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WORKERS' STATE OF HEALTH UNDER LONG-TERM EXPOSURE TO ELECTROMAGNETIC RADIATION IN THE VHF BAND (30-300 MHz)

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[Text] The purpose of our research was to contribute to the solution of the question as to whether human health is affected by long-term exposure to electromagnetic radiation in the VHF band, and thereby to enhance the setting of health norms that would eliminate not only any possible damage but also discomfort during work. The present work ties in with our previous study of the environment of radio transmitters [35], where we did not find any disease due to electromagnetic radiation, despite the fact that the intensity of the electromagnetic field exceeded in most cases the permissible level in Czechoslovakia. We will not dwell on the general problems of electromagnetic radiation and instead refer the reader to certain summary reports and monographs [9, 24, 27, 28, 34, 44]. In the literature, however, we did not find any study that solved the personnel's state of health at television transmitters, in terms of a more accurately defined exposure.

Material and Methods

In 1969 and 1970, during a 5-day confinement at the Clinic of Occupational Diseases in Prague, we examined 58 employees of television transmitters from the entire territory of Czechoslovakia. The criterion for selection was the length and magnitude of exposure. We invited for examination persons who had been exposed the most and the longest. Of the 88 invited employees, 30 declined for family reasons and work schedules. The mean age of the 49 examined males was 31.8 years (s = 7.6), and their mean exposure was 7.3 years (s = 3.0). The average age of nine examined females was 33.9 years (s = 7.6), and their mean exposure was 6.9 years (s = 2.3). Of the mentioned 49 males, nine had worked previously at radio stations, an average of 7.9 years (s = 2.0).

The majority of the examined subjects were employed as technicians and shift supervisors. During most of their working time they monitored the

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operation of the transmitters. During the rest of their working time they recorded the readings of measuring instruments located on the individual transmitters, readjusted them and performed routine maintenance. By nature their work was routine intellectual activity with average requirements in terms of intelligence, vigilance and attention. The educational requirement was secondary education, but 17 technicians were continuing their education under work-study programs. At every work station the work was in shifts, with work cycles of varying length, and the workweek averaged 40 hours. The transmitters' frequency band was 48.5 to 230 MHz.

In the subjects' histories we noted whether some disease occurred more frequently or afflicted several persons from the same work station. We devoted attention also to the subjects' social history, to their commitments outside working hours, particularly to enrollment in work-study programs, to opportunities for resting after a night shift, to the manner of commuting, etc. The results obtained in this manner were evaluated individually, in relation to the overall clinical picture.

The employment history was supplemented by measurements of the electromagnetic field intensity, and by computations of the exposure levels at the individual work stations. The electromagnetic field intensity was measured according to the standard method introduced in Czechoslovakia. Only the field's electrical component was determined by means of an integrating field-strength meter for medical purposes, due to Rezny [46]. Essentially this is a transistorized HF voltmeter. The error of this method is given as ±30 percent. The measurements were made during the transmitters' peak power, with the transmitters' doors always open (Fig. 1), which is typical of the bulk of the operating time during the year. By comparing the accurate time studies of the individual occupations with the employees' data, we computed the exposure per workday, i.e., the products of the field intensity, in volts per meter, and of the exposure time, in hours. The microclimatic conditions, the noise level and temperature, were measured by the routine methods employed in health inspection.

All employees were examined under the same hospital regimen. Of the clinical and laboratory data, we first evaluated the pulse rate, taken at the end of the physical examination at the time of admission. The random blood pressure -- i.e., the mean of three measurements at rest -- was compared with the corresponding age group in Ripka's sample of the Czechoslovak population [37]. Values that exceeded by more than ±2 the standard deviation of the control group were regarded as abnormal. The same method was employed to evaluate the blood-sugar curves obtained by the Hagedorn-Jensen test [22]. Our control was the corresponding age group in Svoboda's sample of healthy individuals without familiar hereditary trends [42]. The protein spectrum of 54 subjects was investigated by the method of paper electrophoresis [22]. We determined the total protein, the percent of alpha 1, alpha 2, beta, and gamma globulins, and the albumin-globulin ratio. We compared the results with a control group of 55 healthy individuals whose mean age was higher by 6 years; we used the "t" test to determine the significance of the differences.

