

**OVERVIEW OF HEALTH EFFECTS OF EXTREMELY LOW FREQUENCY ELECTROMAGNETIC
FIELDS**

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THE MAIN DIRECTIONS IN ELF EMF HEALTH EFFECT STUDIES

FIRST RUSSIAN CLINICAL AND PHYSIOLOGICAL STUDIES OF HUMAN HEALTH STATE

The author, year	Subject and methods of study	Results
T.P.Asanova, A.N.Rakov, A.V.Tsheglova,1963	Clinical and physiological observation of 400-500 kV substation personnel health state	Subjective neurologic complaints (headache, flaccidity, fatigability, sleepiness). The complaints to violations of activity of a cardiovascular system and gastrointestinal path. The cardiovascular distresses in the form of inclination to a tachycardia or bradycardia, arterial hypertension or hypotonias (as exhibitings of a vegetative dysfunction). The changes of a composition of a peripheric blood - moderate thrombocytopenia, leukocytosis, lymphocytosis, monocytosis, tendency to a reticulopenia, lowering of a haemoglobin and number of erythrocytes, retardation of a blood sedimentation rate.
T.P.Asanova, A.N.Rakov, 1966	Clinical observation of health state of 400-500 kV substation personnel. 45 men. The experience of work more than 1 year; every day work time 5 hours. Peripheric blood, rentgenoscopy of thoracal cell, ECG.	The complaints to violation and violations of a functional state of a nervous system, clinically shown in the form of a vegetative dystonia of neurasthenic (hypertonic) symptoms, tachycardia, bradycardia, lability of heart rate and arterial pressure, retardation of atrioventricular conduction. The changes of a peripheric blood content.
N.V.Revnova, T.P.Asanova, et. Al., 1968	Clinical survey of the repair and operative - dispatching personnel of 220, 330, and 500 kV substations (200 persons).	Personnel of 330 and 500 kV substation - cardio-vascular and nervous system functional changes (in form of vegetative-vascular dystonia) are detected. Blood: more expressed in 500 kV substations heightening of a haemoglobin content, tendency to a neutrocytosis with pathological stippling of neutrophils, acceleration of a blood sedimentation rate, heightening of number of reticulocytes.
V.A.Danilin, A.N.Voronin, V.A. Madorski, 1969	Clinical survey of 500 kV substation 12 electric welders	Functional changes of central nervous system attributed of a vegetative polyneuritis with inclination to angiospastic responses are detected.
T.E.Sazonova, Yu.A.Morozov, 1969	Physiological survey of 220, 330, 500 substation personnel (20 substations)	Dependence of an expressiveness of cardio-vascular and nervous system changes from substation voltage. 220 kV substations – absence of significant changes of cardio-vascular and nervous system. 330 kV

		substations – threshold changes, 500 kV substations – expressed changes. The character of changes depend about time of effect for change: at the repair personnel (5 h EF exposure for work day) – vagotonic character of changes; at the operative - dispatching personnel (EF exposure not more than 2 h per work day) – sympathotonic changes.
N.N.Goncharova, V.B.Karamishev, et.al., 1972	Physiological survey of 330 kV substation personnel (2.5-17 kV/m EF strengths)	Functional changes of central nervous and cardiovascular systems. Elongation of time of visual-motor response, heightening of a threshold of olfactory sensitivity, lowering of memory, attention, heart rate, common vascular dystonia with the tendency to a heightening of tone of fine pots. ECG of 1/3 inspected persons - bradycardia and retardation of intracardiac conduction.
L.N. Abramovitch- Poljakov, 1973	Clinical and physiological survey of a state of health of the personnel, maintaining of 330 kV substation with 7-14 kV/m (up to 22 kV/m) 50 Hz EF levels at workplaces	Violations of a functional state of a central nervous system, cardiovascular system and thermoregulation of an organism. At a part of persons - a common vascular dystonia with inclination to a heightening of tone of fine arterias and arterias of medial calibre, and to lowerings tone of arterias of small calibre and veins.
V.D.Dyshlovoi, V.S.Katchura, 1977	Clinical and genealogical survey of 200 330-750 kV substation personnel and linemen monogynopaedium.	Absence of change of an interrelation of floors in brooding. Spontaneous abortions, birth mortality, inheritable illnesses.
T.I.Krivova, V.V. Lukovkin, Yu.A.Morozov, 1977	Research of a state of health of the 220, 330, 500 kV substation personnel (385 men).	220 kV substation service does not produce significant changes of health of the personnel. At the personnel of 330 and 500 kV substations are marked subjective complaint, functional changes of central nervous and cardiovascular systems state (in form of a vegetative dysfunction and neurasthenic (hypersthenic) sets of symptoms. Changes of a cell-like composition of a peripheric blood.. At the personnel of 330 kV substation the tendency to lowering parameters of a red blood is detected; at the personnel of 500 kV substation – elevation of red blood parameters. In a white blood lowering number of leucocytes, heightening of percent of neutrophils with pathological stippling is marked.

