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of people highly exposed to
electromagnetic fields**

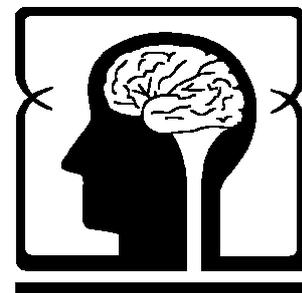
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Hygienic, clinical and epidemiological analysis of disturbances induced by radio frequency EMF exposure in human body

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The aim of the study was to examine the health of workers exposed to HF and microwave range (3 and 10 cm) EMF. Male regulators of communication equipment were exposed to HF EMF (3 – 30 MHz). Microwave effects study was based on health status assessment of female testers of electronic equipment.

Regulators of naval radio communication equipment were exposed to modulated EMF. The EMF intensity levels ranged from units to tens of V/m. Sporadically the regulators could be exposed to 250 V/m EMF. Real time EMF exposure ranged from several minutes to 3–4 hours per shift. Comparison of measured EMF levels and exposure time shows that workplace energy exposure (E^2T) did not exceed the legal maximum permissible values (7000 V/m²/hours). Other physical agents (noise, temperature, air humidity) did not exceed the sanitary standards.

Clinical examination of 72 regulators of radiotransmitting communication devices (1stbasic group), 18 persons previously (5-10 years before) exposed to EMF (2nd-specific group) and 45 persons (3^d-control group) was carried out. The special and the control group comprised of regulators of non-radiating devices. The age of the subjects in the compared groups ranged from 20 to 50 years: the average age was 36.6, 33.2 and 34.6 years, respectively. Taking into account certain age differences of the examined subjects, direct standardization method was used.

Analysis of complaints showed that the regulators of radiotransmitting devices complained of headache, pain in the heart, sleep disturbances, epigastric pains, dyspeptic disorders and increased fatigue (Table 1) significantly more often than the workers of the other groups. The rate of complaints increased depending on the employment duration in EMF exposure jobs. It is most clearly shown by such complaints as headache, heartache, epigastric pains and sleep disturbances. The rate of somatic disorders in the basic group was significantly higher than that in the control (77.8% compared to 28.9%, $P < 0.01$). Table 2 shows the pattern and rate of pathological changes found in HF-exposed workers and in the control. As follows from table 2 the rate of central nervous system (CNS) and cardiovascular system disturbances diagnosed in EMF-exposed workers was significantly higher than that in the control. A tendency to increased rate of gastrointestinal tract pathology was observed. Peripheral nervous system diseases were registered in both of the compared groups, but the differences were not significant. Table 3 illustrates the incidence of functional CNS and cardiovascular system disturbances in the basic, control and special groups. As follows from table 3, the CNS and cardiovascular system pathology level is significantly higher in regulators and in persons previously exposed to EMF than that in the control group. Health status changes induced by EMF-exposure are persistent.

Table 1. Complaint pattern and rate in workers exposed to 3-30 MHz EMF and control groups (%).

Complaint pattern	Basic groups n=72	Control groups, n=45	P
Headache	23.6	8.8	< 0.05
Sleep disturbances	8.3	0	< 0.05
Heartache	18.0	4.4	< 0.05
Epigastric pains	16.7	6.6	NS
Increased fatigue	12.5	4.4	NS
Irritability	4.1	4.4	NS
Dizziness	2.7	4.4	NS

Table 2. Pathological changes pattern and rate in workers exposed to 3-30 MHz EMF and control groups, (%).

Pathological changes	Basic groups n=72	Control groups n=45	P
Central nervous system disturbances	50.0	13.3	< 0.01
Cardiovascular system diseases	34.7	6.7	< 0.01
Gastrointestinal tract diseases (gastritis, cholecystitis)	19.4	11.1	< 0.1
Peripheral nervous system diseases	9.7	6.7	NS
Respiratory organs diseases	12.5	4.4	NS

Table 3. Prevalence of central nervous system functional disturbances and cardiovascular system pathology in basic, special and control groups (%).

Indicators	Basic groups n = 72	Special groups n = 18	Control groups n = 45	P1	P2
CNS functional disturbances	44.3	77.8	13.3	< 0.001	< 0.001
Cardiovascular system pathology	37.5	38.9	13.3	< 0.01	< 0.05

Note: P1 – Confidence level of differences between the basic and the control groups.

P2 – Confidence level of differences between the special and the control groups

The pattern of CNS disturbances in regulators of radiotransmitting devices is shown in Table 4. The first place in the structure of the CNS pathology belongs to the astheno-vegetative syndrome. The second one is taken by the neurasthenic syndrome, then comes the cerebral atherosclerosis, the latter being registered only in the basic group.

The percentage of CNS functional disturbances in workers having employment duration less than 20 years was practically the same as that in workers with 10-20 years of employment. The incidence of CNS functional disturbances decreases in the working group having employment duration over 20 years, but cerebral atherosclerosis is registered in this group. Total percentage of subjects with CNS pathology is the highest in the latter group. Such dynamics of functional CNS disturbances was the same after age-adjusting of pathology incidence in the basic and the control groups (Table 5).