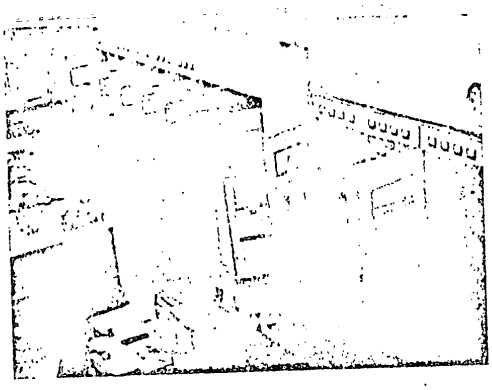

Figure 1. Work station of a TV transmitter's operating personnel.

Venous blood was taken for a complete blood count. The erythrocyte and leukocyte counts were based on the measured-volume principle. The platelet count was made by the Piettes' method [36]. The differential leukocyte count was made from 100 cells. Within the erythrocyte count we also compared the hemoglobin content and the hematocrit, which methodologically is more accurate than counting erythrocytes. In the leukocyte component we determined the total leukocyte count, the number and percent of segmented neurophilic leukocytes and of lymphocytes, and the percent of eosinophils and of monocytes. We compared the results with our own control groups of healthy adults, and then determined the statistical significance of the obtained differences by means of the "t" test. The total plasma cholesterol was determined for all subjects by the routine laboratory method [22]. In view of the fact that in 1969 most hospitalized patients, and hence also the investigated sample, showed excessively high cholesterol levels, we do not regard these values as realistic and have not evaluated them.

Furthermore we performed liver tests (total and direct bilirubin, glucose tolerance, SGOT and SGPT), the ESR test, urinalysis and microscopic examination of the sediment. We took chest x-rays, and electrocardiograms with standard and chest leads. The female subjects underwent gynecological examination. The pathological findings of the examinations and tests mentioned in this section will be analyzed separately below.

Fifty-six subjects underwent neurological examination, according to the customary basic scheme. Close attention was devoted to neurovegetative symptoms (emotional erythema, Maranon's sign, dermographism, changes in acral temperature and sweating, tremor of the extended fingers, and changes in the pulse rate during examination, due to emotional causes or to a type of respirational arrhythmia). The methods of examination and interpretation are described in greater detail in our previous work on the environment of radio transmitters [35]. The results of the

Table 1. Electromagnetic Field Intensities and Exposure Levels by Work Stations

(1) Intenzita pole (V/m)	(2) Označení pracoviště									(3) Průměrné hodnoty
	1	2	3	4	5	6	7	8	9	
(4) Minimální	0	0	0	0,4	1,1	0,2	0	1,5	0,8	0,4
(5) Maximální	6,0	1,6	8,0	7,5	9,0	6,8	7,6	9,2	8,0	7,1
(6) Aritmetický průměr	1,8	0,6	2,4	3,4	5,0	2,4	2,7	5,6	2,8	2,9
(7) Směrodatná odchylka	0,4	0,1	0,4	0,5	0,5	0,3	0,5	0,6	0,4	0,4
(8) Hodnota ozáření během pracovní směny V/m . t (hod)										
Minimální	6,5	6,5	21,4	15,1	94,1	20,4	22,8	73,8	17,5	31,5
Maximální	15,28	14,4	24,2	28,0	97,1	31,3	36,5	83,2	34,4	40,4
Aritmetický průměr	10,8	10,45	22,8	21,5	95,6	26,3	29,6	78,5	25,9	35,7
Směrodatná odchylka	2,89	2,78	1,4	2,72	1,5	2,03	3,95	4,96	8,45	3,80
(9) Počet vyšetřených	4	3	4	13	7	6	6	8	7	

