonspecific regulatory shifts, were less clearly related to intensity of action. Their etiology and clinical significance require further verification.

Only minor changes were found in the peripheral blood in both groups (16, 17). Some decrease in mean erythrocyte count was found (4 600 000 ± 0.18 and 4 600 000 ± 0.031 in the first and second group, respectively), as compared with controls (4 700 000 ± 0.17). Slight thrombocytopenia occurred in the first (221 500 ± 2.53) and second (216 300 ± 4.13) groups; controls: 245 000 ± 1.6. Moderate leukopenia was found in the first group (5 930 ± 0.065); controls: 6 490 ± 0.058. In a number of cases leukocytosis was encountered in the initial period of professional contact.

A tendency to cytopenia was observed predominantly in the first group with longer duration of employment. These people showed signs of a qualitative deterioration of erythrocytes, with a tendency to spherocytosis and an increase in acid fragility. Decreased numbers of mature cells of the neutrophilic series and signs of stimulated erythropoiesis were noted in bone marrow smears. Examination of ordinary bone marrow smears and of metaphase plates did not reveal an increased frequency of chromosome aberrations by comparison with controls.

Examination of deep refracting media of the eye revealed opacities of the crystalline lens as viewed in the slit lamp (1). Opacities were distributed mainly in the cortical layer and in superficial layers of the mature nucleus along its equator, and only single ones were found in the centre. Their frequency did not exceed control values. However, with increasing duration of occupational exposure the opacities of the lenses progressed. In a few cases the subjects of the first group workin gin unfavourable conditions developed cataracts with opacities of the crystalline lens detectable even in transmitted light.

In the majority of those examined single abnormalities in their health status did not interfere with the usual rhythm of life and work.

In a number of cases the abnormalities combined into a complex of symptoms which required therapeutic intervention.

Upon close examination in the ward a complex of symptoms corresponding to microwave sickness was diagnosed only in those patients of the first group who began their work under the most unfavourable conditions. Its frequency in the whole group did not exceed 15%.

We showed previously (4, 7, 13) that the clinical picture of microwave sickness was characterized by a complex of various autonomic vascular disturbances with crises of cerebral and coronary vascular insufficiency and asthenic symptoms. We distinguished three stages in the development of the sickness according to criteria generally accepted by pathologists: initial (I), moderately advanced (II) and advanced (III) with the following main clinical syndromes: asthenic, astheno-autonomic with vascular dysfunction of hypertonic type, and hypothalamic (autonomic vascular form).

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The asthenic syndrome occurred in the initial stages of the disease. It included mainly a complex of asthenic symptoms dominated by autonomic vascular changes with a vagotonic tendency.

The syndrome as a whole took a benign course.

The astheno-autonomic syndrome with vascular dysfunction of the hypertonic type was most frequent and occurred largely in moderately advanced and advanced stages of the disease.

In the clinical picture of a given syndrome, with the background of deepened asthenic phenomena, of primary importance were the autonomic disturbances related to increased excitability of the sympathetic division of the autonomic nervous system as well as vascular instability with hypertensive and angiospastic reactions. The latter frequently determined the severity of the illness.

At a certain stage of development of autonomic vascular disturbances the hypothalamic syndrome (autonomic vascular form) appeared and was characterized by sudden crises, predominantly of a sympathico-adrenal character.

The astheno-autonomic and hypothalamic syndromes took a protracted course. In advanced stages of the disease the asthenic, emotional and autonomic vascular disturbances and crises became more pronounced. In a number of patients the clinical picture of ischaemic heart disease and hypertension developed; the latter was frequently of the cerebral type.

Angiospastic symptoms were confirmed by the results of rheographic examinations of brain hemodynamics which showed a lowered intensity of pulse blood flow and predominantly an increased tonus of intra- and extracranial vessels which was restored under the influence of the nitroglycerine test (14).

Data of mechanocardiographic investigations showed increased tension-relaxation changes of vessels of the muscular type and increased peripheral resistance (4, 11).

Similar changes in the cardiovascular system were observed by a number of investigators (8, 10, 19, 20).

Electrocardiographic changes (3) and abnormal findings in some biochemical tests (13) correlated with the clinical observations.

In the initial stages of the disease electroencephalograms of the patients disclosed changes in alpha activity, stable alpha rhythm or decreased amplitude of alpha waves. In moderately advanced and advanced stages, bilateral synchronous discharges of theta- and delta-waves were found, and sometimes diffuse slow oscillations most clearly seen on hyperventilation, thus showing that subcortical structures were involved in the pathological process.

In the early period changes in protein composition took place, as evident from increase in total serum proteins, dysproteinemia and lowered albumin-globulin ratio.

Changes in the sugar curve after glucose loading — flattening (1st type), so-called diabetic (2nd) type, sometimes of biphasic character — accompanied all clinical forms of the disease, but they predominated in neurocirculatory disturbances with crices.

Some increase in cholesterol level, lowered lecithin-cholesterol ratio and decrease in blood chlorides were seen. Some authors (8, 10) have reported dysproteinemia, dyselectrolytemia and changes in blood lipid levels.

In moderately advanced and advanced stages of the disease catecholamine excretion was changed and the epinephrine-norepinephrine ratio was lowered, although the content of these amines in daily urine collections was normal. A few patients during crises exhibited sharp fluctuations of epinephrine levels, as well as an unusual daily rhythm of norepinephrine, excretion, the latter characterized by increase in the evening and at night.

Certain abnormalities in glucocorticoid metabolism were found: the overall index was

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lowered and the ratios of discrete fractions were changed. Changes in catecholamine excretion and in metabolism of glucocorticoid hormones were more marked after epinephrine loading which led to development of clinical autonomic vascular reactions.

The above investigations confirmed the clinical and electroencephalographic observations showing that deep, and particularly hypothalamic, structures of the brain were involved in pathological processes. Dysfunction of the hypothalamus, hypophysis and suprarenals, appearing against a background of asthenic phenomena, could be of importance in the pathogenetic mechanisms of development of the clinical symptoms of microwave sickness.

Investigations (Tab. 1) of those patients suffering from microwave sickness of one to ten years' duration (3—6 years in the majority of cases) showed that, despite repeated

Table 1

Clinical course of microwave radiation sickness during and after exposure

Clinical syndromes	Period of observation*	No. of cases	Clinical course**		
			Recovery	Stabilization	Progression
Asthenic	A	24	—	13 54±10	11 47±10
	B	5	3 60±24	2 40±24	—
Astheno-autonomic with vascular dysfunction	A	47	—	—	47 100±2
	B	16	—	15 94±6	1 6±6
Hypothalamic (autonomic vascular form)	A	2	—	—	2 100
	B	6	—	5 83±17	1 17±17
Total		100	3 3±2	35 35±5	62 62±5

* A — during employment under conditions of microwave exposure
B — after cessation of exposure to microwaves
** Above, number of cases; below, percentage ± S.E.

therapeutic courses and temporary withdrawal from work with microwave sources, upon returning to previous work conditions symptoms increased in severity, particularly among patients with moderately advanced and advanced stages of the disease. In such patients autonomic vascular disturbances dominated, crises of cerebral and coronary insufficiency progressed and development of ischaemic heart disease and hypertension was observed.

Cessation of work involving irradiation frequently resulted in stabilization of the processes, or even recovery, if withdraval took place in the initial stage of the illness

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REFERENCES

1. BELOVA, S. F. In: *Trudy instituta gigieny truda i professionalnyh zabolevani AMN SSSR*. Moskva, 1960, **1**, 41.
2. GEMBICKI, E. V. In: *Vlyanie SVČ izlučeni na organizm čeloveka i životnyh*. Izdatelstvo Medicina, Leningrad, 1970, p. 112.
3. GINZBURG, D. A. and SADČIKOVA, M. N.: *Trudy Laboratorii elektromagnitnyh polei radiočastot instituta gigieny truda i professionalnyh zabolevani AMN SSSR*, Moskva 1968, p. 30.
4. GLOTOVA, K. V. and SADČIKOVA, M. N.: *Gigiena truda i professionalnye zabolewanija*, 1970, **7**, 24.
5. GORDON, Z. V.: *Voprosy gigieny truda i biologičeskogo deistvia elektromagnitnyh polei sverhvysokih častot*. Izdatelstvo Medicina, Leningrad, 1966.
6. DROGIČINA, E. A.: *Trudy instituta gigieny truda i professionalnyh zabolevani AMN SSSR*, Moskva, 1960, **1**, 29.
7. DROGIČINA, E. A. and SADČIKOVA, M. N.: *Gigiena truda i professionalnye zabolevanija*, 1965, **1**, 17.
8. LYSINA, G. G.: *Gigiena truda*. Izdatelstvo Zdorove. Kiev, 1967, p. 229.
9. MOLYŠEV, V. M. and KOLESNIK, F. A.: *Elektromagnitnye volny sverhvysokih častot i ih vozdeistvie na čeloveka*. Izdatelstvo Medicina, Leningrad, 1968.
10. MEDVEDEV, V. P.: *Gigiena truda i professionalnye zabolevanija*, 1973, 3, 6.
11. MONAENKOVA, A. M. and SADČIKOVA, M. N.: *Gigiena truda i professionalnye zabolevanija*, 1966, 7, 18.
12. ORLOVA, A. A.: *Trudy intsituta gigieny truda i professionalnyh zabolevani AMN SSSR*, Moskva, 1960, p. 36.
13. PAVLOVA, I. V., DROGIČINA, E. A., SADČIKOVA, M. N. and GELFON, I. A.: *Gigiena truda i professionalnye zabolevanija*, 1970, 3, 20.
14. SADČIKOVA, M. N., OSIPOVA, V. G., and DURNEVA, Z. N.: *Gigiena truda i profes-sionalnye zabolevanija*, 1972, **9**, 12.
15. SMIRNOVA, M. N. and SADČIKOVA, M. N.: *Trudy instituta gigieny truda i professionalnyh zabolevani AMN USSR*, Moskva, 1960, **1**, 50.
16. SOKOLOV, V. V. and AREVIČ, M. N.: *Trudy instituta gigieny truda i professionalnyh zabolevani AMN SSSR*, Moskva, 1960, p. 43.
17. SOKOLOV, V. V. and ČULINA, N. A.: *Trudy laboratori instituta gigeny truda i professionalnyh zabolevani AMN SSSR*, 1968, **3**, 41.
18. TJAGIN, N. V.: *Kliničeskie aspekty, oblučenija SVČ-diapozana*. Izdatelstvo, Medicina, Leningrad, 1971.
19. USPENSKAJA, N. V.: *Vračebnoe delo*, 1961, **3**, 124.
20. FOFANOV, P. N.: *Kliničeskaja medicina*, 1966, **4**, 44.
21. HEALER, J.: Review of Studies People Occupationally Exposed to Radio-Frequency Radiations. In: *Biological Effects and Health Implications of Microwave Radiation*. Ed.: Cleary S. F. US Dept of Health, Education and Welfare. Report BRH (DBE 70—2). Richmond, 1969, p. 90.
22. KLIMKOVÁ-DEUTSCHOVÁ, E.: *Arch. Gewerbepathol. und Gewerbehyg.*, 1957, **16**, 72.
23. KLIMKOVÁ-DEUTSCHOVÁ, E., ROTH, B.: *Arch. Gewerbepathol. und Gewerbehyg.* 1963, **20**, 1.
24. MICHAELSON, M.: Biological Effects of Microwave Exposure. In: *Biological Effects and Health Implications of Microwave Radiation*. Ed.: Cleary S. F. US Dept of Health, Education and Welfare, Report BRH (DBE 70—2). Richmond, 1969, p. 35.

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NEUROLOGIC FINDINGS IN PERSONS EXPOSED TO MICROWAVES

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Twenty years ago, when I started the systematic examination of persons occupationally exposed to electromagnetic fields, no detailed neurologic findings had been reported in the literature. At that time, no instruments were available for making precise measurements of field intensity values. There was also a lack of other technical information, for example concerning the absorption of energy within the organism. Much later, however, special departments were established in the Institute of Industrial Hygiene for research work on the hazards of electromagnetic waves and it took several more years before instructions were published regarding preventive measures and measurements.

Our first experimental findings in people occupationally exposed to electromagnetic fields were confirmed by other investigators. This applied especially to changes in EEG recordings, which were observed even under rigorously controlled experimental conditions, using precise intensities and frequencies.

Depending upon the frequency with which the neurologic findings deviated from normal in groups observed at different places of work, it was possible for us to differentiate various levels of hazard in the working environment even before we knew the precise exposure intensities. In my previous work, I was able to show that there were significant clinical and electrobiologic changes in exposed persons as compared with controls. I distinguished three main stages in the clinical picture, based on the signs and symptoms observed. In agreement with the clinical and EEG findings, the results of biochemical studies on selected groups exposed to radiation in the centimeter band could be interpreted as dependent on an impairment of central nervous regulatory mechanisms.

I introduced into the neurologic examination the detailed investigation of the extrapyramidal system, making use of the contralateral responses to cerebellar and extrapyramidal disturbances. Using a refined test battery of cerebellar functions, we were able to interpret the phenomena corresponding to cerebellar irritation as extrapyramidal signs, e.g. hypotonus as opposed to hypertonus. Together with other motor disturbances these were the earliest manifestations of organic microsymptoms, even in persons without subjective complaints.

By making an exact evaluation of the extent of the disturbances, we were able to estimate that most of our patients had suffered less serious injury than had some other groups working with chemical noxious agents. In several papers, I discussed the possible pathophysiology of the nervous system damage on the basis of thermal or non-thermal effects.

A special feature of our results lies in the fact that when the investigations were started preventive measures were not strictly observed and less attention was paid to the hazards than is the case today. Nowadays, strict hygienic supervision of working places prevents the development of serious organic injury. Our previous results provide useful evidence of the nature of the lesions that can develop.