FIRST WESTERN CLINICAL AND PHYSIOLOGICAL STUDIES OF HUMAN HEALTH STATE

The author, year	Subject and methods of study	Results
Kowenhoven, 1967	11 linemen, health state	Absence of significant changes
Fole et al., 1974	400 kV substation personnel, health state	Subjective complaints: headache, flaccidity, fatigability, nausea
P.F.Roberge, 1976	735 kV substation personnel state of a health	Absence of differences from control group
E. Malboysson, 1975	From 11 to 400 kV overhead transmission line personnel (linemen), health state survey (4 years): interview, cardiovascular system survey, psycho-physiological, biochemical analyses, vision, hearing functions	Absence of differences between 400 kV linemen and 11-22 kV linemen health state
M.L.Singewald et al., 1973	400 kV substation personnel, 56 persons health state survey. Clinical survey : ECG, blood, biochemical survey, subjective complaints	Lack of deflections from norm on the majority parameters Deflections from norm: an eosinophilia, urinary acid, calcium, crude protein, alkaline phosphatase.
J. Peceny, et al., 1983	220, 400 kV substation personnel , health state survey	More often complaints of 400 kV substation personnel
D.E.Broadbent et al., 1984	400 kV electrical power transmission and distribution workers health state interviews (390 persons)	More high than in manual workers in other industries general level of health.

90th YEARS RUSSIAN STUDIES OF 50 Hz EMF HUMAN HEALTH EFFECTS

The author, year	Subject and methods of study	Results
I.S.Bezdolnaja, 1990	750 kV linemen health state survey	Absence of cardio-vascular, nervous, immune systems changes outside of physiological norm limits. Stable changes of these system parameters in physiological norm limits.
N.Rubtsova, I Kosova, 1992	500, 750 kV overhead transmission line personnel. (29 linemen). Clinical survey; cardio-vascular system (blood pressure, heart rate, ECG, thoracal, hand rheography, rheoencephalography, visual-motor reaction time, light flash critical frequency, blood (Amount of erythrocytes, reticulocytes, thrombocytes,, relative and terrain clearance content of a blood component	Lack of pathological changes of health. Blood pressure, heart rate, ECG, visual-motor reaction time, light flash critical frequency were inside of norm limits. Part of blood and immune system parameters were outside of physiological norm limits as a result of immune system oppression (Monocytosis, change of an interrelation in a bullet ?- and B lymphocytes, lowering of a level IgG in serum of a blood
O.V.Troitski, et al., 1996	750 kV substation personnel (41 men). Interview of health state complaints	Possible tendency to chronic neurosis (frequently meeting complaints on headaches, irritability, pain in range of heart, pulsing in temples, heightened fatigability, delicacy).
Yu.V.Grabski et al., 1996	750 kV substation personnel (27 men, 35 women) psycho-physiological and psychological survey	Lack of rasping violations. The tendency to deterioration of quality of attention and memory (correlation with age and experience); the tendency to lowering adaptive reserves of psychics.
V.A. Zaslavets et al., 1996	750 kV substation personnel (22 men, 10 women). Research of a cardio-respiratory system	Stress change of cardio-respiratory system functional state more expressed at the women
S.Yu.Chebanov., 1996	750 kV substation personnel (41 men). Morphological functional state of the visual analyzer: choronomic clinical attributes of a	Absence of changes, bound with EMF effect Correlation of changes with age .