Key:

1. Field intensity (V/m)
2. Designation of work stations
3. Mean values
4. Minimal
5. Maximal
6. Arithmetic mean
7. Standard deviation
8. Exposure per shift V/m·t (hours)
9. Number of subjects examined

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examination were compared with a 57-member control group of the same age. Docent Styblova, who interpreted the electroencephalograms, did not find any statistically significant difference in the distribution of the normal, abnormal and pathological rhythms, as compared with the control group [41].

On the basis of random selection, 46 subjects underwent psychiatric examination. The results were compared with the findings for a 21-member control group of the same age and educational background, and were subjected to the chi-square test. The selected level of the least significant difference was $p = 0.05$. All the examined subjects completed psychological questionnaires aimed at detecting neurasthenic symptoms: Knobloch's N 5 questionnaire, the Eysenck EPI questionnaires A and B [17], and the MHQ questionnaire [11]. The results of the examination were compared with the findings for the Czechoslovak population, as reported on the basis of such questionnaires by Engelsmann et al [15, 16].

One ophthalmologist examined 51 subjects, and the rest were examined at another work station. This does not affect the evaluation of the results in any way, because also here the findings were routine, commonly occurring among the Czechoslovak population. The anterior segment of the eye was examined in focal light, the refractive power was measured subjectively and objectively, and the lens was examined by biomicroscopy under artificially induced mydriasis. Intraocular tension was measured in subjects over 40, and the field of vision was checked when indicated. By means of the "t" test, the results were compared with a control group of 106 healthy individuals whose mean age was 33.1 years.

Examination and Test Results

The measured intensities of the electromagnetic field are presented in Table 1. It is evident that the standard limit of 10 V/m was not exceeded at any work station. To the contrary, the mean values for the individual work stations are fairly low. However, the mean level of exposure at one of the work stations exceeded the permissible limit of 80. What the field intensities were in the past cannot be determined accurately, because systematic measurements were not conducted. To some extent it may be assumed that initially, during the installation of the equipment, the field intensity might have been temporarily higher, but upon the commencement of transmission the intensity was probably lower than now when the transmitter operate more hours per day.

Noise at the work station consisted predominantly of low-frequency noise generated primarily by the air-conditioning equipment. The numbers of the noise-level grades ranged from 65 to 81 N. The optimal temperature at every work station was exceeded by 2°C on average.

In the following we will dwell on the results of the clinical examinations and laboratory tests. In the subjects' histories we did not find any accumulations of nosological units; the individual diseases occurred

Table 2. Protein Spectrum

(1) Kontrola	(2) Celkové bílkoviny	(3) Albuminy	(4) Alfa 1	(5) Alfa 2	Beta	(6) Gama	(8) A/g
			(7) globuliny				
n	54	54	54	54	54	54	54
$\bar{x}$	6,99	55,41	6,13	8,06	10,74	18,03	1,28
$ts_{\bar{x}}$	0,12	1,33	0,32	0,47	0,49	0,70	0,07
(9) Televizní pracovníci							
n	53	53	53	53	53	53	53
$\bar{x}$	7,67	54,72	6,56	8,43	10,57	19,72	1,26
$ts_{\bar{x}}$	0,27	1,37	0,35	0,40	0,47	0,84	0,07
(10) Televizní a rozhlasoví pracovníci							
n	9	9	9	9	9	9	9
$\bar{x}$	7,69	53,89	7,02	9,43	11,01	18,64	1,18
$ts_{\bar{x}}$	0,33	2,64	0,04	1,30	1,42	1,19	0,14
(11) T-testy							
(12) Kontrola: televizní	2,88**	0,73	1,84	0,75	0,50	1,45	0,56
(13) Kontrola: televizní a rozhlasoví	2,90**	1,16	2,03*	1,20	0,41	0,46	1,54

*Level of least significant difference 5 percent. **1 percent.