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MATERIALS AND METHODS

We have made repeated observations on 530 persons occupationally exposed to non--ionizing radiation, so that we have at our disposal more than 1000 findings. We succeeded in compiling data from 29 places of work. In view of the variability of the material, I attempted to undertake a computer analysis of a selected sample of 352 detailed case histories on the basis of 119 parameters. The most homogeneous groups consisted of 162 workers who were exposed to radiation of centimeter wavelengths. The other groups were used for comparison.

Among the parameters studied were: age, characteristics of exposure, constitutional factors, non-specific influences unconnected with occupation, clinical signs and symptoms, EEG findings, and biochemical changes. On the basis of the computer analysis, the subjects studied may be divided into 8 groups:

1. Workers engaged in metal welding, exposed to frequencies ranging from 0.5 MHz up to 3.5 — 32 MHz.
2. Workers from two steel factories engaged in tempering steel and exposed to frequencies of 0.45—150 MHz, with a daily exposure of 50—112 V/m, and occasionally 400 V/m.
3. Welders of plastics: frequency range 12—150 MHz, daily exposure 20—57.7 V/m.
4. Technicians operating television transmitters.
5. Workers at a radio transmitting station operating at a wide range of frequencies, from 6 MHz up to 30 MHz, and using a pulsed field system.
6. Persons exposed to radiation in the 3—13 cm wave-band working in industry and at research institutes with frequencies ranging from 3 GHz to 30 GHz. Intensity measurements showed permissible levels in some places, but in others values exceeding the permissible level ten or more times were found.
7. Persons working on a linear particle accelerator.
8. A mixed group which included the administrative staffs of two factories, who were not directly exposed to non-ionizing radiation, some workers with exposures of less than 300 MHz and others with exposures of 300—800 MHz.

Symptoms were found most frequently in workers exposed to radiation in the centimeter wave-band. The occurrence of such symptoms as headache, fatigue, and excitability was statistically significant, while the frequency of anxiety and some other symptoms was not significant. In nearly all the groups, fatigue was noted more often than excitability, statistically significant differences being again found in workers exposed to centimeter wavelengths.

Subjective complaints were even more frequent in group 5, who were mainly exposed to a pulsed field. As regards objective signs, there was a statistically significant increase in the frequency of signs of autonomic nervous system disturbances in groups 5 and 6 and cerebellar symptoms appeared in group 6. Signs attributable to the extrapyamidal system were observed in groups 1, 2 and 6, but the frequency was significant only at the 5 percent level, while in groups 2 and 6 the frequency of signs attributable to the pyramidal system was significant at the 1 percent level.

Age played no significant role in the frequency of symptoms. In our computer analysis, only people below 30 years of age showed a significantly higher incidence of autonomic disorders. Physiologic impairment of the autonomic nervous system played a role in young persons. In the fourth decade, a raised diastolic blood pressure, significant at the 1 percent level, was found in 51 percent of our subjects. Only limnal changes were found in the EEG between the ages of 20 and 40 years, and blood pressure was normal in the second and fifth decades. Intracranial arachnitis was present in the fourth decade, the frequency being significant at the 5 per cent level. Memory distur-

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bances were seen in persons over 50 years of age. Most of the parameters studied were not significantly correlated with age. It can be assumed that, as a rule, there is practically no dependence on age as far as symptomatology is concerned. Measurements of the temperature of the cerebrospinal fluid showed maximal values in the cisterna magna. The incidence of cerebellar signs may thus be explained by the heating effect in the posterior fossae.

ELECTROENCEPHALOGRAPHIC EXAMINATION

In agreement with the subjective complaints of fatigue, we found a reduction in vigilance in 59 percent of persons exposed to radiation in the centimeter band. A predominance of inhibitory processes was proved not only by the EEG findings but also by use of the conditioned reflex method of examination. In addition to subclinical activity, pathological findings in the EEG recordings included pointed synchronized waves of high amplitude and slowed rhythms. Synchronized activity as a proof of functional disturbance of the CNS could be seen even in recordings showing limnal changes. Such activity was present in 14.3 percent of persons in group 5 and can be explained by the involvement of midline structures. It must be emphasized that in most instances the alterations in the EEG were only very slight, appearing most frequently after activation by hyperventilation. The EEG offers an important objective method of examination at a time when clinical evidence of disordered function — in particular neurotic signs — is only slight. The EEG findings are often more important than the clinical ones. EEG examination makes it possible to reach conclusions about the prognosis for the patient and about a suitable assignment of work.

BIOCHEMICAL STUDIES

Biochemical studies on a group of 40 persons exposed to radiation in the centimeter band included the determination of the levels of pyruvic acid and lactic acid in the serum and of creatinine in the urine. In the majority of persons all three metabolites showed normal levels, but there were twice as many with decreased values as with increased values. We also found some abnormalities in the blood sugar curve, with a slight increase in the fasting blood sugar in about 74 percent of cases. A few persons showed a flat or prediabetic type of curve, with slight glycosuria.

In persons exposed to radiation in the 30—800 MHz range, we studied the serum protein levels and the levels of cholesterol and lipoproteins. Serum protein levels were found to be raised in 75 percent of subjects with an average age of 45.5 years. Raised beta-lipoprotein levels were found more than twice as frequently in exposed workers as in controls. Cholesterol levels were elevated in 40.9 percent of the exposed subjects, but in only 9.5 percent of the controls. These data are in agreement with those previously reported in the literature.

DISCUSSION

The quantity of creatinine excreted during 24 hours is practically constant in any individual, but it depends on the total muscle content of the body and on muscular activity. Fever, starvation, irradiation by waves shorter than the visible part of the spectrum, and catabolic processes accompanied by destruction of muscle all raise the

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level of creatinine in the urine. On the other hand, in our series creatinine levels were more often decreased than increased. We can only attribute this to a disturbed regulation of creatinine excretion in 60 percent of cases.

The increased levels of fasting blood sugar and the variations in pyruvic acid and lactic acid levels, together with the anomalies in creatinine excretion, point to slight disturbances in enzyme functions. The most constant observation was the slight increase in fasting blood sugar. A similar increase is observed in cases of hypertension and arteriosclerosis and in nervous system involvement accompanied by altered glucose tolerance. In the light of these findings, hypolacticemia may be interpreted as evidence of a tendency to acidosis. It is also of interest that in our earlier studies we observed a statistically significant increase in the incidence of hypertension, particularly in the third decade, as compared with that reported by Böger and Wetzler in a large survey undertaken for American insurance companies.

In contrast to the values determined in persons subjected to experimental sleep deprivation, in our cases we found that decreased levels of the metabolites mentioned occurred twice as often as increased ones. It is known that heat by itself changes the relative concentrations of the protein fractions in the blood serum, causing especially an increase in the gamma fraction.

The reduction in vigilance and the pathologic changes in the EEG were attributed to a diminution in afferent stimuli from the reticular formation in the brain stem. From the metabolic disurbances, the EEG changes, and the clinical signs and symptoms, it may be concluded that the impairment of regulatory mechanisms is localized in the mesodiencephalic region. The focal, temporal and brain stem lesions may be explained by the rectangular branching of the vessels in these parts of the brain. The heating effect is a consequence of the poor efficiency of the cooling by the blood stream. However, the involvement of midline structures in persons exposed to certain wavelengths may be presumed to be due to a direct influence of the radiation.

One consequence of the heating effect is, however, a rise in basal metabolism, which could increase the oxygen requirement of the tissues. The rise in temperature may also reduce the oxygen-carrying power of the hemoglobin, causing decreased oxygenation, and lead to respiratory alkalosis. This metabolic effect could explain the pathologic changes in EEG activity, with subclinical episodic rhythms similar to those seen in epileptic seizures. Studies made by Lawrence on irradiated skin have also shown that tissue activity is decreased under the influence of electromagnetic waves. The EEG disturbances may also be explained on a non-thermal basis as the result of direct stimulation; they may even be provoked by nociceptive stimulation of the skin.

It is well known that non-thermal effects of irradiation have been demonstrated by the induction of mutations in some primitive organisms and by the ability of such organisms to sense the presence of weak electric and magnetic fields. A non-thermal origin is also assumed for the effects on endocrine organs, changes in membrane permeability, and chromosome aberrations.

Molecular resonance, the splitting off of free radicals, and the interruption of enzymatic chain processes leading to disturbances in fine regulatory mechanisms are possible ways in which electromagnetic waves may influence living organisms. Such mechanisms would explain the alterations in tissues with high enzymatic activity and a high oxygen requirement. The distribution of energy also depends on the conducting and reflecting properties of the tissues.

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CONCLUSIONS

1. By means of computer analysis, a qualitative and quantitative evaluation was made of the data obtained on 352 persons in regard to clinical, biochemical and bioelectric signs, and their dependence on age and the characteristics of the exposure to electromagnetic radiation.

2. Our results confirm our earlier conclusion that the disturbances of the nervous system may be divided into three main stages:

(a) the neurasthenic syndrome with autonomic disorders,

(b) pseudoneurasthenia with similar subjective complaints, but with microsymptoms of an organic nature, especially in motor systems,

(c) very rare cases of encephalopathy.

3. The occurrence of contralateral responses to cerebellar and extrapyamidal disturbances facilitates the detection of early signs of extrapyramidal syndromes, which are identical with those caused by cerebellar irritation.

4. The predominance of fatigue in certain of the exposed groups was paralleled by a reduction in vigilance, as noted in the EEG recordings and in our earlier studies of higher nervous functions.

5. The occurrence of synchronized EEG activity, with slow rhythms of high amplitude similar to those seen in epileptic seizures, taken in conjunction with the clinical and biochemical findings, permits the conclusion that the involvement of the nervous system is localized in the mesodiencephalic region. Such activity is seen in persons subjected to high levels of exposure, particularly in the form of a pulsed field.

6. Possible explanations of the pathophysiology include direct penetration of the radiation into the midline structures and the thermal effect in the cisterna magna, which would explain the rare cases of arachnitis of the posterior fossae and the cerebellar phenomena. The rectangular branching of the blood vessels of the temporal and basal ganglia explains the slowing of the blood stream in these parts of the brain, accompanied by reduced oxygenation. It may be assumed that the subclinical paroxysmal activity is induced by alkalosis resulting from these disturbances.

7. The non-thermal effects and reversible neurotic manifestations may be attributed to the interruption of synaptic transmission and to changes in reflex activity under enzymatic influences.

8. In our considerations of the pathophysiology, we have concentrated on the fine regulatory mechanisms, which are disturbed before organic changes occur. The detection of these very early effects is important for preventive measures.

9. For a more precise evaluation of the technical parameters, further work will be necessary.

10. From our rather modest findings, it is nevertheless possible to deduce some preventive measures. Persons liable to paroxysmal activity of the central nervous system should be excluded from work involving exposure to non-ionizing radiation, and in certain cases persons with a pseudoneurasthenic syndrome or disturbances of motor systems may be unsuitable for work of this kind.

11. International and interdisciplinary collaborative studies are needed to develop such preventive measures in order to ensure that every worker will live and work under optimal conditions and will be enabled to use his knowledge and abilities to the full.

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A STUDY OF THE HEALTH STATUS OF MICROWAVE WORKERS

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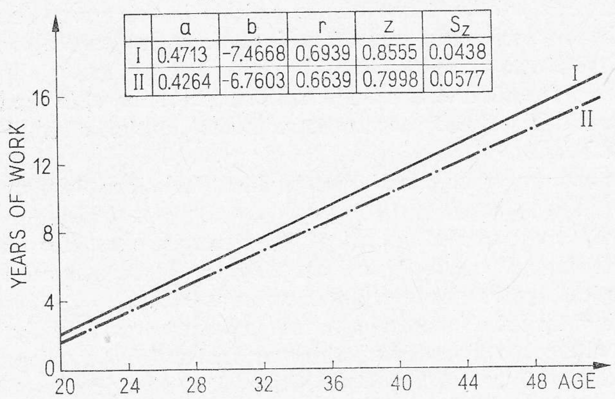
The study was undertaken of the health status of a group of 841 men aged from 20 to 45 years. All of them were occupationally exposed to irradiation with pulsed microwaves of various frequencies within the whole range used in radar operations.

They worked both in closed rooms and in the open, observing typical individual protective measures according to the regulations of work safety and hygiene existing in this country.

The field work performed was individually checked and the power density estimated. The population investigated was divided into 2 groups according to exposure levels. Figure 1 shows the correlation between age and duration of employment. The first group numbered 507 persons exposed during working hours at power densities above 2 W/m^2.



	a	b	r	z	S_z
I	0.4713	-7.4668	0.6939	0.8555	0.0438
II	0.4264	-6.7603	0.6639	0.7998	0.0577

Fig. 1. Correlation between duration of occupational exposure (years of work) and age (years).

The second group included 334 persons exposed to a power density below 2 W/m^2.

In both groups hygienic factors were comparable, i.e. the type and intensity of various stress factors, changes in circadian cycle, noise intensity, temperature and humidity of the rooms, etc.

All the persons in the study were examined at the same clinical center in stationary conditions from 1966 to 1972.

The program of clinical trials was typical for an internal medical clinic, including detailed ophthalmoscopic examination performed by means of a slit-lamp and a neurologic check-up, supplemented by psychologic tests and EEG recordings.

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Both the ophthalmoscopic and neurologic examination were undertaken by the same specialists using the same classification of abnormalities. After the clinical observation period and possible treatment had been completed a decision was taken (according to the regulations existing in this country) as to the fitness of the individuals examined for further work in conditions of microwave exposure. In view of the difficulties of selection of an adequate control group for a population characterized by such specific work and exposure conditions, it was decided to compare the results obtained between the groups exposed to microwaves at two different power density levels as well as to analyse the relationship between the frequency of the characters investigated and the duration of employment and age.