	lesion of an organ of sight, sharpness of vision, color perception, transparency of mediums of an eye, state of an eyeground.	
L.G.Andrienko, Yu.D.Dumanski, 1999	750 kV substation personnel (65 men, 10 women). Questionnaire (10 items) characterized sexual function. Calculation of general prognostic index of sexual function	The decrease of men sexual function total prognostic index in connection with age and extent upon profession.
V.G.Zuev et al., 1999	500, 750 kV substation personnel (40persons). Social-psychological state.	Lack of changes of an evaluation of night dream, activity, mood, speed of intellection, mental fastness, conscientiousness, reliability. Heightening of a level of a neurotization.
V.N.Nikitina et al., 1999	High voltage installation personnel. 50 Hz MF levels at work places. Operative memory index, mental working capacity, EEG, ECG, excretion of adrenaline, noradrenaline and serotonin, number of sponaneous aborts and still-boms, sexual function	Decrease of adaptation possibility of cardio-vascular system, circulatory apparatus, men sexual function reduction, statistically significant increase of embryonic death among occupationally MF exposed women (as well as husband were EMF exposed).
N.B.Rubtsova et al, 1999	500, 750, 1150 kV substation personnel and linemen (349 persons). Health state survey: polyclinical inspections by therapist, neuropathologist, ophtalmologist and otholaringologist; the detailed analysis of a cardio-vascular and nervous systems; determination of parameters of an immune system and peripheral blood.	Persons have the greatest loads to EMF, increase of pathology of cardio-vascular and nervous systems, or in case of absence of a pathology - overstepping the norms limits of a modification of general and regional blood flow parameters, nervous system adaptive changes and shifts of peripheral blood and immune system parameters (magnification of monocyte counts, violation of a immunoregulatory cells parity, tendency to reduction of eosynophyle counts /up to eosynophylia/, tendency to depressing of a humoral part of immunity), indicating both on their adaptative-compensatory processes, and on risk of its failure

VOLUNTEERS STUDIES OF 50/60 Hz EFFECTS TO HUMAN ORGANISM

The author, year	Subject, levels, duration of exposure	Results
F.F.Fole, 1974	Volunteers, 30.5 h EF exposure, 4 h with 1-1.5 h interval Blood pressure and heart rate	Blood pressure and heart rate changes
R.Hauf, 1974	Volunteers, 50 Hz EF exposure with E=1; 15; 20 kV/m; 2 h Time of visual-motor reaction	Time of visual-motor reaction changes (not outside of physiological norm limits)
R.Hauf, 1976	Volunteers, 50 Hz EF exposure with E=1; 15 kV/m Blood pressure and heart rate	Absence of influence on blood pressure and heart rate
J.P.Rupilius, 1976	Volunteers, 50 Hz EF exposure with E=20 kV/m; B=0.3 μ T Visual-motor reaction, EEG	Absence of influence on visual-motor reaction time, EEG
Yu.D.Dumanski, B.M.Popovitch, I.P.Kozjarin, 1977	34 volunteers (17 men, 17 women). 50Hz EF exposure with $E=5$ kV/m, 2 h/day, 30 days, or $E=12$, and 15-16 kV/m 30 min 3 time per day, 6 days. Central and vegetative parts of a nervous system, cardio-vascular system, the work capacity, metabolism, nonspecific immunity.	After $E=15-16$ kV/m EF exposure: change of concentration of attention, work capacity, EEG, skin temperature of different parts of a body, frequency of heart rate, ECG, content of blood glucose and blood cholinesterase activity, parameters of nonspecific immunity. After $E=5$ $E=12$ kV/m EF exposure changes is not detected.
T.I.Krivova, V.V. Lukovkin, Yu.A.Morozov, 1977	Physiological researches of 23 volunteers.. 10, 16, 32 $E=64$ kV/m EF exposure effects to development of a composite motorial stereotype and exactitude of work on ergograph.	At a research of volunteers after 16 kV/m EF 1.5-2 h exposure lowering an exactitude of work was marked. 16 kV/m EF strength s surveyed as threshold for changes of composite motor reactions of the man.. After 10 min exposure of 32, or 64 kV/m EF Lowering an exactitude of work, augmentation of a stage of latency of visual-motor responses, differ responses disinhibition was detected..
R.Hauf, 1982	Volunteers, 50 Hz EF exposure with E=1; 15; 20 kV/m; 2 h	Hear rate changes (not outside of physiological norm limits)