Table 4. Pattern of central nervous system disturbances in workers exposed to 3-30 MHz EMF and control groups, (%).

Pathological changes	Basic groups	Control groups
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Astheno-vegetative syndrome	25.0	2.2
Vegetative dysfunction	13.8	8.9
Neurasthenic syndrome	5.6	2.2
Cerebral atherosclerosis	5.6	0

Table 5. Age-adjusted incidence of central nervous system functional disturbances in workers exposed to 3-30 MHz EMF and control groups.

Age, years	Total number of persons in groups under study	Age structure (%)	"Expected" number of pathologies per 100 workers	
			Basic groups	Control groups
20-29	42	35.9	19.5	0
30-39	38	32.4	19.1	6.0
40-50	37	31.7	7.9	2.1
Total	117	100	46.5	8.1

Cardiovascular system pathology observed in workers exposed to HF radiation was manifested as vegetative vascular dystonias, hypertonic disease, atherosclerotic and myocarditic cardiosclerosis (Table 6).

Table 6. Cardiovascular system diseases in workers exposed to 3-30 MHz EMF and control groups, (%)

Nosologic forms	Basic groups n=72	Control groups n=45	P
Vegetative vascular dystonia	18.1	4.4	<0.05
cardial type	9.7	0	<0.05
hypertonic type	6.9	4.4	NS
hypotonic type	4.2	0	<0.05
Hypertonic disease	9.7	2.2	NS
Atherosclerotic and myocarditic cardiosclerosis	6.9	0	<0.05

Age-adjusted incidence of cardiovascular system disease was higher in HF radiation exposed workers in all groups as compared to the control (Table 7).

It is evident that employment duration results in an increase of percentage of subjects having 2 or 3 diseases. Employment duration of 5-10 year corresponds to 24% of those subjects. Employment over 10 years entails 39% of such persons, 9% of them were found to have cerebral atherosclerosis or hypertonic disease. It should be emphasized that the given pathology was observed in workers of rather young age (38–47 years).

Table 7. Age-adjusted incidence of cardiovascular system diseases in workers exposed to 3-30 MHz EMF and control groups, (%).

Age, years	Total number of persons in groups under study	Age structure	"Expected" number of pathologies per 100 workers	
			Basic groups	Control groups
20-29	42	35.9	6.5	0
30-39	38	32.4	11.8	4.1
40-50	37	31.7	14.7	3.9

Total	117	100	33.0	8.0
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Biochemical findings are shown in Table 8. Table illustrates the differences observed between the compared groups. Thus, the basic group subjects had a significantly higher β -lipoprotein level as compared to the control. 76% of the basic group were revealed to have β -lipoprotein levels significantly exceeding physiological standards in comparison with 36.4% of the control group ($P < 0.01$). The basic group was reported to have a tendency to the increased total lipid concentration. Carbohydrates metabolism changes in the basic group were manifested in the reliable increase of lactic acid, pyruvic acid and glucose concentration, as compared to the control. Four subjects with glucose levels exceeding physiological standards also belonged to the basic group. Thiol disulphide system changes were characterized by SH-groups concentration decrease and disulphide group concentration increase.

Table 8. Biochemical study findings.

Indicators studied	Groups			P	
	basic	special	control	1	2
Total lipids, g/l	9.33 \pm 0.33	10.27 \pm 0.83	8.03 \pm 0.59	< 0.1	< 0.05
Cholesterol, mmol/l	6.54 \pm 0.20	7.05 \pm 0.31	6.64 \pm 0.20	NS	NS
β -lipoproteids, g/l	6.73 \pm 0.20	6.51 \pm 0.51	5.45 \pm 0.2	< 0.01	< 0.1
Lactic acid, mmol/l	1.1 \pm 0.04	1.16 \pm 0.29	0.89 \pm 0.05	< 0.01	NS
Pyruvic acid, μ mol/l	115.0 \pm 3.0	122.6 \pm 7.5	98.6 \pm 6.0	< 0.05	< 0.05
Glucose, mmol/l	4.4 \pm 0.09	4.16 \pm 0.16	3.64 \pm 0.09	< 0.01	< 0.05
Blood SH – groups, mol/l	23.67 \pm 0.71	23.15 \pm 1.25	27.76 \pm 1.15	< 0.01	< 0.05
Blood SS – groups, mol/l	2.82 \pm 0.14	2.05 \pm 0.21	1.89 \pm 0.22	< 0.01	NS
SH/SS, units	9.42 \pm 0.59	11.3 \pm 1.1	12.93 \pm 1.49	< 0.05	NS

Note: 1 – confidence level of differences between the basic and the control groups.
2 – confidence level of differences between the special and the control groups.

Subjects previously exposed to EMF were observed to have biochemical changes as compared to the control as well.

For the assessment of possible EMF effects on the male reproductive function reproductive hormone levels in blood system were determined by radioimmunological methods (Table 9). Table 9 shows that testosterone levels in regulators are lower than those in the control. Luteinizing hormone (LH) blood levels in male workers exposed to EMF did not change reliably, but the concentration of the other gonadotropic hormone – follicle-stimulating hormone (FSH), – increased under EMF exposure.