Only selected data are discussed in this report, viz. those constituting the most frequent problems in determining the health status of the groups examined and their fitness for work. Thus, the causes of the unfitness for work in microwave exposure conditions, the frequency of what is called functional abnormalities and the lens translucency were analysed. In the analysis of causes of unfitness for work in both groups the following criteria were taken into account: eye changes, functional disturbances and finally all other causes taken together.

In the analysis of frequency of functional disturbances the patients were divided into subgroups with clinically apparent neurosis, neurosis with abnormal EEG patterns, gastrointestinal tract complaints of functional origin, and neurosis with abnormal ECG. The subgroup with abnormal EEG tracings included persons with various neurotic disturbances and distinct pathological EEG recordings as well as flat EEG recordings, i.e. with the frequency of α-waves decreased to 20 per cent and the amplitude of these waves lowered to 20 mV. Abnormalities in ECG recordings concerned mostly a partial block of the right His bundle. None of the patients in this group had organic heart muscle lesions. Lens translucency was determined according to the scale proposed by Dr. Żydecki (this volume).

The frequencies of the characters examined (mean percentages) in the first and second group and the correlation of their occurrence with the duration of employment and age were analysed statistically.

Here Student's t test was used and the standard deviations were compared by the F test of Fisher (2).

Correlation analysis was carried out using the mean square test (for multi-area tables), while the determination of the reciprocal coupling was made using the Čupurov coefficient. The statistical significance level has been set as 0.05.

In subgroups in which the independency test indicated a statistically significant correlation between characters investigated, this was analysed by drawing regression lines and by determination of the regression coefficient. The significance of the correlation coefficient was verified according to Fisher's transformation (2).

Table 1

The structure of groups I and II according to duration of employment and age

Group	Duration of employment			Total	Age			
	1—5	6—10	10		20—25	26—30	31—35	36—45
I	193	207	107	507	125	158	109	115
II	134	114	86	334	73	67	65	129

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Table 2

Comparison of mean percentage values of corresponding data of groups I and II as divided according to the age

			x_1	S_1	x_2	S_2	I t I	F	
Fitness for work	Cause of unfitness	Able	47.9	12.1	47.3	16.0	0.109	1.741	$n_1\ n_2 = 13$ K = 24
		Ophthalmologic	8.2	4.3	10.1	5.2	1.006	1.475	$f_1\ f_2 = 12$
		Functional	29.3	7.7	28.7	13.1	0.137	2.849	Verified:
		Other	14.6	8.4	13.9	5.5	0.263	2.327	I t I to $t_{0.05;\,24} = 2.064$ F to $F_{0.05;\,12;\,12} = 2.690$
Incidence of functional disorders	None		37.2	11.7	34.3	11.8	0.605	1.015	$n_1\ n_2 = 12$
	Neurosis		34.2	9.6	31.8	6.0	0.738	2.549	K = 22
	Gastrointestinal tract		19.7	6.5	23.5	8.5	1.236	1.721	$f_1\ f_2 = 11$ Verified:
	Abnormal ECG		8.8	3.4	10.4	3.3	1.154	1.018	I t I to $t_{0.05;\,22} = 2.074$ F to $F_{0.05;\,11;\,11} = 2.850$
Lens translucency	1°		28.1	11.7	22.0	15.3	1.141	1.714	$n_1\ n_2 = 13$
	2°		23.4	13.5	58.8	15.5	0.940	1.309	K = 24
	3° and higher		18.3	14.8	19.1	8.9	0.157	2.766	$f_1\ f_2 = 12$ Verified: I t I to $t_{0.05;\,24} = 2.064$ F to $F_{0.05;\,12;\,12} = 2.690$

Explanations:
- $x_1\ x_2$ — mean values
- $S_1\ S_2$ — standard deviations
- $n_1\ n_2$ — number of results
- ItI — module of Student's t-test
- K — degrees of freedom
- F = F — number of Fisher's test
- $f_1\ f_2$ — degrees of freedom

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Table 3

Comparison of mean percentage values of corresponding data of group I and II as divided according to the duration of employment

			x_1	S_1	x_2	S_2	I t I	F	
Fitness for work	Causes of unfitness	Able	51.5	18.7	43.7	15.1	1.332	1.523	$n_1\ n_2 = 17$
		Ophthalmologic	8.0	5.2	10.3	6.2	1.144	1.427	$K = 32$
		Functional	28.1	10.5	30.4	8.8	0.684	1.429	$f_1\ f_2 = 16$
		Other	12.7	7.4	15.2	8.1	0.931	1.208	Verified: I t I to $t_{0.05;\,32} = 2.042$ F to $F_{0.05;\,16;\,16} = 2.350$
The frequency of functional disorders		None	37.1	17.8	30.4	9.5	1.635	3.546	$n_1\ n_2 = 17$
		Neurosis	35.1	9.7	34.2	8.4	0.288	1.334	$K = 32$
		Gastrointestinal tract	21.6	9.3	22.9	8.4	0.429	1.222	$f_1\ f_2 = 16$
		Abnormal ECG	8.2	4.5	11.4	5.5	1.272	1.478	Verified: I t I to $t_{0.05;\,32} = 2.042$ F to $F_{0.05;\,16;\,16} = 2.350$
Lens translucency		1°	27.5	13.1	23.6	12.5	0.885	1.103	$n_1\ n_2 = 17$
		2°	53.3	9.8	56.8	13.5	0.860	1.872	$K = 32$
		3° and higher	22.4	18.2	19.4	8.3	0.610	4.754	$f_1\ f_2 = 16$ Verified: I t I to $t_{0.05;\,32} = 2.042$ F to $F_{0.05;\,16;\,16} = 2.350$

Explanations:
$x_1\ x_2$ — mean values
$S_1\ S_2$ — standard deviations
$n_1\ n_2$ — number of results
ItI — module of Student's t-test
K — degrees of freedom
F — F — number of Fisher's test
$f_1\ f_2$ — degrees of freedom

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RESULTS

Results of the statistical analysis are presented in successive tables. Table 2 shows a comparison between groups I and II with respect to the mean values of the characters analysed, according to age. The same comparison as related to the duration of employment is presented in Table 3. No statistically significant differences were found among these groups. The calculated I t I value was lower than that given in the statistical tables. The results of the correlation analysis between characters investigated and age separately for each group are shown in the next tables.

Table 4

Analysis of the relationship between fitness for work, duration of employment and age in group I

Fitness ability for work		Duration of employment			Total	Age			
		1—5	6—10	10		20—25	26—30	31—35	36—45
Fit		107	102	59	268	69	80	53	66
Causes of unfitness	Ophthal-mologic	16	20	13	49	14	11	12	12
	Functional	42	53	15	110	25	41	27	17
	Other	28	32	20	80	17	26	17	20

p = 0.31506
χ^2 = 7.06300
K = 6
φ^2 = 0.01393
K = 0.00569

p = 0.53686
χ^2 = 7.97312
K = 9
φ^2 = 0.01573
K = 0.00524

Table 5

Analysis of the relationship between fitness for work, duration of employment and age in group II

Fitness for work		Duration of employment			Total	Age			
		1—5	6—10	10		20—25	26—30	31—35	36—45
Fit		74	51	42	167	52	30	35	50
Causes of unfitness	Ophthal-mologic	14	17	9	40	5	7	10	18
	Functional	34	23	23	80	10	19	10	41
	Other	12	23	12	47	6	11	10	20

p = 0.16180
χ^2 = 9.21574
K = 6
φ^2 = 0.02759
K = 0.01126

p = 0.00353
χ^2 = 24.35290
K = 9
φ^2 = 0.073345
K = 0.02448

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Each of the multi-area tables includes the results of statistical analysis, i.e. the: probability p distribution, degree of freedom k, correlation coefficient and Čupurov coefficient K. The Table 4 represent the results of the analysis of the dependence between the ability to work and the duration of employment and the age of the population of group I, while in Table 5 the same analysis is shown for group II.

No statistically significant correlation was found between the causes of the unfitness for work and the duration of employment in the two groups. A significant probability factor in group II divided according to age is characterized by a very low Čupurov coefficient of reciprocal dependence. Table 6 shows the results of the analysis of correlation between the occurrence of functional disorders and the duration of employment and age of the investigated persons of group I, while the same analysis for group II is given in the Table 7.

Table 6

Analysis of the relationship between the incidence of functional disorders, duration of employment and age in group I

Functional Disorders	Duration of employment			Total	Age			
	1—5	6—10	10		20—25	26—30	31—35	36—40
None	83	68	39	190	63	58	26	43
Neurosis	64	78	38	180	38	64	49	29
Gastrointestinal	26	38	23	87	10	23	24	30
Abnormal ECG	20	23	7	50	14	13	10	13

$p = 0.14777$
$\chi^2 = 12.07780$
$K_2 = 8$
$\varphi^2 = 0.02382$
$K = 0.00842$

$p = 0.00002$
$\chi^2 = 43.26527$
$K_2 = 12$
$\varphi^2 = 0.08534$
$K = 0.02463$

Table 7

Analysis of the relationship between the incidence of functional disorders, duration of employment and age in group II

Functional Disorders	Duration of employment			Total	Age			
	1—5	6—10	10		20—25	26—30	31—35	36—45
None	50	31	27	107	32	22	21	33
Neurosis	40	41	35	116	23	25	20	48
Gastrointestinal	29	33	16	78	10	14	19	35
Abnormal ECG	15	9	8	32	8	6	5	13

$p_2 = 0.26254$
$\chi^2 = 10.03560$
$K_2 = 8$
$\varphi^2 = 0.03005$
$K = 0.01062$

$p_2 = 0.14367$
$\chi^2 = 17.16013$
$K_2 = 12$
$\varphi^2 = 0.05138$
$K = 0.01483$

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The occurrence of statistically significant differences was found only for group I, in relation to age. No correlation of the occurrence of these disorders with the duration of employment could be demonstrated. An additional analysis of dependence of the occurrence of functional disorders in relation to age does not indicate any linear relationship.

Table 8 shows the analysis of the correlation between the lens translucency, duration of employment and age in group I, while Table 9 represent a similar analysis for group II.

Table 8

Analysis of the relationship between lens translucency duration of employment and age in group I

Lens translucency	Duration of employment			Total	Age			
	1—5	6—10	10		20—25	26—30	31—35	36—45
1°	71	24	16	141	55	45	26	15
2°	95	108	67	270	54	89	60	67
3° and higher	27	45	24	96	16	24	23	33

$p_2 = 0.00094$
$\chi^2 = 18.61215$
$K_2 = 4$
$\varphi^2 = 0.03671$
$K = 0.01836$

$p_2 = 0.00001$
$\chi^2 = 34.40868$
$K_2 = 6$
$\varphi^2 = 0.06787$
$K = 0.02771$

Table 9

Analysis of the relationship between lens translucency, duration of employment and age in group II

Lens translucency	Duration of employment			Total	Age			
	1—5	6—10	10		20—25	26—30	31—35	36—45
1°	50	30	19	99	32	24	18	25
2°	65	61	49	175	32	40	40	63
3° and higher	19	23	18	60	9	3	7	41

$p_2 = 0.12097$
$\chi^2 = 7.29769$
$K = 4$
$\varphi^2 = 0.02185$
$K = 0.01092$

$p_2 = 0.00000$
$\chi^2 = 37.20359$
$K = 6$
$\varphi^2 = 0.11139$
$K = 0.04547$

Statistically significant correlation exists in both groups between lens translucency and age, but between lens translucency and duration of employment in group I only.

A regression analysis of the degree of lens translucency as a function of age and of the duration of employment was made.

Additional regression analysis was made as a function of age and duration of

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employment. The results are shown in Table 2. A linear regression slope was obtained, the correlation coefficient indicating a highly significant correlation between the age and the duration of employment.

DISCUSSION

The occupationally exposed group of persons who formed the subject of this study should be considered as highly preselected.

Approximately one half of the examined persons consists of workers in institutions where high exposures to irradiation occur and considering this in the light of the field measurements made, it may be said that the above mentioned data are representative of the most exposed group in this country. At the initial stage of this analysis several trials were performed in dividing investigated populations into a greater number of subgroups according to age, duration of employment and other characteristics. If both groups, however, had been divided into subgroups the number of individual observations in each particular group would not have reached the minimum required for valid statistical analysis.

Besides exposure to microwaves several hygienic factors were analysed, i.e. such as could exert a negative influence on the health status of the investigated population. In practice a control group for a population with such specific working conditions does not exist.

In view of this no traditional comparison of incidence of deviations from normal values inside each investigated group and no comparison with what is called "standard man" was made. Taking the above-mentioned complex conditions of irradiation into, account, such calculated deviations could not be related to the effects of microwave exposure. The present paper describes only a part of the analysis performed, viz.: the causes of unfitness for work, the determination of lens translucency and the incidence of several neurotic disturbances — that means the problems considered as related to the influence of the microwave irradiation on the human organism, especially stressed in testing the fitness for work in conditions of exposure to microwaves. The analysis of the data indicate an absence of differences between the groups exposed in various degrees to microwaves and an absence of correlation of incidence of the investigated characteristics with the duration of employment, in contradistinction to the obviously existing correlation between certain characters and age.

For example a decreasing frequency of 1° in lens translucency proportional to age has been observed. This may indicate that microwave irradiation by itself does not influence the incidence or quality of the characters analysed in an exposed population. The final conclusion is: the analysis within the groups, as well as between groups of persons occupationally exposed to various power densities of microwave radiation does not indicate a correlation between the degree of exposure or duration of employment in conditions of exposure and the incidence of the analysed health disturbances and the degree of lens translucency.

REFERENCES

1. ŻYDECKI S.: *Assessment of Lens Translucency in Juveniles, Microwave Workers and Age-matched Groups* (this volume).
2. YULE G. U., KENDALL M. G.: *An Introduction to the Theory of Statistics.* Charles Griffin and Co., Ltd, London, 1958.