LEUKEMIA IN ELECTRICAL OCCUPATIONS (by J.Goldsmith,1995)

Occupation	Relative risk	95% CI
Telegraph, radio and radar operators	1.8*	1.4-2.6
Electronic technicians	1.3	0.9-1.8
Electrical and electronic engineers	1.2	1.0-1.5
Electricians	1.1	0.9-1.2
Electrical equipment assemblers	2.4	1.0-4.8
Power station operators	1.6	0.8-3.0
Linemen	1.3	1.0-1.6
Phone repair and installation	0.9	0.6-1.3
Aluminum workers	1.9*	1.2-2.9
Motormen, streetcar	1.7	0.7-3.3
Projectionists, movie	1.1	0.5-2.2
Welders	0.9	0.7-1.2
Total	1.2*	1.1-1.3

OCCUPATIONAL PF EMF EXPOSURE AND LEUKEMIA

Author, year	Group	Method	Cases	SRR/OR (95% CI)
Milham, 1982	Electrical occupations Substation operators; linemen	Case-control	156 death reasons (438 cases of death) :	2.59 (p<0.01) 1.59
Wright et al., 1982	Electrical occupations 10 professional group (1972-1979), Los Angeles	Case-control	Substation operators: Leukemia Acute leukemia Acute myeloid leukemia Linemen: Leukemia Acute leukemia Acute myeloid leukemia	2.81 4.6 6.65 3.10 (p<0.05) 5.94(p<0.05) 8.17(p<0.05)
Bowmann et.al., 1988	400 kV power installations 3,358 workers	cohort	Leukemia	1.3 (0.7-2.1)
Garland et al., 1990	Naval shipyard worker (US NAVY)	Case-control	leukemia	2.4 (1.0-5.0)
Sahl et al., 1993	36,221 electrical occupations (1960-88)	Cohort and case- control	44 deaths PF MF >25 μ T.years	1,07 (0,8-1,5)
Floderus et al., 1993	Workers in Sweden (1983-87)	Case-control	250 leukemia morbidity cases PF MF \geq 0,41 μ T	1,7 (1,0-2,7)
London et el., 1994	Cancer Register of Los Angeles (1972-90) electrical occupations	Case-control	121 case PF MF \geq 0,8 μ T	1,4 (1,0-2,0)
Teriault et al., 1994	223,292 workers of 3 power systems(1970-1989)	Case-control	140 Cases of diseases PF MF \geq 1,57 μ T .years	1,75 (0,8-4,0)
Savitz & Loomis, 1995	138,905 power systems workers	cohort	164 death 19,1 μ T .years	1.1 (0,6-2,10)
Gurvich et al., 1999	Mortality of 500 kV power system staff; 1956-1992 (1532 deaths)	Retro-cohort	EF and MF exposure load evaluation (calculation)	2.0 (0.23-7.31)
Tikhonova et al., 1999	General public of Moscow region;	Case-control	571 leukemia (case), 1208 stomach cancer (control)	1.64 (not statistically significant)