Key:

1. Control
2. Total protein
3. Albumin
4. Alpha 1
5. Alpha 2
6. Gamma
7. Globulin
8. Albumin-globulin ratio
9. Television personnel
10. Television and radio personnel
11. "t" tests
12. Control vs. TV personnel
13. Control vs. TV and radio personnel

in an isolated manner and at the same age that we encounter the diseases in other patients. This in itself excluded the possibility of any correlation between these diseases and exposure, and therefore we did not evaluate them statistically. In four male subjects we found hypertension that was diagnosed already during the study. Hypertension in two of these subjects was of the juvenile type. One patient aged 60 showed also pronounced signs of coronary insufficiency and hypertension that is not readily curable. The fourth hypertonic had also an anginal syndrome. In all these cases, hypertension had been diagnosed already before

employment at television transmitters. The blood pressure of the other subjects did not differ significantly from the blood pressure of the control group. Neither physical examination nor electrocardiography revealed any pathological irregularities of the pulse rate.

The blood-sugar level was pathological only in the case of the already mentioned 60-year-old patient who showed signs of general arteriosclerosis. In the other patients there were no significant differences as compared with the control group. We present the protein spectrum in Fig. 2 because there are certain irregularities already in the second sample from an environment exposed to electromagnetic radiation. The mean hemoglobin content was higher for the male subjects than for the control group: 16.46 g% (ts = 0.29) as compared with 16.15 g% (ts = = 0.18). The difference is merely at the 5-percent level of the least significant difference. The hematocrit values did not differ from the control group. The erythrocyte count of the female subjects did not differ significantly from the control group. The mean leukocyte count of the investigated subjects was higher than for the control group: 6655 (ts = 457.8) as compared with 6028 (ts = 371.7, based on a least significant difference level of 5 percent. Equally significant was the rise in the absolute lymphocyte count of the investigated sample, while the percent breakdown did not show any significant difference. Leukocytosis in five subjects was a concomitant symptom of inflammation of the upper respiratory tract or of the urinary tract. Without these five subjects, the mean leukocyte count was 6280, without any significant difference in comparison with the control group.

Two males with hypertension and coronary insufficiency had corresponding pathological electrocardiograms. The electrocardiograms of the other subjects were normal. We diagnosed a single case of focal pulmonary tuberculosis, in the induration to calcification phase. According to this patient's history, infection occurred in childhood. The liver tests were pathological for one female subject with chronic liver damage and pronounced hypercholesterolemia, for which she had been treated for some time. The gynecological findings of four female subjects were pathological: two had cystic degenerations of the ovaries, diagnosed prior to their present employment; one girl had chronic adnexitis; and one woman in her menopause had a myoma of the uterus. However, these women did not report any impairment of fertility, if and when pregnancy was desired.

Entirely rare were complaints of a loss of potency in males, always within the framework of a neurasthenic syndrome, specifically among the male subjects who were enrolled in work-study programs and were overburdened. There was no opportunity for a systematic sexuological examination, and therefore we did not evaluate these data.

In Table 3 we present in detail the results of our neurological examination, because they are often the subject of discussion. Of the 46 persons who underwent psychiatric examination, 19 or 41.3 percent had no

Table 3. Results of Neurological Examination, and Comparison with the Control Group

	Persons	Percent
1. Clinical neurological findings entirely normal	29	51.70
2. Abnormalities that unquestionably are unrelated to electromagnetic radiation		
Carpal tunnel syndrome	1	
Radicular syndromes	4	
After basocranial fracture, with minor neurological symptoms	1	
After paresis of the facial nerve	1	
Intercurrent hypertension	3	
History of psychic disorder	1	
Vasomotoric cephalalgia already before exposure	2	
Subtotal	13	23.00
3. Abnormalities of a vegetative type		
With history preceding exposure, or with recognized exogenous causes	3	
Without apparent exogenous or endogenous causes	11	
Subtotal	14	25.00
Control group (57 individuals) Abnormalities of a vegetative type	16	28.07