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BLOOD PROTEINS IN PERSONNEL OF TELEVISION AND RADIO TRANSMITTING STATIONS

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In an earlier paper the influence of working conditions on the state of health of the staff of the TV and radio transmitting stations in Czechoslovakia was studied (4, 5). 140 persons were carefully examined (Tab. 1) during hospitalization, which represented about $^2/_3$ of all employees with an exposure time of more than 5 years. The results were compared with those in control groups and statistically evaluated.

Table 1

Review of clinical and laboratory examinations

Laboratory examinations	Clinical examinations
Analysis of urine	Physical
Blood count	Neurologic
BSR	Psychologic
BMR	Psychiatric
Liver tests + Transaminase	Ophthalmologic
Proteinalysis	
Blood sugar curve	
Cholinesterase activity	
X-ray of chest	
ECG	
EEG	

No signs of damage due to electromagnetic radiation nor any changes in health status were ascertained with the exception of modifications in the blood protein ratio. The mean percentage of gamma-globulin was increased in the personnel of radio transmitting stations (20.2—21.0% in comparison to 18.3% in the control group), as well as the total blood protein level in the staff of the TV transmitters (7.6 g% : 6.9 g% in the control group). Small differences in the alpha$_1$-globulin were also found in certain groups. Though all individual and average values were within physiologic limits, the statistical differences in the mean values of the exposed and control groups were confirmed by means of the F-test and the Duncan test at a 1% or 5% confidence level.

We did not feel sure whether these alterations were caused by electromagnetic fields or if they could have been due to other factors. The exposed persons came from all parts of Czechoslovakia, especially from the countryside and mountainous regions, whereas the members of the control group lived in the capital and differed in their living standards, habits and nutrition. Another factor which caused doubt was that the protein analyses were made in a routine biochemical laboratory where the possibility of the inaccuracies that frequently occur in this type of work could not be excluded.

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In order to eliminate the above-mentioned sources of error and to elucidate the possible influence of electromagnetic radiation on the blood proteins, we repeated the investigation on all TV and radio transmitter technicians in Bohemia who have been working for at least 5 years in their profession. This paper deals with the final conclusions drawn from the investigations on TV technicians and the preliminary results of the investigations carried out on radio technicians.

The characteristics of the working and environmental conditions are given in the following tables.

The transmitters broadcast in the usual TV, SW and MW frequencies (Tab. 2).

Table 2

Frequencies of electromagnetic radiation

TV	60—300 MHz
SW	3—30 MHz
MW	640—1500 kHz

The intensity of the electromagnetic fields in the TV stations (Fig. 1.) was estimated by means of a Režný apparatus, which measures the integral intensity of electromagnetic fields. In radiostations the universal wide-zone voltmeter B 388 A was used. The error of the former method reaches up to ± 30%, and of the latter up to ± 100%. Only the electric, but not the magnetic component of the field was measured. The Czechoslovak maximum permissible level corresponds to 10 V/m. Higher values were found only rarely in one station. The number of persons investigated in every TV station is

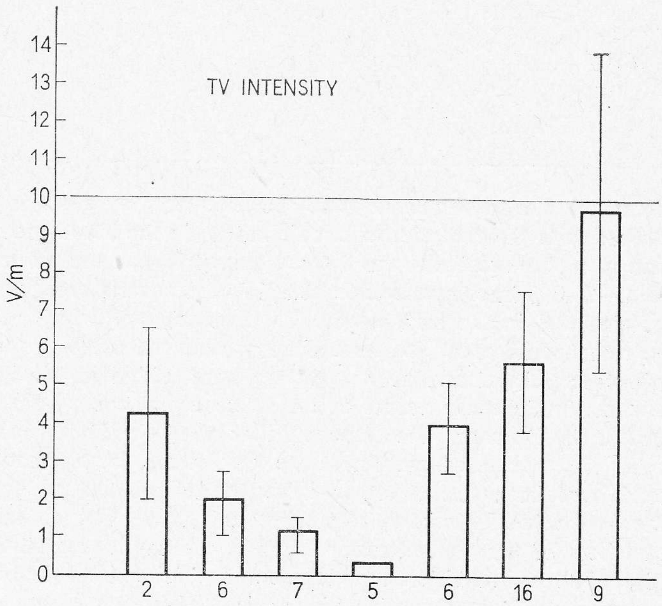

Fig. 1. Intensity of electromagnetic fields in TV stations.

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given below the vertical columns, which represent the mean intensity at the stations with their standard deviations.

The values of irradiation for one working day equal the sum of the intensity of the electromagnetic field (V/m) and the time of exposure (number of hours in one working day) (Fig. 2).

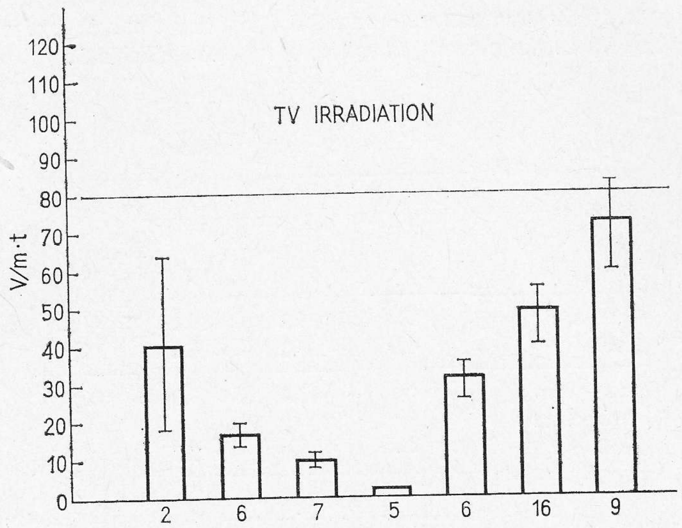

Fig. 2. Values of irradiation in TV stations.

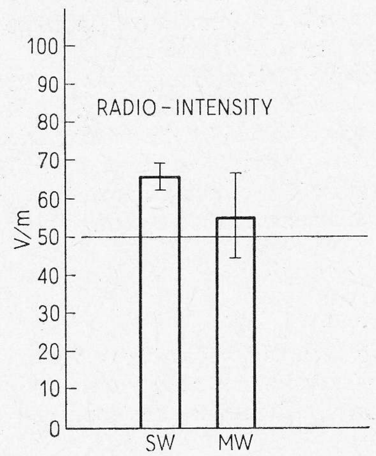

Fig. **3**

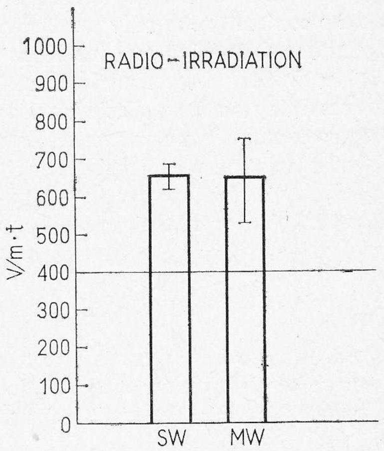

Fig. **4**

Fig. 3. Intensity of electromagnetic fields in radio transmitters.
Fig. 4. Values of irradiation in radio transmitters.

The maximum permissible value for these frequencies in Czechoslovakia is 80. Practically all measurements were within these limits.

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The intensities of electromagnetic fields in radio transmitting stations (Fig. 3) were higher than the permissible maximum of 50 V/m in the majority of measurements.

The same applies to the irradiation values for the radiowaves (Fig. 4) (maximum permissible value 400).

The work is done in light, well-equipped rooms with agreeable microclimate conditions. The noise level varied in TV stations within the range of the class of noise N 65 — 81 and in radio transmitters 65 — 71.

The employees of the transmitters worked a 40.5 hour week in irregular shifts.

The characteristics of the persons examined are given in Table 3.

Table 3

Characteristics of persons examined

	Controls	TV	SW	MW
No. of workers			58	
	59	51	19	39
Mean age	35.4	35.2	39.3	41.3
±s.d.	9.0	6.2	6.3	9.7
Mean years of exposure		10.4	16.8	16.8
±s.d.	—	3.5	7.8	4.9

The mean age of the control group is approximately the same as that of the exposed persons. The control group was chosen from the same regions as the exposed persons, and from the same social standard and living conditions. The only difference is that the exposed technicians worked in irregular shifts, while more than half of the people in the control group only worked morning shifts, but we have not found any data in the literature describing any influence of irregular shifts on the blood proteins.

The persons were examined and blood was taken during their working shifts in the transmitting stations. Each blood sample was examined twice in our laboratory. Total serum proteins were calculated from the nitrogen balance estimated by the colorimetric Nessler method (3). Fractions of proteins were separated by means of paper electrophoresis (6). Differences in the results of the two examinations of one person did not exceed 1%. For statistical evaluation the F-test and the Duncan test were used.

RESULTS

As our previous work did not reveal any pathologic changes attributable to the influence of electromagnetic radiation, the physical examination aimed mainly at excluding patients with the kinds of disease which are known to influence the blood chemistry.

The levels of blood proteins and their fractions were within physiologic limits, both mean values and individual ones, but statistically significant differences were found between the mean values for the control and exposed groups.

Total protein level (Fig. 5) was higher in people operating medium wave transmitters. One asterisk indicates the 5% and two asterisks the 1% level of confidence. The albuminoglobulin quotient (Fig. 6) decreased in radiotechnicians, which was due to the drop in albumin (Fig. 7) and increase in alpha$_1$ (Fig. 8) and beta globulin (Fig. 9 Alpha-$_2$

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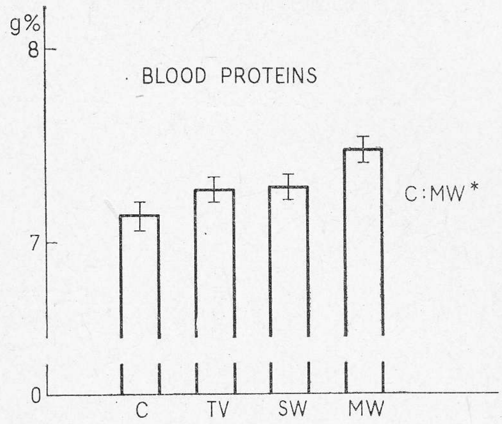

Fig. 5. Total blood protein level.

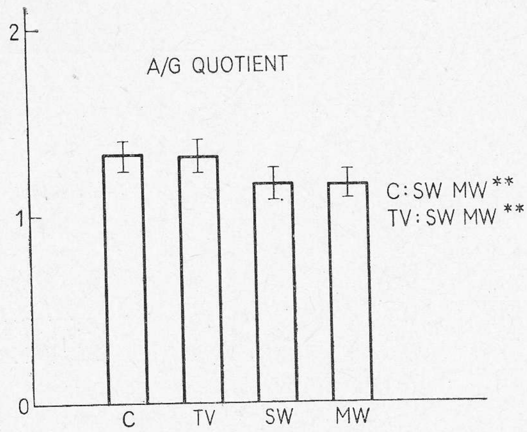

Fig. 6. Albumino-globulin quotient.

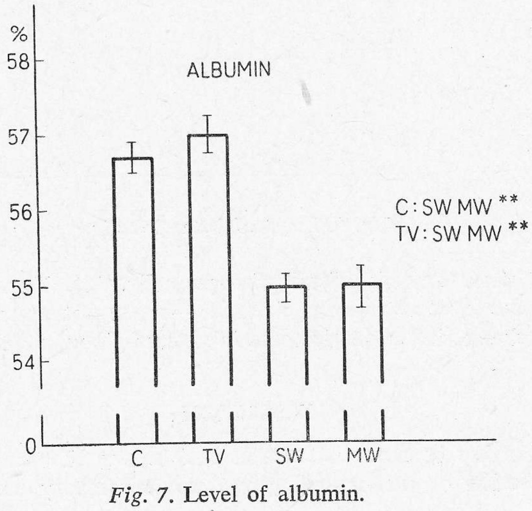

Fig. 7. Level of albumin.

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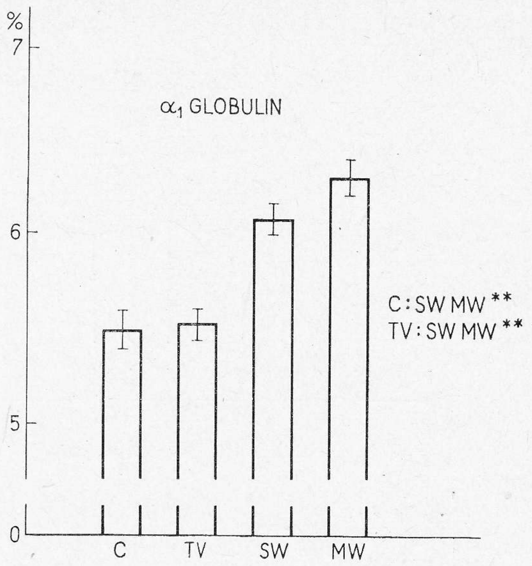

Fig. 8. Level of $alpha_1$ globulin.

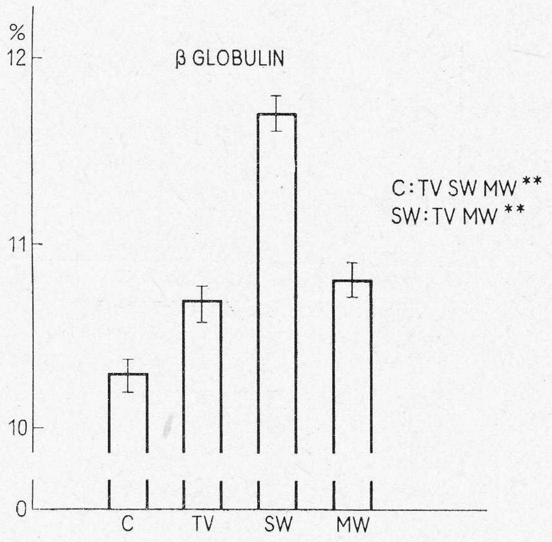

Fig. 9. Level of beta globulin.

globulin did not show any significant changes (Fig. 10). These alterations — with the exception of the increase in beta globulin — were not present in TV technicians, the most striking change being the decrease in gamma-globulin (Fig. 11).