RELATIVE RISK OF MORTALITY/MORBIDITY
OF EHV POWER INSTALLATION PERSONNEL

	SRR/OR	95% CI
Deaths from all reasons (RAMS Institute of Occupational Health) (1532 deaths)	0.59	0.50-0.70
Deaths from cardio-vascular system diseases (RAMS Institute of Occupational Health)	0.53	0.39-0.70
Deaths from all forms of cancer (RAMS Institute of Occupational Health)	0.89	0.64-1.21
Deaths from leukemia (RAMS Institute of Occupational Health)	2.03	0.23-7.31
Teriault et.al., 1994 (223,292 persons) Leukemia morbidity	1.54	0.90-2.63
Acute myeloid leukemia	3.15	1.20-8.27

PF EMF OCCUPATIONAL EXPOSURE AND BRAIN CANCER

Autor, year	Group	Method	SRR/OR (95% CI)
Olin, 1985	Electrical engineers	Cohort	1.0
Coggon, 1986	Male cancers in 3 UK countries; 97 brain cancers; 2845 other countries; questionnaires: electrical and electronic workers	Case-control	2.0 (0.8-4.1)
McLaughin, 1987	Electricians, powerline workers, telecommunications	Cohort	0.8; 1.0; 1.1
Speers, 1988	East Texas residents; 202 glioma deaths; 238 random non brain tumour deaths; utility workers	Case-control	2.26 (1.18-4.32)
Pearce, 1989	Male cancers from New Zealand Cancer registry: 452 brain cancers: electrical workers; electrical engineers; electricians	Case-control	1.01 (0.6-1.8) 4.74 (1.7-13.6) 1.91 (0.8-4.3)
Guberan, 1989	Electricians	Cohort	1.54
Juutilanen, 1990	Electrician installers; linemen & cable jointers	Cohort	2,37; 0.91
Tynes, 1992	All electrical workers; heavy EMF exposure; weak EMF exposure	Cohort	1.09; 1.37; 2.20 (p,0.05)
Preston-Martin, 1993	Male cancers from New Zealand Cancer registry: 1113 brain cancers: electrical/electronics technicians; electrical/electronics engineers; electricians	Case-control	3.3 (0.9-12.1) 8.2(2.0-34.7) 4.6 (1.7-12.2)
Gurvich et al., 1999	Mortality of 500 kV power system staff; 1956-1992 (1532 deaths)	Retro-cohort	1.3 (0.64-3.7)

PF EMF OCCUPATIONAL EXPOSURE AND MALE BREAST CANCER

Autor, year	Group	Method	SRR/OR (95% CI)
Matanoski et.al., 1989, 1991	New York Telephone Company (1976-1980); line workers, central office workers	Retro-cohort	0.0 6.5 (0.7-23.4)
Demers et al., 1991	SEER program, 1983-1987; 227 cases, 300 controls; self-reports	Case-control	1.8 (1.0-3.7)
Tynes et al., 1992	37,952 Norwegian males, 1961-1985; 10 occupations with potential exposure to EMF	Retro-cohort	2,1 (1,1-3,6)
Loomis, 1992	24 State of USA, 1985-1988, electrical occupations	Case-control	0.9
Guenel et al., 1993	Danish male, 20-64 years old, diseases, 1970-1987,	Case-control	1.4 (0.2-4.9)
Theriault et al. (1994)	223,292 workers of 3 power systems (1970-1989)of Canada and France, diseases	Case-control, nested within 3 cohorts	0.8 (0.4-1.8)
Savitz & Loomis, 1995	138,905 workers of power companies, 1950-1988	Case-control	0.8 (0.3-1.7)
Sahl et al., 1996	40,3355 workers of power companies, 1960-1988	Case-control	0.0