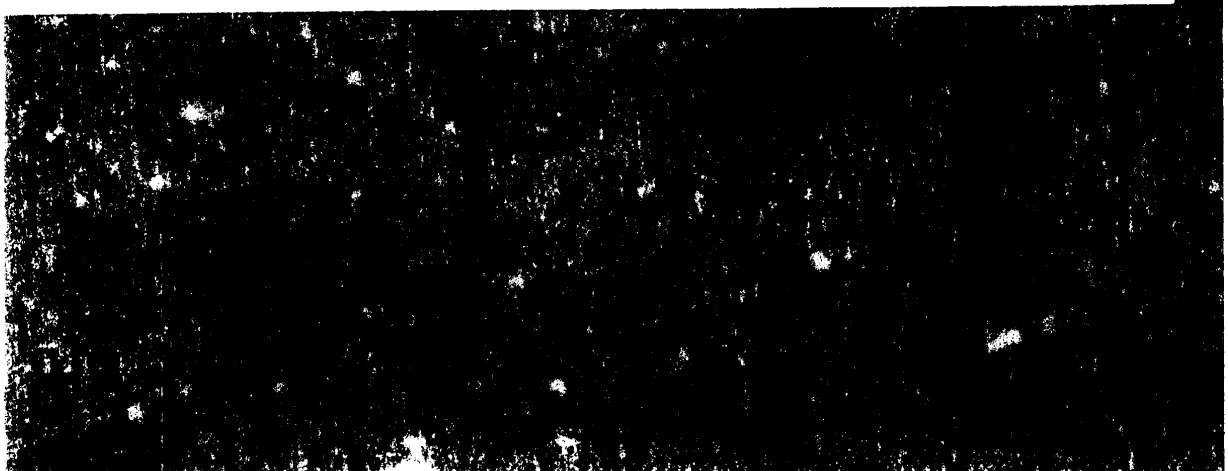
psychic disorder. Psychis disorders were found in the remaining 27 subjects or 58.7 percent. On the basis of their symptoms these subjects have been divided into four groups.

1. Subjects with light neurotic disturbances (insomnia, loss of appetite, fatigue, restlessness, nervousness, depression, and vegetative disturbances). These symptoms were light and did not affect the subjects' ability to work, nor their ordinary way of life. In this group we included 18 persons or 39.1 percent.

2. Aberrant and psychopathic personalities, i.e., individuals whose abnormality was tolerated by themselves or by their environment. Such symptoms were encountered in two subjects or 4.4 percent.

3. Aberrant and psychotic personalities with neurotic disturbances. A total of five persons or 10.8 percent.

4. Persons who had a record of treatment in a psychiatric institution, or who showed psychotic traits during examination. This included two



subjects or 4.4 percent. Statistical evaluation established that the difference between the examined subjects and the control group was not significant, and that there was no correlation with the subjects' age or their length of service at television transmitters.

The results of the questionnaire tests to determine neurotic disorders were favorable: neurotic complaints were reported less frequently than in the control group.

The ophthalmologist found refractive disorders, including presbyopia, in 15 of the examined subjects. In three subjects the refractive disorder was accompanied by strabismus. One patient had chronic conjunctivitis, and another had small congenital cataracts. The results were more favorable than in the control group, but the difference was not significant. Because of the few ophthalmological findings in the population at present, the correlation with the duration and magnitude of exposure was not investigated.