DISCUSSION

This investigation has been carried out in such a way that sources of error in particular in the selection of the control group and laboratory procedures were dimin-

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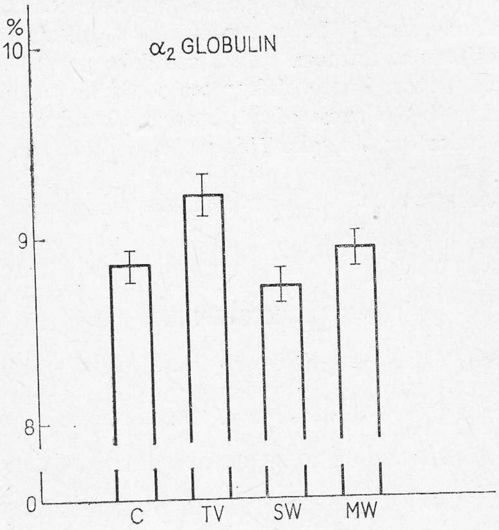

Fig. 10. Level of alpha$_2$ globulin.

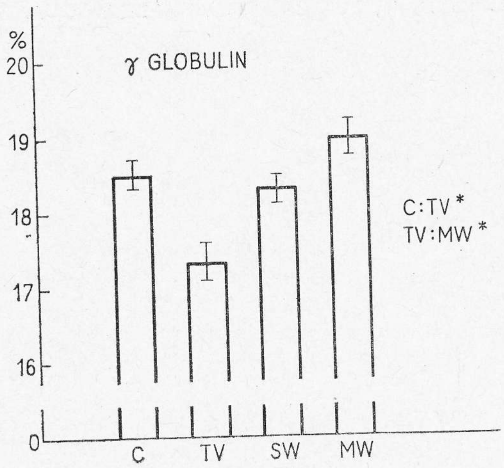

Fig. 11. Level of gamma globulin.

ished. Our previous findings confirmed the data from the literature (1, 2, 7, 8, 9) on the existence of blood protein changes in persons and experimental animals exposed to electromagnetic radiation. To our great surprise, the character of the changes diverged from those so far described, as we did not find any elevation of gamma-globulin, which is considered to be typical. We are unable to explain this difference, unless we attribute it to the fact that, contrary to our previous investigation, blood was taken directly at the transmitting stations immediately after exposure to electromagnetic fields. This explanation still remains open to discussion. The more pronounced changes in radio technicians might be ascribed to the higher and longer exposures in comparison with TV technicians.

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It must be emphasized that no pathologic findings have been revealed either in clinical or in laboratory examinations. The values of blood proteins were all within normal limits and only a difference in mean values could be proved statistically between the exposed and control groups. These differences could be considered as a general response of the organism to the stress of electromagnetic radiation, like similar reactions to other factors, chemical or biologic. This response, however, is not to be considered as a pathologic state.

We intend to continue studies to further elucidate the processes involved.

REFERENCES

1. BACH, S. A., LUZZIO, A. J., BROWNELL, A. S.: *J. Med. Electronics,* 1961, 9.
2. GUSKOVA, A. K., DVIŽKOV, P. P., DROGIČINA, E. A.: Occupational disease due to electromagnetic radiation. In: *Occupational diseases,* Ed.: Letavet A. A. Medicine, Moscow, 1964.
3. HOŘEJŠÍ, J.: *The foundations of clinical biochemistry.* The State Health Publisher, Prague 1963.
4. PAZDEROVÁ, J., FISCHER, R., FORMÁNEK, J., JOHN, J., LUKÁŠ, E., STÝBLOVA, V.: *Prac. Lék.,* 1969, **21**, 346.
5. PAZDEROVÁ, J., BRYNDOVÁ, V., JOHN, J., LUKÁŠ, E., NĚMCOVA, M., ZUBRIK, J.: *Prac. Lék.,* 1971, **23**, 265.
6. PECHAR, J., HAVALOVÁ, M.: *Čs. Gastroent. Výž.,* 1955, **9**, 205.
7. SACCHITELLI, F., SACCHITELLI, G.: *Folia Med.,* 1960, **43**, 1219.
8. SINGATULLINA, R. G.: *Bjullet. Eksper. Biol. Med.,* 1961, **52**, 69.
9. SLEPIČKA, J., SLÍVOVÁ, A., POCHMON, O., ZAPLETALOVÁ, E.: *Prac. Lék.,* 1967, **19**, 5.

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THE BIOLOGIC ACTION AND HYGIENIC SIGNIFICANCE OF ELECTROMAGNETIC FIELDS OF SUPERHIGH AND ULTRAHIGH FREQUENCIES IN DENSELY POPULATED AREAS

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With the powerful development of television, radar, radioastronomy and radiometeorology, hygienists are faced with a number of tasks, one of which is the assessment of energy of ultrahigh (UHF) and superhigh (SHF) ranges in densely inhabited areas. Until recently these ranges of radiofrequencies were investigated by hygienists only from the point of view of industrial hygiene and occupational diseases, while the problems of the biologic action and hygienic significance of UHF and SHF ranges, in relation to public hygiene, remained insufficiently elucidated. Taking this into account, we performed special investigations both on the distribution of electromagnetic energy in the UHF and SHF ranges under modern urban conditions and on the biologic effects of this energy.

Results of these investigations showed that at sites where television transmitters, TV links and radar stations are placed, the intensity of electromagnetic energy is much higher than that of the earth's background and covers a wide range, depending on the capacity of the emitters and the distance from radiating devices (antenna). Electromagnetic energy of various intensities penetrates living, administrative and other buildings located in the vicinity of the sources of radiation.

In order to assess the biologic action of the defined intensities of electromagnetic energy, as well as the hygienic importance of such radiation in densely populated areas, experimental studies on animals were conducted. Investigations were performed in shortened wave guides within the ultrahigh frequency range (wavelength 6 m) at the following power densities: 10, 2.4, 1.9, 0.06, 0.01 and 0.0006 $\mu W/cm^2$. Within the range of superhigh frequencies, irradiation was carried out at a distance which corresponded to the following power densities: 10, 5, 1 and 0.5$\mu W/cm^2$ (continuous generation, 12 cm wavelength) and 10, 5, and 1 $\mu W/cm^2$ (pulsed generation, 3 cm wavelength, pulse duration τ = 1 μsec and 1000 and 20 pulses per second).

In addition, using the pulsed regime of irradiation, the movements of the radar antenna were imitated with a beam angle of 2° and a rotation frequency of 10 revolutions per minute.

The computed intensities were close to those encountered in areas adjacent to television transmitters, links and radar systems.

The intensity of electromagnetic energy during experiments was controlled with IEMP-1 and PTSH-5A instruments for the UHF range and PO-1 ("Medik") for the SHF range.

Investigations of biologic effects for the UHF range were conducted on 128 white rats and 28 rabbits, and for the SHF range on 100 white rats and 32 rabbits. The ani-

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mals were irradiated daily for 10—12 h with electromagnetic energy in the UHF range and for 8 h in the SHF range. For each range and each intensity, the duration of the experiment amounted to 180 days (120 days of irradiation and 60 days of follow-up).

The results showed that the action of the electromagnetic field both in the UHF and SHF ranges during the first 10—12 days of irradiation resulted in some changes in the general status of the organism. Within this period the animals were somewhat excited and reacted to switching-on of the electromagnetic field.

These findings substantiated the notion that, as a result of the action of the electromagnetic energy, certain changes in the central nervous system were elicited. In order to define the changes more closely, investigations of the conditioned reflex activity of the animals were performed.

These experiments showed that, under the action of UHF and SHF fields, certain periodic changes appeared in the conditioned reflex activity of the animals. On the whole, the latent period was longer, reflex reactions to positive stimuli weakened, and the number of those missing increased. All this was evidently connected with the development of consequent inhibition related to impairment of nervous reactivity, and leading to pathologic stagnation and inertia. The intensities which produced statistically significant changes were 1.9—10 $\mu W/cm^2$ and 5—20$\mu W/cm^2$ in the UHF and SHF ranges, respectively.

These data were supplemented by electroencephalographic studies conducted on rabbits. The dynamics of changes in the central nervous system were assessed, as reflected in bioelectric activity of the brain cortex. The results showed that in the investigated rabbits the action of electromagnetic energy elicited some disturbances in relations between the potential frequency groups of the cortex (Tab. 1). At the beginning (2—14 days), activition of the biocurrents in the brain was observed, testifying

Table 1

Changes in biocurrents in the brain cortex of rabbits under the influence of electromagnetic energy of UHF range

Groups of animals and field intensity	Rhythms of biocurrents	Periods of examination				
		Before irradiation	2 days later	10 days later	30 days later	60 days later
Group I 10 $\mu W/cm^2$	Slow	26.0±1.8	11.0±1.8	6.0±1.6	17.0±2.9	58.2±5.1
	intermediate	50.1±1.7	34.0±4.1	24.5±2.7	54.2±3.3	27.2±1.9
	fast	23.1±0.6	55.0±5.8	72.0±1.7	29.8±0.7	11.6±3.1
Group II 1.9 $\mu W/cm^2$	Slow	19.0±2.1	11.5±1.0	16.0±1.7	12 8±2.2	52.0±2.7
	intermediate	66.4±3.2	72.0±3.3	46.0±8.5	65.0±3.9	38.8±4.8
	fast	14.2±1.6	16.5±2.5	44.0±9.7	22.2±4.6	9.2±2.3
Group III 0.01 $\mu W/cm^2$	Slow	18.7±1.4	19.0±1.6	17.5±1.7	14.0±1.2	22.5±1.4
	intermediate	70.2±0.9	70.0±2.2	68.5±2.9	69.5±2.4	65.0±2.9
	fast	10.5±0.9	11.0±1.7	14.0±1.9	11.0±1.7	11.0±2.2
Controls	Slow	17.2±1.4	17.2±1.4	14.8±0.7	14.2±0.8	16.0±0.4
	intermediate	65.7±2.4	67.7±2.4	68.2±1.4	70.7±1.8	67.8±0.4
	fast	16.6±1.2	16.6±1.2	17.0±2.0	15.6±1.9	16.2±0.7

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to some increase in the excitation process. With increasing duration of exposure an initial stage of inhibition developed, characterized by synchronization of the cortical rhythms. Thus, upon prolonged irradiation, the strength of the process of inhibition within the brain hemisphere cortex was appreciably increased, as evidenced by the appearance of slow rhythms in the electroencephalograms. The observed changes in bioelectric activity of the brain cortex of rabbits confirmed previously reported results of studies on conditioned reflex activity of animals and showed that electromagnetic energy in the UHF range and 0.06—10 μW/cm² intensity, as well in the as SHF range and 5—20 μW/cm² intensity, was indeed active biologically according to the results of statistical analysis.

Bearing in mind that electromagnetic fields of radiowaves act predominantly on the central nervous system, our biochemical studies concentrated on those indicators which directly or indirectly characterized the functional activity of the nervous system. Such tests in our investigations included cholinesterase activity and sulphydryl (SH) groups in the blood.

These experimental investigations showed that electromagnetic fields in the UHF and SHF ranges appreciably lowered blood cholinesterase activity and quantity of SH groups (Tab. 2 and 3). It could be noted that with increasing duration of exposure to the field, inactivation of SH groups in the blood also increased. It could therefore be assumed that a lowered activity of both cholinesterase and SH groups in the blood, as induced by the action of UHF and SHF electromagnetic energy, resulted in impairment of the biochemical mechanisms which ensure the normal course of nervous processes in the animal organism. Such was the likely explanation of the

Table 2

Changes in certain indicators of metabolic processes in rats exposed to UHF electromagnetic energy in chronic experiments

Indicator	Group I, 10 μW/cm²				Group II, 1.9 μW/cm²				Group III, 0.01 μW/cm²			
	Before irradiation	30 days later	90 days later	120 days later	Before irradiation	30 days later	90 days later	120 days later	Before irradiation	30 days later	90 days later	120 days later
Blood cholinesterase activity, ΔA/min	154	121	84	98	154	152	108	101	156	152	151	173
± S.D.		3.8	7.2	5.0		0.3	6.0	6.9		0.4	0.5	1.9
Blood SH groups, μmol/100 ml	1697	1750	1410	1190	1500	1340	1030	857	1702	1537	1587	1550
± S.D.		0.8	4.0	6.6		3.1	7.3	10.8		1.8	0.8	0.5
17-ketosteroids, in urine, mg/24 h	0.019	0.032	0.055	0.060	0.018	0.024	0.040	0.047	0.021	0.018	0.022	0.023
± S.D.		8.6	19.4	16.4		2.7	8.4	10.4		0.7	1.2	0.4

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Table 3

Changes in certain indicators of metabolic processes in rats exposed continuously to SHF electromagnetic energy in chronic experiments

Indicator	Group I, 10 μW/cm²				Group II, 5 μW/cm²				Controls			
	Before irradiation	30 days later	90 days later	120 days later	Before irradiation	30 days later	90 days later	120 days later	Before irradiation	30 days later	90 days later	120 days later
Blood cholinesterase activity, ΔA/min	123	142	110	104	125	134	110	110	123	122	122	147
p		<0.05	<0.05	<0.05		<0.05	<0.05	<0.05				
Blood SH groups, μmol/100 ml	1411	1694	1320	1340	1427	1640	1340	1350	1461	1461	1527	1533
±S.D.		5.7	2.5	2.2		3.6	2.8	2.9		0	1.0	1.1
17-ketosteroids in urine, mg/24 h	0.0225	0.0375	0.0368	0.0343	0.0230	0.0380	0.0375	0.0420	0.0230	0.0256	0.0243	0.0213
p		<0.05	<0.05	<0.05		<0.05	<0.05	<0.05				
RNA in the liver	—	—	—	70.2	—	—	—	71.4	—	—	—	89.3
±S.D.	—	—	—	4.9	—	—	—	3.6				
DNA in the liver	—	—	—	51.5	—	—	—	51.0	—	—	—	70.7
±S.D.	—	—	—	5.0	—	—	—	5.0				

changes which we found in conditioned reflex and bioelectric activities of the brain cortex of irradiated animals.