Table 9. Endocrine system state indicators in persons exposed to short-wave electromagnetic fields (basic group), in previously, EMF-exposed persons (special group) and in control persons

Hormone	Cont. group	Basic	Special group
Control (nmol/l)	480.7 \pm 31.5	452.9 \pm 31.3	411.8 \pm 26.8
Testosterone (ng/ml)	4.39 \pm 0.33	3.48 \pm 0.28, $p < 0.05$	3.03 \pm 0.34, $p < 0.05$
Luteinizing hormone (IU/l)	7.54 \pm 0.98	7.66 \pm 0.52	8.49 \pm 0.64

Follicle-stimulating hormone (IU/l))	2.65 ± 0.35	3.52 ± 0.30 p< 0.05	3.72 ± 0.63 p< 0.05
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Analysis of results shows that hormonal gonade function inhibition occurs after 10 years of EMF exposure, and the induced changes persist after exposure removal. The changes of endocrine system parameters prove that.

In order to compare the HF EMF and microwave effects on human body, the findings of the earlier studies obtained by Dr. N.N. Uspenskaya (1966) at our Institute are given. The author carried out the dynamic clinical follow-up of health status of female electronic device testers exposed to 3 and 10 cm wavelength EM radiation, power flux density reaching tens of $\mu\text{W}/\text{cm}^2$.

Dynamic study involved 70 female testers, 15 of them being examined twice, 55 – three times or more. In the initial study the average age in the group was 28 years, and the employment duration was 3 years and 8 months. In the final study the average age was 31.7 years, and the employment was 6 years and 7 months, i.e., young workers having short employment duration were examined.

Table 10 illustrated the pattern and rate of complaints among workers exposed to SHF radiation in the beginning and at the end of the study. Table shows that the range of the complaints among the HF workers is much the same as among the SHF workers. Complaint rate in female testers increased with the increase of employment duration.

Functional CNS disturbances, cardiovascular system and gastrointestinal tract diseases were diagnosed in SHF-workers as well as in HF workers (Table 11). Pathology incidence increased significantly with the increase of EMR exposure duration. Gynecological disease incidence was high in the female testers.

Table 12 shows the pattern of CNS functional disturbances in the first and in the second study. It is seen that the employment duration increase results in the decrease of percentage of vegetative dysfunction and neurasthenic syndrome cases, but the number of combined vegetative dysfunction and asthenic syndrome cases increases significantly.

Table 10. Complaint pattern and rate in workers exposed to microwave radiation in the beginning and at the end of the study (%).

Complaint pattern	First examination	Last examination	t
	n=70	n=70	
1 Headache	38.5	62.8	2.9
2 Increased fatigue	30.0	54.0	2.9
3 Sleep disturbances	30.0	45.7	1.9
4 Irritability	15.7	37.1	2.9
5 Pain in the heart	15.7	35.7	2.7
6 Dizziness	12.8	22.9	1.6
7 Dyspnoea	12.8	32.8	2.9
8 Epigastric pains	14.2	8.5	0.8
9 Memory disturbances	2.8	14.2	2.5
10 Sweating	2.8	12.8	2.3

Table 11. Pathological changes pattern and rate in workers exposed to 3 cm and 10 cm microwave radiation, tens of W/m² intensity in the dynamics of occupational employment (%).

	Pathological changes	First exam. n=70	Second exam. n=70	t
1	Central nervous system functional disturbances	41.4	77.0	4.4
2	Cardiovascular system diseases (myocardiodystrophy, hypotonic syndrome)	8.8	20.0	1.9
3	Gastrointestinal tract diseases (gastritis, cholecystitis)	2.8	8.5	1.5
4	Gynecological diseases	27.1	31.4	0.6
5	Visual organ diseases	10.0	10.0	-
6	Otolaryngological diseases	11.4	18.5	1.18

Table 12. Pattern of central nervous system functional disturbances in workers exposed to 3 cm and 10 cm microwave radiation, tens of W/m² intensity, %.

Pathological changes	1st examination	2nd examination
Vegetative dysfunction	58.6	46.2
Neurasthenic syndrome with vegetative dysfunction	34.6	29.6
Asthenic syndrome with vegetative dysfunction	6.8	24.0

Conclusions

1. Performed studies suggest the identity of health disturbances among the workers exposed to low intensity HF and SHF EMR.
2. The disease induced by electromagnetic radiation is clinically manifested in vegetative dystonia syndrome with typical subjective complaints, disturbances in the central nervous system, cardiovascular system, reproductive system and gastrointestinal tract and biochemical changes in blood.
3. Revealed changes are persistent in character and do not disappear after ceasing the EMF exposure.
4. Early ageing syndrome observed in the group of HF-device regulators should be attributed to the remote effect of chronic RF EMF exposure. Polypathology, early development of age pathology, lipid metabolism disturbance, hormonal gonade function decrease, the character of thiol disulphide changes are the symptoms of ageing syndrome.
5. Hygienic assessment of exposure conditions and of accompanying workplace factors, consideration of social and living conditions, and dynamic health status follow-up are of utmost importance for the diagnosis of chronic EMR effects.

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