Discussion

The data in the literature on the blood pressure and pulse rate of persons exposed to electromagnetic radiation differ. Most authors emphasize hypotension and bradycardia as signs of disturbed vagal tone, or at least the tendency to these states [18, 19, 20, 21, 40]. The tendency to hypertension [22] or the fluctuations in both directions [42] are reported less frequently. In agreement with certain clinical studies on both the VHF and HF bands, we have not found any changes in blood pressure or pulse rate that could be attributed to the effect of electromagnetic radiation. We likewise are unable to confirm the views of some authors [13, 14, 31, 40, 43] who report electrocardiographic changes, particularly a disorder of intraventricular conduction or in the terminal portion of ventricular conduction, and various irregularities of the R wave. The two abnormal electrocardiograms in our sample are in complete agreement with the clinical picture of hypertension and coronary insufficiency. These electrocardiograms were obtained from persons in their sixties, respectively in their fifties, which is a common occurrence in our population. It can be proved that hypertension in these two subjects predates their employment at television transmitters. This rules out the possibility of any causal relationship between hypertension and electromagnetic radiation.

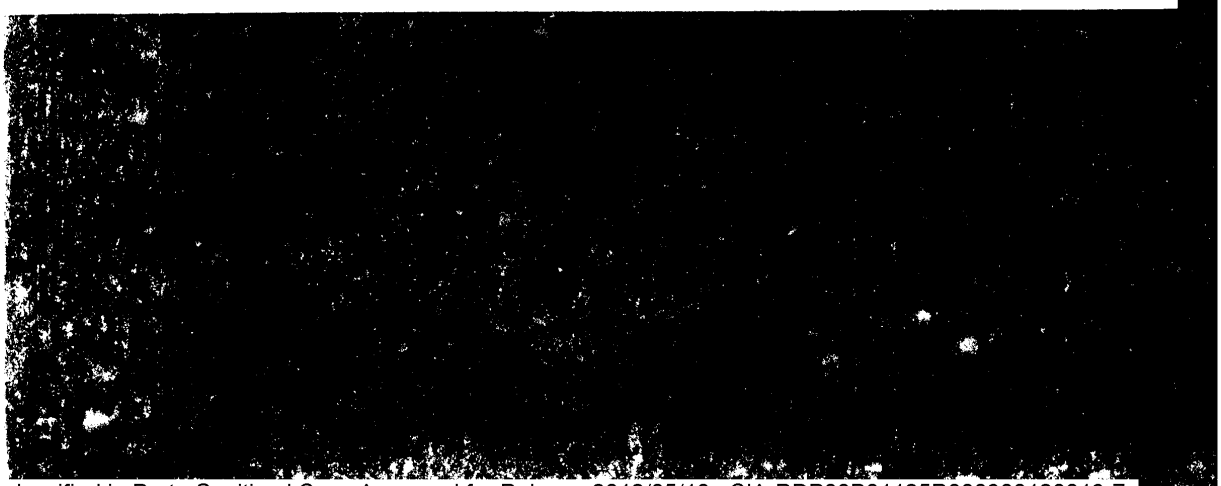
The blood counts of the investigated sample are entirely favorable. The difference between the mean hemoglobin contents is not accompanied by a significant differences between the hemocrit values and is due mostly to the selection of the control group. Most subjects within our sample live in a healthy outdoor environment, on mountainous terrain, due to the location of the television transmitters. But in our control group we have individuals from the Prague area. Ideal for the evaluation of all the tests and examinations would be a control group that is similar to our sample in terms of age, way of life, and educational background.

We did not have an opportunity to select such a control group, because it would have meant hospitalizing for one week at least 40 to 50 healthy individuals from the provinces. It had been difficult to select blood-count control groups also in our evaluations of other samples [33, 35] because also the test results reported in the literature [summarized in 35] for healthy population groups in Czechoslovakia mutually differ. Thus, we are not attributing any undue significance to these small differences.