It is well known that steroid adrenal hormones, weight of the suprarenal glands and their ascorbic acid contents are all important biochemical parameters of metabolic processes of the human and animal organism. These parameters characterize not only general metabolic processes of the organism, but also reflect certain relations between biochemical reactions and the functional status of the nervous system, and are therefore of particular interest.

Our results showed that prolonged action of electromagnetic fields of UHF and SHF frequencies resulted in increased weight of the adrenals, a reduction in their ascorbic acid content and increased secretion of 17-ketosteroids in the urine of experimental animals. The above changes could probably be explained by an increased functional activity of the hypophysis-adrenal cortex system. It is widely accepted that activation of the cortical function points to an influence of unfavourable conditions, so-called stress stimuli, acting upon the whole organism. In this case we considered

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electromagnetic fields in the UHF and SHF ranges to be such unfavourable stimuli. The lesions occured in animals irradiated at power densities of 0.06 to 10 and 5 to 20 $\mu W/cm^2$ with UHF and SHF electromagnetic fields, respectively.

While investigating the biologic influence of electromagnetic fields in the SHF range, we tried to define the action of this factor upon the endocrine system and took as an example the thyroid gland. In order to asses the functional status of the thyroid, use was made of the radioactive iodine indicator method (uptake of radioactive iodine by the thyroid gland) and the method employing ^{131}I-thyroxine. These investigations showed that under the influence of SHF fields of 10, 5 and 1 $\mu W/cm^2$ power density, the ability of the thyroid gland to concentrate radioactive iodine was increased: the maximum uptake amounted to 48.0 ± 1.88 at 10 $\mu W/cm^2$, 51.2 ± 4.03 at 5 $\mu W/cm^2$, and 51.1 ± 6.0 at 1 $\mu W/cm^2$, as compared with 28.3 ± 3.38 in control animals. This testified to the fact that SHF energy induced intensification of thyroid function. Taking into account that the thyroid gland has a regulatory influence on a number of functions of the organism, one could imagine that an increase in its activity induced a number of undesirable changes in the organism as a whole.

The above investigations were accompanied by studies on the morphologic composition of the blood. It was found that electromagnetic energy in the UHF and SHF ranges caused an insignificant decrease in the number of leukocytes, eosinophils and reticulocytes; some tendency to lowered erythrocyte and hemoglobin values was also observed.

Bearing in mind that electromagnetic fields influence general metabolic processes, we performed investigations on the effects of this factor on nucleic acid metabolism. Results of these investigations showed that the factor under study induced a statistically significant increase in the RNA and DNA contents of the spleen and liver of the animals (see Tab. 2). It is difficult at present to explain these findings. To solve this problem, special investigations will be needed.

In addition, we studied the influence of electromagnetic energy in the UHF range upon carbohydrate-phosphorus metabolism. These investigations showed that a prolonged exposure to a field of 0.06—10 $\mu W/cm^2$ intensity resulted in disturbances of glycogen metabolism, i.e. a reduction in the glycogen content in the liver due to increased phosphorylase activity accompanied by simultaneous accumulation of lactic acid. At the same time a marked influence of UHF fields on oxidative coupling and phosphorylation processes in rat liver mitochondria was detected. Long-term irradiation led to a fall of phosphorylation and oxidation functions of hepatic mitochondria.

The biologic experiments were complemented by histomorphologic studies which showed that the lesions which appeared under the influence of electromagnetic energy in the UHF and SHF ranges took the form of dystrophic changes in the brain, liver, spleen and testes, along with impairment of blood circulation. The severity of these changes depended on the intensity of the electromagnetic field. More pronounced changes were found in the organs of animals exposed to relatively high intensities.

Analysing the results of the above experimental investigations, it should be noted that prolonged action of electromagnetic energy of low intensities in the UHF and SHF ranges resulted in appreciable changes in the general status of the organism, conditioned reflex activity, bioelectric activity of the brain cortex, a number of biochemical parameters, blood composition and morphologic structures of the tissues and organs of the animals under study. The biologically active intensities of electromagnetic fields were 10—0.06 and 20—5 $\mu W/cm^2$ for UHF and SHF ranges, respectively.

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SELECTED CASES OF MICROWAVE CATARACT IN MAN ASSOCIATED WITH CONCOMITANT ANNOTATED PATHOLOGIES

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INTRODUCTION

In man, microwave radiation can cause cataracts via several different mechanisms. Only rarely is exposure relatable to or associated with clinically recognizable thermal injury. Ordinarily, there are no signs or symptoms suggesting thermic insult. Instead, the irradiations usually occur without the subject displaying any sense of awareness.

Where microwaves serve as the primary etiological factor for lens opacification, the resultant cataract may be referred to as "microwave cataract". Here the characteristic appearance and clinical course of the lens pathology are in a general way related to the intensity-duration function of and time interval between exposures. It is my practice to reserve the term, microwave cataract, for those cases which exhibit capsular opacification, a signature of radiation injury, after having had known, significant exposures only to the microwave portion of the electromagnetic radiation spectrum. (A similar clinical course can follow exposure, for example, to shorter or longer wavelengths where the diagnosis could be infrared or hertzian cataract, respectively).

At least three different stages or presentations of microwave cataract can be identified. Although they appear to be related to dosage, dose-rate and dose-interval, the relationships are not clear-cut. Transitions between stages are not distinctly demarcated probably because both cumulative and additive effects are contributing to produce a variable pathogenic evolution. Nevertheless, microwave cataracts can be classified as either (1) acute, (2) subacute or (3) delayed. Although this is not an entirely satisfactory method for describing all the permutations, it does serve to facilitate understanding of the findings as actually encountered in clinical practice.

Before describing the classification, it is necessary to provide some pertinent information about the normal lens and cataract formation. The lens is a mostly transparent biconvex tissue, measuring about a centimeter in equatorial diameter and about one half a centimeter in axial depth. It is located near the front surface of the eye immediately behind the iris so that its anterior surface is about one half a centimeter from the corneal surface. It is surrounded by a thin elastic membrane capsule perhaps averaging about 10 microns in thickness in the living eye. Because of its thinness and almost total transparency, the capsule is not easily detectable by slit-lamp examination. On the other hand, the normal lens substance, when viewed by slit-lamp biomicroscopy, has an observable relucency of the light beam so that it does not appear to be optically empty but, instead, it can be examined readily and much detail can be recognized. Further, the light beam relucency is not uniform throughout the lens substance but, instead, regions of optical density differences are apparent permitting a gross division of the peripheral portion, the lens cortex, from its central portion, the lens nucleus.

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In addition, the slit-lamp magnification readily permits identification of small lens substance imperfections such as granules, vacuoles, precipitates and sutural markings. These are frequently referred to by ophthalmologists as opacities without much further description and the differentiation between capsular and contiguous cortex opacifications is seldom noted but, instead, pathology at this site is ordinarily described as subcapsular opacification.

Opacification can be present without a measurable reduction in visual acuity. The term cataract has been used often in the literature for localized regions of opacification which do not significantly interfere with vision. However, I prefer that its use should be correlated to the clinical relationship of visual function. In this context a cataract may be considered to be mature when it prevents any useful vision, immature when vision is partially present and incipient when disturbance of visual discrimination has just become apparent. This is the criterion by which I further define microwave cataract and differentiate it from microwave injury, an earlier stage of capsulopathy without any effect on vision.

In my experience and by my definition, all pure cases of microwave cataract must exhibit capsulopathy. Without capsular opacification I would not consider microwaves to be the primary etiologic agent. This is not to say that microwaves would not be contributory in accelerating the cataractogenic process for the usual types of cataract, all of which take origin in the lens substance. Thus, in hereditary, congenital, hormonal, toxic, metabolic, ionizing radiation or senile cataracts, microwave irradiation does not ordinarily produce or superimpose a new kind of cataract but, instead, it acts as a secondary, contributory or synergistic agent by shortening the time interval required for maturation.

Regarding microwave capsulopathy, it is not born fully formed. Instead, it ordinarily begins insidiously. The earliest recognizable stages are usually found at the posterior lens surface where it appears as if small, scattered regions of the capsule are roughened and thickened. Although it does take proficiency in the use of the slit-lamp to identify this finding, when the next stage, opacification of these regions of the capsule, commences, ordinarily this is readily observable if searched for. Once established, capsular opacification is irreversible. With the passage of time, additional loci appear and, depending upon the number, relative location to each other, degree of confluence and relative density of the opacification, which can vary from light gray to dense white, the capsular opacification can acquire a variety of localized forms. In some instances these give rise to a honeycomb, brush-mark, lace-cloth, spider-web, breadcrumb or peppered-surface appearance. Although the honeycombed configuration can usually be recognized, it is not uncommon ultimately to find variations of all of these descriptive appearances as more and more areas of the capsule become involved and adjacent areas coalesce. Eventually, as these areas become larger and denser, there can arise gross plaque-like or sheet-like areas having millimeter dimensions. At no time, however, does the entire lens capsule become uniformly or homogeneously dense white but instead, even when capsular opacification involves practically the entire lens surface some areas of clear capsule can still be recognized.

Although capsular opacification precedes lens substance opacification, the former does not become complete before the latter commences. Indeed, visual acuity does not diminish to any measurable degree until the lens substance has started to become cataractous. Further, the subsequent reduction in visual acuity varies directly with the site and quantity of lens substance pathology. For this reason, a brief description of the lens substance changes ordinarily associated with microwave cataract is in order. Many of the same lens substance processes are also associated with cataracts due to other causes.

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Due to its avascularity and the barrier against penetration by wandering cells afforded by the capsule, the ordinary processes of inflammation and tissue repair after injury, which would be termed phakitis, cannot occur in the lens. However, the intact capsule acts as a Donnan's membrane so that water, for example, as well as some ions and solutes can pass through. When the lens substance imbibes fluid it can become edematous (hydrated) and this results in a swollen physical state (intumescence). This could be termed phako-hydritis and it can either be localized to a microscopic region of the lens giving rise to vacuoles, a minute macroscopic region giving rise to vesicles, a larger portion of the lens substance recognized grossly as a limited region of altered translucency or it can involve practically the total lens substance, producing a swollen appearance of the entire lens.

Phakohydritis is reversible providing its duration is brief or its extent is not massive. For example, if a single vascuole is present, a not uncommon finding in any lens, usually it will disappear completely, occasionally what appears to be a microscopic sharply demarcated precipitate remains behind for a period of time and subsequently, this too, ordinarily will be resorbed and disappear after a few months have elapsed or rarely a permanent minute microscopic coagulate will persist. However, when vesicles have formed, these persist for long periods of time and should they be resorbed they almost always result in some permanent coagulation of the contiguous lens substance appearing as a macroscopic imperfection or dot when the lens is viewed by ophthalmoscopy. When a sector or a gross portion of the lens exhibits altered relucency due to diffuse hydration it is usually visible to direct view, if it persists from weeks to months it almost always will result in some permanent degree of opacification and usually the opacification becomes denser with time. When the entire lens is intumescent and the hydration persists for more than one to two weeks, then the lens will become cataractous rapidly; this is a rare fulminating type of cataract which can be referred to as "hydrops" of the lens.

In the name of science (?), some unrelated ophthalmological conditions which cannot conceivably be mistaken for microwave cataract have been offered to raise questions about this clinical entity. For example, cataracta complicata and congenital capsular cataract have been such offerings. Cataracta complicata, also known as complicated cataract, arises secondary to inflammatory and degenerative changes in the retinal or uveal tissues and results from the release of toxins into the intraocular fluids. As the toxins diffuse into the lens they produce a polychromatic lustre at the posterior capsule and a rosette type cataract. At no time, does microwave cataract exhibit either polychromatic granules or polychromatism of any sort at the posterior capsule nor does it produce rosette cataracts.

Congenital capsular cataract is a rare, freak medical curiosity. When present, it is incompatible with useful vision and associated with other concomitant intra-ocular anomalies. The lens is smaller than normal, deformed and surrounded by an opaque, membraneous mesodermal sheath instead of a capsule. At no time can this be mistaken for capsular cataract.

CLASSIFICATION OF MICROWAVE CATARACT

1. The "acute" cataract rarely occurs in man. Although it could conceivably follow a single massive exposure, and thereby resemble most of the reported animal experiments, I do not yet know of such a human case. Instead, the typical acute microwave cataract has a history of repeated, short duration exposures, for example, from looking into a generator cavity to observe the color of the grids or to view an antenna

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rotary joint for arcing through a hole cut into a waveguide. Ordinarily, the time duration of each individual exposure is estimated in seconds to minutes and repeated exposures vary from many times daily to several times per week during a period of weeks to months. Under these conditions, vision usually begins to fail during or immediately following these exposures. In addition to diminution of vision, which is ordinarily the chief complaint bringing the patient to the ophthalmologist, occasionally other ocular symptoms related to an irritable eye also develop. None of the patients reported sensing heat during any of the exposures.

The ophthalmological findings at the first examination are striking and vary from acute hydrops of the lens to an advanced stage of capsulopathy. Regarding the capsulopathy, ordinarily the posterior region of the capsule is more involved than the anterior region and some lens substance cataractogenesis, even though it may be minimal at this time, is evident. Within months to years, even if no further exposures take place, a practically complete capsular cataract will form and subsequently or simultaneously the lens substance also will become completely cataractous.