CHILDHOOD AND ADULT LEUKEMIA AND PF EMF EXPOSURE

Autor, year	Group	Method	SRR/OR (95% CI)
Wertheimer & Leeper , 1979	Children, 344 case, 344 control, residence near high code electrical systems	Case-control	3.0 (1.8-4.9)
Fulton et al., 1980	Children	Case-control	1.1 (0.7-1.6)
Tomenius, 1986	Cancer Register, Sweden, 716 cases of cancer, residence near PF EMF sources	Case-control	1.1 (0.3-4.6)
McDowall, 1986	Residence near electricity transmission facilities, death, adult	Case-control	1.0 (0.4-2.2)
Savitz et al. ,1988	Children, residence near high code electrical systems	Case-control	2.8 (0.9-8.0)
Severson et. Al., 1988	Residence near transmission lines, adults	Case-control	1.0
Coleman et al., 1989	Residence near transformer substation , children 84 case, 141 control adults	Case-control	1.6 (0.3-9.8)
London et al. , 1991	Children, Los Angeles, residence	Case-control	2.2 (1.1-4.3)
	Measurements		1.7 (0.6-3.3)
Youngson et al., 1991	Residence near transmission lines, adults	Case-control	1.2 (0.6-1.9)
Feychting & Ahlbom, 1993	Sweden, residence	Case-control	2,7 (1,0-6,3)
	measurements		0.65 (0.2-1.9)
Gurvich et al., 1999	General public residence near power transmission; 1971-1990. Total cohort members: 50,460 person-years	Retro-cohort	1.3 (0.2-7.0)
Tikhonova et al., 1999	Children, parents occupational exposure, 208 cases, 319 controls	Case-control	1.69 (non statistically significant)

CHILDHOOD BRAIN CANCER

Autor, year	Group	Method	SRR/OR (95% CI)
Wertheimer & Leeper , 1979	344 cases of deaths , residing near to high current constructions	Case-control	2.4 (1.1-5,1)
Spitz et al., 1985	Parents exposure	Case-control	2,2 (1,03-4,6)
Tomenius, 1986	Cancer Register, Sweden, 716 cases of cancer, residence near PF EMF sources	Case-control	3.9 (1.2-12.7)
Nasca et al., 1988	Parents exposure	Case-control	1,6 (0,8-3.1)
Wilkins et al., 1988	Parents exposure	Case-control	2,9 (1,2-7,5)
Johnston et al.,1989	Parents exposure	Case-control	1,5 (0,9-2,5)
Bunin et al. , 1990	Parents exposure	Case-control	1,0 (0,4-2,3)
Wilkins et al., 1990	Parents exposure	Case-control	0,8 (0,3-1,6)
Feingold et al. 1991	Parents exposure	Case-control	0,9 (0,3-2,3)
Savitz et al., 1988	356 cases of disease near to high current constructions	Case-control	2,0 (0,5-8,0)
Prestom-Martin et al., 1996	300 cases in Los Angeles (1984-1991)	Case-control	1,1 (0,6-2,5)
Gurney et al., 1996	Washington State; 133 cases, 270 control	Case-control	0,99 (0,5-1,5)
Preston-Martin et al., 1996	Parents exposure	Case-control	1,3 (0,8-2,2)

Occupational exposure human health effects:

- Lack of pathological alterations in a state of health;
- Lack of reliable correlation with risk of leukemia;
- Presence of uncertain augmentation of risk of development of leukemia;
- Presence of uncertain augmentation of risk of brain tumour;
- Lack of augmentation of breast cancer risk;
- Probability augmentation of risk of sex distresses (conjecture);
- Presence of unproved probability of augmentation of reproductive risk;
- Presence of statistically reliable changes of a functional state of cardiovascular, nervous and immune systems showing of a heightening of their unfavorable alterations risk.

General public power frequency EMF exposure:

- Statistically uncertain augmentation of leukemia risk at the adult and children;
- Statistically uncertain augmentation of risk of development of brain tumour at children;

Necessity of the further study and ascertaining of possible correlation between effects of 50/60 Hz electric and magnetic field component time-value parameters and probability of unfavorable changes of health.

Absence of proof and weakness of data of carcinogenic effects of MF with levels $> 0,3 \mu\text{T}$

Evaluation of individual sensitivity to PF EMF methods development.

OVERVIEW OF HEALTH EFFECTS OF EXTREMELY LOW FREQUENCY ELECTROMAGNETIC FIELDS

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