The literature sometimes reports leukopenia, or at least a tendency to leukopenia, in persons exposed to electromagnetic radiation [8, 12, 13, 14, 20, 21, 30]. The mean leukocyte count of our sample was higher, but the difference was significant only when we included subjects with acute infections. Because the length of hospitalization was determined in advance, there was no way of controlling the leukocyte counts only after the infections had ended, and therefore we had to exclude these subjects from the sample. Cosic reports thrombocytopenia in personnel servicing radar installations, but in the literature we have not found other, convincing data on blood platelet changes in an HF environment. Our sample did not show any significant differences as compared with the control group. We are unable to confirm certain views [29] that radiation of this type affects carbohydrate metabolism.

Both experimental and clinical studies occasionally report differences in the protein spectrum, mostly in the sense of an increase of gamma globulin, in the the HF and VHF bands [2, 3, 6, 9, 35, 39]. Because in our investigation of radio station personnel we likewise had found a significant increase of the mean gamma globulin content, in our present study we compared separately the subjects who had been employed also at radio stations. We did not find an increase of the gamma globulin content, but both groups differed from the control group in that their plasma protein was higher. Even if we take into account Nitsche's finding [22] that the plasma protein level declines with age (the mean value is 7.09 gram percent at age 15 to 19, and 6.89 g% at age 40 to 59), this does not explain the difference between our sample and the control group that on average was only 6 years older. If we take as the normal range the 6.8 to 9.2 g% reported by Mathews [22], then neither the investigated sample nor the control group has higher values. However, the central laboratory uses 6 to 8 g% as the normal range, and it was exceeded by several subjects in the investigated sample, although their other laboratory tests and clinical findings were normal. We do not have any explanation for the higher mean plasma protein level. Therefore we recommend the systematic monitoring of the electrophoretically determined protein levels of persons exposed to electromagnetic radiation, and also the experimental study of this question, so as to clarify the possible correlation with electromagnetic radiation.

It is difficult to evaluate the gynecological findings in such a small number of females. In the literature we have not found any data on the



more frequent incidence of diagnosed diseases among women working in an environment exposed to electromagnetic radiation, and we do not think that there is any causal relationship here.

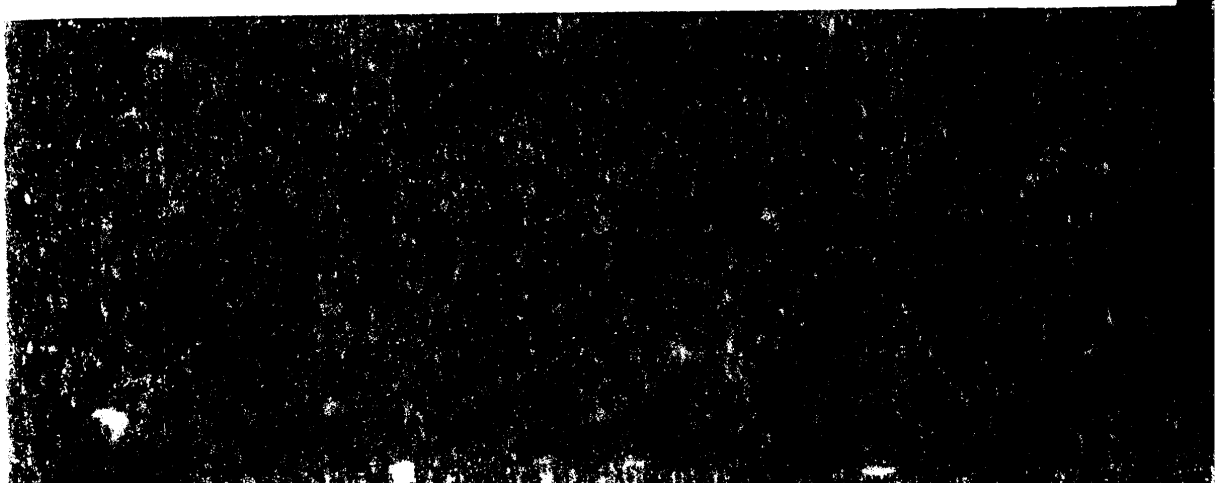
Data on the incidence and evaluation of neurovegetative symptoms differ considerably by authors [4, 13, 14, 23, 25, 26, 38]. Some neurologists [4, 23,25, 26, 38] have not found more-frequent neurovegetative symptoms in persons exposed to electromagnetic radiation, as compared with their control groups. Other neurologists, however, regard neurovegetative symptoms of varying severity as evidence of damage due to the electromagnetic field. We investigated this problem in greater detail in our preceding study of radio station personnel, and in a summary report [34, 35]. The examination results of our sample and of the control group are in agreement with the findings for the Czechoslovak population where a reported 30 percent of the individuals have pronounced neurovegetative symptoms of varying intensity.