When a fulminating hydrops of the lens occurs, an inflammatory panophthalmitis occurs with evidence of keratitis, blepharo-conjuctivitis, iridocyclitis and chorioretinitis, leading to a stormy post-irradiation clinical course. In such a case, the contralateral eye may also develop a secondary uveitis. In some features, this contralateral uveitis resembles sympathetic ophthalmia except that it is less severe and more responsive to anti-inflammatory therapy than the primary radiation uveitis in the exposed eye.

2. The "subacute" microwave cataract ordinarily results from frequently repeated subclinical exposures carried out over a duration measured in months to years. Usually, the patient's only complaint is gradually failing vision. As a rule, there is a clear-cut history of intimate daily contact with a microwave source. Although some evidence of pathology is usually present in both eyes, it is seldom equal or bilaterally symmetrical. These cases are the most instructive so far as following the clinical course of microwave cataract is concerned because the two eyes present different stages of the injury and in follow-up examination of these cases the frequently observed latency and delayed evolution of microwave cataract can be determined. Further, when the source becomes identified, the patient can be spared from additional irradiation. By following the clinical course of such patients, the latency and slow progression of the cataract becomes evident as well as the fact that regression of the capsulopathy never occurs although it may remain at an arrested stage of development for long periods of time.

In a typical case, the patient, unaware of having been irradiated, is surprised to learn that the gradual almost imperceptible reduction of vision he has experienced over the course of a few months, predominantly in one eye, is due to an incipient cataract. He is further surprised to learn that his other eye has evidence of lens opacification. Unless a radiation etiology is suspected and the source identified or, for some other reason, such as changing job assignment, the covert exposures cease, the cataractogenic process will progress slowly but continuously in both eyes, and result in mature cataracts being formed over a period of several months to a few years.

Where the chronic exposures have been terminated, the rate of cataractogenesis frequently becomes reduced and may even appear to be arrested for many months or years. However, ordinarily this is only an apparent latency and the incipient cataract is not really dormant but, instead, it is developing at such a reduced rate that it takes years before becoming mature. Interestingly, in many of these cases, the cataract will spread along the capsule and remain localized to the capsule and contiguous cortex, almost completely surrounding the lens without producing opacification in the remaining bulk of the lens substance. As such, it is frequently referred to by most

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ophthalmologists as "capsular cataract". Subsequently, the entire lens substance will also become opacified although this may take many additional months or years.

3. The "delayed" microwave cataract usually forms insidiously over a five to thirty year period. The best documentation for this has been found where the contralateral eye has a subacute microwave cataract. Here, there is real latency as the capsulopathy frequently lies dormant for many months at a time. In the early years, progression, which occurs intermittently, is ordinarily recognized by additional areas of capsule becoming opacified. Eventually, lens substance opacification will ensue, either in the manner already described or by the intervention of nuclear sclerosis. Ordinarily the nuclear sclerosis form of cataract is considered to result from the aging process. However, I have found it to occur prematurely and follow an accelerated course in the presence of microwave capsulopathy.

REPORT OF CASES

Case 1. Mr. C. J., a 44 year old white male. At age 27 while working as a microwave researcher, he performed an experiment testing the function of a radar rotary joint by watching for arcing through a small hole cut into the waveguide. He performed this task intermittently on several different days during a three to four week period. On the testing days, the task was repeated many times. Each viewing lasted from seconds to a minute or two in duration. All the viewing was performed with the right eye. Although the highest possible calculable exposure field strength to the right eye could have been 4 W/cm², it is more reasonable to estimate that his exposures averaged about 500 mW/cm². His work was interruped because the vision of his right eye failed rapidly. Ophthalmological examination revealed that he had an acute, fulminating microwave cataract and panophthalmitis of his right eye. Within a few weeks, he developed a mild uveitis of his left eye. The bilateral uveitis responded to anti-inflammatory therapy within a few months and has not recurred.

Seven years later, a cataract extraction combined with sector iridectomy and anterior and posterior synechiotomies was performed on the right eye. During this seven year period, the patient developed a few microscopic areas of capsular opacification at the posterior surface of the left lens and a 0.1 millimeter thick linear streak of pigment, subtending an arc from 4—8 o'clock, also became prominent on the posterior surface of the lens. During the next ten years, the capsulopathy gradually increased in size, in number of loci and in density of opacification; however, the visual acuity can still be corrected to 20/20 although the patient states that his vision is not sharp. Also, during this time, the trabecular region of the eye and the posterior surface of the cornea have gradually become pigmented and degenerative changes have occurred in the corneal endothelium and peripheral retina. Perhaps most significantly, recently the streak of pigment containg cells on the posterior surface of the lens appears to be undergoing active growth. It has extended to encompass practically the entire equatorial region of the lens. At each end of the original pigmented streak, there is now a further suggestion of cellular activity as these regions have enlarged and appear like satellite colonies. The medial end is now circular with a diameter of 1.0 millimeter and the lateral site is oval and measures about 1.0 × 3.0 millimeters. Technically, the diagnosis is melanoma and the question to be resolved is whether it is completely benign or will become malignant.

Several years ago the patient developed degeneration of an intervertebral disc in the lumbar region requiring spinal fusion but, otherwise, he has been in good general health.

Case 2. Mrs. B. L., a 51 year old white female. The patient had been in excellent health throughout her life and the only history of potential radiation exposure was that she used a consumer type microwave oven regularly for five years between 1966 and 1971. Because of her failing sight due to cataracts of an unusual type, the oven was tested in 1971 and found to be leaking at a maximum level of 2.0 mW/cm² during operation and 40.0 mW/cm² when the door was opened. The oven was not used afterwards but it was retested in 1972, at which time it was reported to be leaking microwaves at a level of 1.0 mW/cm² during

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operation and 90 mW/cm² when the door was opened. Her exposures were covert and occurred between 1966 and 1971.

In prior years, her eyes were examined and found to be completely free of disease. In June 1969, because of a sense of blurred vision of the right eye, she was examined by her ophthalmologist who reported that although her visual acuity could be corrected to 20/20 in the right eye and 20/15 in the left nevertheless incipient opacities were forming at the posterior subcapsular area of both lenses, being more pronounced in the right eye than the left. The cataracts progessed so that by April 1972 it was necessary to perform cataract surgery for the right eye and the best refracted vision of the left eye had been reduced to 20/50. The patient was referred to me for consultation in February 1973 and she had the typical findings of subacute microwave cataract in her left eye.

Case 3. Mr. A. K., a 44 year old white male. At age 21, he served in the United States Navy during the Korean War as a radar maintenance man. For about a year during 1950 to 1951 he was exposed repeatedly to microwave radiation from patrol aircraft radars at field strengths up to a maximum of 1.0 W/cm². I first examined the patient in 1964 when he was 35 years old and his ophthalmic findings were immature subacute microwave cataract of the right eye and a minimal stage of delayed microwave cataract of the left eye. During the next nine years, the cataract of the right eye has progressed slowly but steadily so that now it involves practically the entire capsule and most of the contiguous lens cortex. The central portion of this lens remains clear so that it can now be classified clinically also as a capsular cataract. There has been very slight progression of the posterior capsulopathy in the left eye which can still be corrected to 20/20 visual acuity.

Since being discharged from the Navy, the patient has had episodes of mental illness, cardiovascular disease with depressed and inverted T waves, osteoarthritis and thyroid dysfunction.

Case 4. Mr. D. B., a 41 year old white male examined by me in 1968. He was identified only as a member of a large group of researches working with microwaves at field strengths lower than 10 mW/cm². He was a participant in a screening examination designed to identify microwave injury. His examination revealed the typical microwave-induced honeycombed opacification of the posterior capsule in both eyes. As the involved areas were large, about 3 millimeters in diameter for the left eye and 2 millimeters in diameter for the right, and inert because there was very little opacification of the contiguous cortex, the diagnosis was an early stage of delayed microwave cataracts. During the previous year, the patient had undergone surgical removal of a testicular malignancy.

Case 5. Mr. J. F., a 44 year old white male. The patient was first examined by me in 1971, when he was 42 years old, because he had been advised that he was developing microwave cataracts. Examination revealed extensive capsular cataract of the left eye, a late stage of subacute microwave cataract with beginning exfoliation of the capsule and a suspicion of posterior synechiae (which was confirmed at surgery) and an early stage of delayed microwave cataract in the right eye.

The patient had worked on several different radar systems from the time he was 26 years old until he was 35 during the period from 1955 through 1964. The highest field strength to which he was regularly exposed was about 1 mW/cm² for durations up to three hours and occasionally he could have been exposed to field strengths up to about 25 mW/cm² for a minute or less.

The patient fathered a son, born early in 1964, the product of a normal pregnancy, who did not appear as alert and did not develop as rapidly as other children. The child sat at six months, stood at twelve months and walked at eighteen months. About that time, brief head nodding developed which progressed to a form of psychomotor epilepsy, subsequently exhibiting symmetrical clonic movement of all extremities and the eyes lasting a few seconds and finally he exhibited lethargy. The boy died at age 7 and autopsy revealed that he had a rare, most unsual degeneration of his thalamus.

Case 6. Mr. M. D., a 50 year old white male. At age 49 the patient was referred for a consultation because he had a cataract in one eye and he had worked as a radar engineer since 1951. Examination revealed a minimal microwave capsulopathy at the posterior surface of both lenses and advanced nuclear sclerosis of the right lens without any trace of nuclear

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sclerosis in the left lens. Vision in the right eye could not be corrected to better than 20/400 while it was 20/20 in the left eye. Prior to 1970, when he was discovered to have a nuclear sclerosis type of cataract in his right eye, his vision was excellent in both eyes and no ocular pathology had ever been noted previously.

The patient's occupational history was reliable. The only work assignment that could have led directly to exposure occurred 20 years previously when for 18 months he was employed testing magnetrons. This assignment involved viewing the cathode emitter through a small hole via a mirror arrangement. All of the viewing was performed with his right eye. The maximum exposure was estimated to be at a field strength no higher than 1 mW/cm^2. The diagnosis was delayed microwave cataract of the right eye and delayed microwave injury of the left eye.

In March 1973 the patient sustained a cerebrovascular accident secondary to occlusion of the right internal carotid artery. Emergency surgery, endarterectomy with resection of atheroma and plastic revision of the artery were performed successfully and the patient is making a slow recovery from the cerebrovascular accident.

Both sites of delayed appearing pathology, the right eye and the right internal carotid artery, were located within the zone being irradiated while the patient was viewing the magnetron cathodes.

DISCUSSION

Each of the case reports has prima facie evidence of microwave injury, i.e., a clear history of inhabiting microwave environments and the signature radiation cataract. In addition, each case exhibits in at least one eye, the covert nature of exposure, the long duration latency and the slow evolution of pathology typically found in man.

These cases have been selected from a reservoir of more than 50 patients having primary microwave cataract. They signify clearly that most of the previously collected experimental microwave cataract data are inappropriate, inapplicable and unsuitable either for the understanding of the disease process as it ordinarily occurs in humans or for the formulation of permissible levels of irradiation. Perhaps the most important and significant finding in this regard is the pre-senile appearance of nuclear sclerosis of the lens which indicates that the aging process may be initiated prematurely or accelerated by microwave irradiation.

Aside from premature aging, there are a number of other microwave bio-effects that have been reported in both animals and humans, such as ocular, testicular, embryological, cardiovascular, neural and endocrine disorders. Although microwave lens injury is common to all the cases I have reported, each has additional findings which could be attributable to irradiation.

Among the ophthalmological findings are hydrops of the lens, kerato-conjunctivitis, irido-cyclitis and chorioretinitis which can develop immediately following irradiation. At a later date, keratopathy, capsular exfoliation, synechiae, glaucoma, retinal degeneration and melanomata can appear. After years of latency, endothelial dystrophy of the cornea and nuclear sclerosis of the lens, indicating premature aging, also can appear. Further, because the capsule is weaker and there is a greater likelihood of adhesions between the lens and the adjacent iris anteriorly and vitreous posteriorly than with most other types of cataracts, the surgical extraction of microwave cataracts carries a higher complication rate and requires greater than ordinary skill in order to minimize surgical complications.

Non-ophthalmological findings observed in this select group of cases include mental illness, cardiac, vascular, hormonal and arthritic disease and testicular malignancy. In addition, one of the subjects, after many years of chronic exposure to microwaves, fathered a child with a rare bizarre, fatal central nervous system degeneration.

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The mere chronicling of these case reports provides a grim picture. This is particularly true when it is coupled to the protean nature of the electronic smog pollution problem. In this context, let us consider only our background microwave habitat. The solitary significant natural source is the sun. Under worst case conditions (sunburst activity), the integrated sum for the entire microwave bandwidth produces a field strength less than 1×10^{-8} mW/cm^2. In this regard, there is not much difference between western or eastern oriented standards and nothing about either that can be recognized as being safe. For example, the west emphasizes avoiding a burn while the east desires to prevent a simmer. Both imply that a vacation from the microwave environment is curative. Neither has faced up to the real problem identification and prevention of the late or delayed appearing radiational effects.

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RETINAL CHANGES IN MICROWAVE WORKERS

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The cataractogenic effect of exposure to microwaves has been reported by several authors. Effects on the central nervous system have also been discussed. It is unknown whether the effect is thermal or nonthermal in origin. In this paper the authors show that in a factory where radar and other microwave equipment was tested an over--representation of lens opacities could be observed in personnel in the lower age groups. Furthermore it was noted that changes in the retina resembling chorioretinal scars were present in a significant number of workers.

During the last quarter of a century there has been a marked development and increased utilization of devices that emit various forms of non-ionizing radiant energy, including equipment for industrial and medical applications as well as for military use. Microwaves have come into use primarily in the military field but also for short-wave diathermy medical therapy and for domestic use in cooking. Today microwave emitters are widely spread. The electromagnetic radiation characterized as microwaves has a wavelength between 0.3 mm and 300 cm corresponding to 10^8—10^{12} Hz. The microwave energy can be propagated either pulsed or as a continuous wave (CW).

Where the microwaves are absorbed they give an increased kinetic energy to the molecules exposed, which will increase the possibility of collisions between molecules and hence result in increased temperature in the entire material.

The biologic effects of microwaves have been very thoroughly investigated in many places but especially in the Triservice Program (5). There is general agreement that the effect of microwaves in tissues is mainly of thermal origin. However, non-thermal effects have been suggested and there is still a great deal of controversy on this subject.

One of the most throughly investigated aspect of the pathologic effects of microwaves is the denaturation of lens proteins resulting in lens opacities — cataract (2, 3, 6, 7). General effects on the central nervous system, i.e. headache and nausea, have been reported from the USSR, but it is still a matter of dispute whether these symptoms are secondary to temperature increase in the organism or direct non-thermal effects on the nervous tissues. In most industries and military organizations involved in microwave work yearly controls of their personnel are recommended, especially checking of the eyes. In one of the industries working with radar equipment such check-ups started quite recently. The preliminary findings were rather astonishing in two ways; first, the frequency of significant lens opacities in the younger age group was greater than expected and secondly, retinal lesions in the paramacular and macular region were observed in a number of cases, with decrease in vision in two cases. As retinal lesions have never been reported in the literature as far we have found, an epidemiologic study was performed, in order to find out whether the above-mentioned changes had any significance.

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MATERIAL

98 employees in an electronic industry developing radar equipment were investigated. 68 had been exposed to microwaves for a certain time or were still working in this field. This group could be divided into persons testing radar equipment and measuring microwave radiations from different klystrons and persons from the experimental laboratories. A control group of 30 persons from the same industry was exposed to microwave radiation, as far as was known.

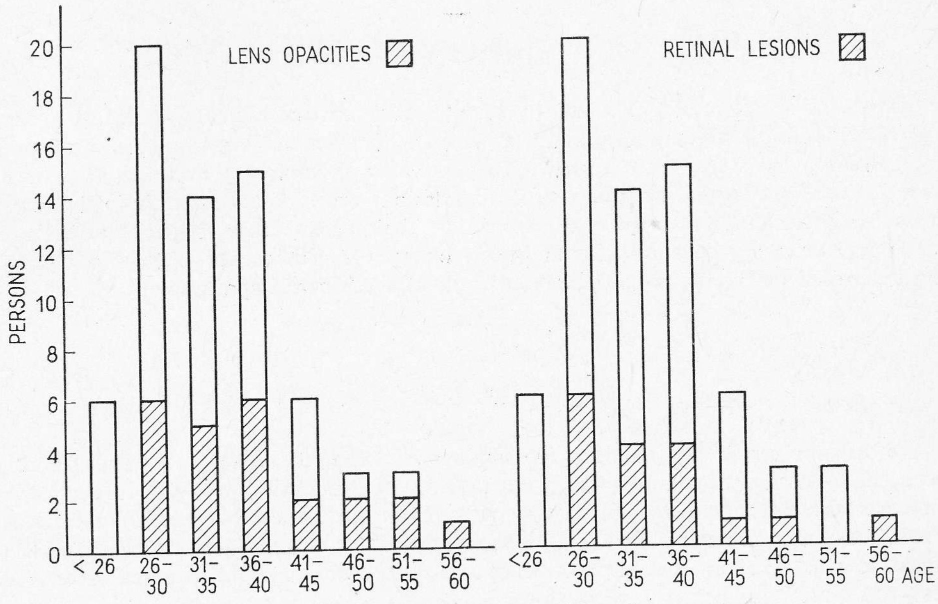

Fig. 1. Exposed persons (68 cases).

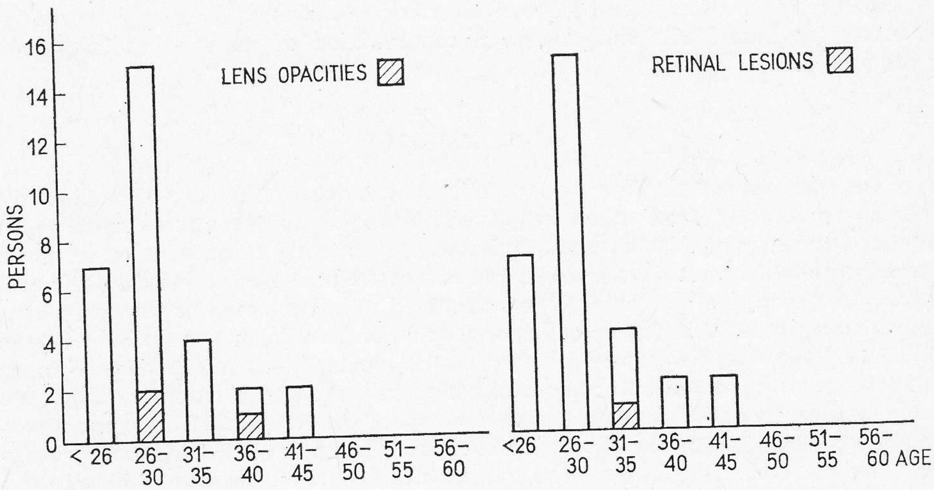

Fig. 2. Controls (30 cases).

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METHODS

Two eye specialists independently made a careful eye examination of all personnel mentioned above without any knowledge of their occupation or microwave exposure. The examination included determination of refraction and visual acuity, a study of the optic media with the aid of a corneal microscope and slit lamp in complete mydriasis, and a study of the retina with an ophthalmoscope.

DEFINITIONS

Only lens opacities of a diameter of more than 0.5 mm or a high concentration of smaller opacities in the subcortical region were taken as significant. Very small opacities spread out in the lens were not recorded. The opacities should be detectable also in the ophthalmoscopic media examination. Retinal lesions were looked for only in the central part of the fundus and were characterized by their resemblance to chorioretinal scars after inflammatory reactions. Small yellow changes in this region were also observed and recorded but were not classified as lesions of significant importance.

RESULT

As can be seen in the diagram the number of exposed subjects with lens opacities is high, even in the younger age groups. Only in two cases was there disagreement between the examiners and these two cases from the exposed group were excluded from the material. In the higher age group — above 41 years — it was impossible to separate lens opacities due to microwave exposure from a senile cataract because no controls were examined.

Retinal lesions, hitherto never reported, are also of high frequency. Only one case was found in the control group, which makes the exposed group significantly different. Dividing the group of exposed personnel according to their tasks (testing personnel — laboratory personnel), one can observe a concentration of lens and retinal lesions in the former.

DISCUSSION

It is of great interest that eye lesions, both lenticular and retinal, were found in this material significantly more often in persons belonging to the test group than in persons working in the laboratories. It is difficult to draw conclusions as to which kind of work is the most risky, but one knows that the personnel testing the equipment or measuring radiation are more apt to be exposed to higher power levels than others, i.e. laboratory personnel. This is of importance as the maximum permissible exposure (MPE) of 10 mW/cm^2 might be a figure that is too high — a comparison with the Soviet figures suggests this. Another explanation is that the eye lesions observed are due to leakages from the equipment or carelessness of the personnel. As we have a concentration of damaged persons in a certain exposed group the MPE is probably sufficient and the other suggestions more reasonable. The retinal lesions observed were earlier briefly reported by the authors (1). Since then we have been informed by

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a Polish scientist (4) that in a very recent study initiated by our findings similar retinal lesions were observed in personnel exposed to microwaves, which confirms our observations.

The pathogenesis of the retinal lesions is very obscure. The transmission properties of microwaves in biological tissues do not explain why certain areas in the retina should be changed as a result of thermal effects. The change in dielectric constants in the different layers of the retina might give an increase in intensity of three to four times between the layers but this seems too small an increase to explain the damage.

It is, of course, not known whether non-thermal radiation effects cause these changes. Further experimental and theoretical work has to be carried out in order to find the explanation. The most important findings reported here are the retinal lesions as these lesions have resulted in a decrease of vision in two cases. In no case known have the lens opacities resulted in a comparable loss of vision. In the future the necessity for a careful examination of the fundus of the eye has to be stressed and further experiments will hawe to be carried out as damage to such nervous tissue as the retina suggests that similar changes might appear in other kinds of nervous tissue after exposure to microwaves.

REFERENCES

1. AURELL E., TENGROTH B.: *The Third International Conference on Medical Physics, Including Medical Engineering*. Chalmers University of Technology, Göteborg, Sweden, 1972.
2. CARPENTER R. L.: *Proc. 3rd Ann. Tri-service Conf. Biol. Hazards of Microwave Radiating Equipment*. Ed. C. Susskind. University California, Berkeley, 1959, **25—27**, 279 (August).
3. CARPENTER R. L., VAN UMMERSEN C. A.: *Microwave Power*, 1968, **3**, 1.
4. CZERSKI P.: Personal communications.
5. MICHAELSON S. M.: *The tri-service program — A tribute to George M. Knauf, USAF (MC)*. IEEE Trans. Microwave Theory Techn, 1971, **MTT-19**, 131 (February).
6. RICHARDSON A. W., DUANE T. D., HINES H. M.: A. M. A. *Arch. Phys. Med.*, 1948, **29**, 765.
7. ZARET M. M.: *Foundation report*, RADC-TDR-64-273, October, 1964. Contract AF 30 5602-3087; Final report for Rome Air Development Center.

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ASSESSMENT OF LENS TRANSLUCENCY IN JUVENILES, MICROWAVE WORKERS AND AGE-MATCHED GROUPS

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In recent years much attention has been paid to possible health hazards of microwave radiation. In the eye, the lens is considered particularly sensitive and divers changes have been described. Microwave changes in the lens are, however, the subject of controversy and opinions on the effects of occupational exposure differ. One of the reasons is that different criteria are used for the assessment of lens translucency.

The aim of this study was to establish criteria for evaluation of lens translucency and to examine it in individuals who did not have any contact with microwave radiation and in microwave workers. Taking into account exposure levels, age and duration of occupational exposure it should be possible to determine microwave effects in the lens.

3000 individuals of both sexes were examined. The whole population examined comprised 3 groups, 1000 persons in each. Group A comprised two subgroups. A_1 contained 542 individuals exposed directly to microwave radiation at power density about 0.1 mW/cm^2 and up 1 mW/cm^2. During short periods of time the mean power density could reach up to 6 mW/cm^2. Group A_2 comprised 458 individuals exposed to microwaves at 0.01 mW/cm^2 or less. All the persons examined were exposed on the average during 4 h daily, the history of occupational exposure ranging from 1 to 15 years. Several consecutive examinations were made in hospital (590 persons) or out-patient department conditions (410 persons). Group B comprised 1000 age-matched individuals not exposed occupationally to microwaves, while group C was made up of children and juveniles aged 5 to 17 years. Both groups B and C were subjected to a single examination in an out-patient department.

The examination of the lens was made using a slit lamp after dilatation of the pupil. Lens translucency was assessed using a 5-grade scale presented in Table 1.

The translucency of the lens was highest in group C and because of this, this group will be considered first. Grade 1 was found in 68.8% of cases on the average. Subdivision of this group into age-groups demonstrates clearly the influence of age, the incidence of grades 2 and 3 increasing between 10 and 17 years of age. Sporadic cases of grade 4 and 5 translucency confirm the fact that certain changes may be inborn (cf. Tab. 2). In comparison with group C, group B demonstrated worse characteristics of lens translucency, lenticular opacities increasing with age. Both groups, B and C, served as controls for group A, making it possible to determine both the frequency of inborn defects as well as defects appearing with age. A detailed analysis of these groups allows the conclusion that a close correlation (linear relationship) exists between age and the grade of lens translucency; the frequency of inborn defects may be estimated at about 0.7% (grades 4 and 5). Before a comparison with group A is made, it should be stressed that it was highly preselected, all individuals with grade 4 or 5

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Table 1

Classification of lens translucency

Lens changes	Grade	Qualification as to fitness for microwave exposure
None	1	fit
Single, small, multishaped (dust-like points, radial striations) opacities, which may be counted; no visual acuity impairment	2	fit
Numerous small, multishaped (dust-like points, irregular, radial striations) opacities, which are difficult to count; no visual acuity impairment and no tendency to increase on successive examinations	3	fit to continue occupational exposure, should be observed; unfit as a candidate for admission to work or for training in a profession involving microwave exposure
As above, but with a tendency to increase in number or size on successive examinations	4	unfit
Any change impairing visual acuity	5	unfit

Table 2

Percentage incidence in various lens translucency grades in groups examined

Lens translucency grade	Group A			Group B	Group C
	A_1	A_2	A_1+A_2		
1	13.0	31.1	21.7	29.7	68.8
2	62.0	52.6	57.7	50.3	26.9
3	19.7	12.2	16.2	16.6	3.6
4	4.8	3.5	4.1	2.6	0.3
5	0.5	—	0.3	0.8	0.4

translucency being eliminated before admission for work in microwave exposure conditions.

Statistically significant differences in the frequency of various grades of lens translucency exist between group A and groups B and C. Moreover the comparison between subgroups A_1 and A_2 also demonstrates statistically significant differences. A more detailed analysis, according to the duration of occupational exposure, demonstrates that this does not play a decisive role. The decrease in lens translucency seems to depend rather on power density levels. If safe exposure limits are observed and single exposures remain below the permissible power density levels and respective exposure times per 24 h no effects on the incidence of lens opacities are observed.

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It should be stressed that no particular morphologic features, distinguishing the lens opacities in microwave workers from those seen in the control population, could be detected. This may indicate that long-term overexposure to low doses of microwaves (below cataractogenic levels) may tend to accelerate the normal aging process of the lens. This indicates also that grade 4 lens translucency should be considered a contraindication for continuing occupational microwave exposure.

It should be stressed also that any case of cataract suspected of being due to occupational exposure to microwaves should be fully documented. Any other cataractogenic factors should be excluded and the results of earlier ophthalmologic examinations presented.

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