Psychiatric examination revealed a higher incidence of neurasthenic stresses as compared with the objective symptoms of neurovegetative stigmata. This is entirely understandable because neurasthenic disorders are not necessarily accompanied by objective symptoms, especially not in less severe cases. Most neurasthenics within our investigated sample had only light neurotic disorders that did not affect in any way their ability to work, evident also from the results of the psychological tests that were aimed at detecting neurotic disorders. If we sum up the results of the neurological, psychiatric and psychological examinations, we may say that these examinations did not reveal any signs of organic or functional damage to the central nervous system.

Lenticular changes are described especially in experiments, but rarely in people working in superhigh-frequency (microwave) fields where the power density exceeds the tolerance limit by at least three or four orders of magnitude [6, 7, 8, 9, 24, 44, 45]. Therefore it is not surprising that in our sample we did not find any eye damage caused by electromagnetic radiation.

We have examined two-thirds of all persons in Czechoslovakia who have worked the longest at television transmitters and have been exposed the most. This is a sufficient number to make our conclusions reliable. We found that hygienic conditions at the work stations were favorable, that on average the electromagnetic field's intensity never exceeded the permissible 10 V/m, and that only at one transmitter was the exposure higher on average than the 80 specified in the standard. In none of the subjects did we find damage caused by electromagnetic radiation. Thus, we may say with full responsibility that disease due to electromagnetic radiation cannot occur at the television transmitters if the hygienic limits are observed.

If with the lengthening of the television program the hygienic conditions at the work stations deteriorate -- i.e., if the electromagnetic field's intensity and the exposure rise -- after a certain time it will



be necessary to conduct a complete checkup of the employees' state of health. The task will be the easier because the medical examinations of newly hired personnel for transmitter stations include also electroencephalograms, and thus it will be possible to compare the findings with the state of health at the time of hiring.

Summary

Fifty-eight employees of television transmitter stations, 49 males and 9 females, were examined. Their mean age was 32.1 years, and their mean length of employment at television transmitters was 7.2 years. The transmission band ranged from 48.5 to 230 MHz. The electromagnetic field's mean intensity was 2.9 V/m (s = 0.4, range from 0 to 9.2 V/m). The mean exposure per workday, computed as the product of the field intensity (V/m) and of the period of exposure (hours), was 30.7 (s = 3.8, range from 6.5 to 97.1). The error in the methods of measurement is given as ±30 percent.

The subjects' state of health was evaluated on the basis of a complete medical checkup that included the patients' history and the following tests: ECG, x-rays of heart and lungs, erythrocyte sedimentation rate, urinalysis, liver tests, and gynecological examination of the female subjects. The following examination and test results were compared with control groups and were tested for statistical significance: blood pressure; complete blood count including thrombocytes, protein spectrum and blood-sugar level; and ophthalmological, neurological, psychiatric and psychological examinations. Interpretations of the electroencephalograms will be published separately.

In the examined subjects we found no sign of damage due to electromagnetic radiation. Among the laboratory test results, the mean plasma protein levels were significantly increased. Even though we do not regard this as pathological, the possibility of its correlation with exposure to electromagnetic radiation cannot be ruled out. The other test results did not differ from those of the control groups.

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