Proceedings from the International workshop

Clinical and physiological investigations of people highly exposed to electromagnetic fields

St. Petersburg, Russia, 16–17 October, 2000

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Institute of Human Brain

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“Clinical and physiological investigations of people highly exposed to electromagnetic fields” St. Petersburg, Russia, 16-17 October, 2000

Organised jointly by
Swedish National Institute for Working Life (NIWL), Sweden,
and
The Institute of Human Brain, St. Petersburg, Russia
In collaboration with The Bioelectromagnetics Society (BEMS)

This two day-workshop covered most of the topics related with possible effects of exposure to strong electromagnetic fields (EMF), as well RF/microwaves as fields in the ELF range. The WHO has an interest in producing a fact sheet dealing with the medical handling of people overexposed to EMF and therefore has an interest in finding out about previous experience in medical investigations of these persons. The workshop will also be helpful in facilitating scientific collaboration between different research groups in Baltic region.

The main focus of the workshop was on methods used in the clinical investigations of people exposed to electromagnetic fields; both acute accidentally overexposed or chronically exposed.

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This workshop is part of an INCO-Copernicus project (Concerted Action Project ERB-1C15-CT0303)

SCHEDULE

Monday 10.00 – 10.30: Introduction

Dr Sviatoslav Medvedev, Institute of the Human Brain, St Petersburg
Dr Monica Sandström, The Bioelectromagnetics Society
Dr Kjell Hansson Mild, National Institute for Working Life, Sweden

Session 1. Monday 10.30 – 13.00 **CONTENT**

Mobile phones

Electrical hypersensitivity and physiological investigations.

Session 2. Monday 15.00-18.00

Clinical investigations

Session 3. Tuesday 9.00 –11.00

Enginge drivers

Tuesday 11 – 12 General discussion

* No abstract available at time of publication.

Participants

St. Petersburg, October 2000

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The problem of estimation of biological effect of chronic exposure

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Russian National Committee on protection from non-ionizing radiation has carried out analysis of the EMF guidelines for population and has paid attention to the gaps in our knowledge about the criteria of EMF pollution hazards evaluation of human environment.

The basic summary requirement to develop permissible EMF value limits is the absence of even temporary disturbance of human homeostasis including reproductive function, as well as protective and adaptation-compensator mechanisms strain neither in the nearest, nor in the remote period of time. It means that EMF limits are the fractional quantity from the minimal level of EMF which is capable to provoke some reaction in the human being.

Such EMF permissible value limits of daily radiation regimes which do not lead to diseases or health deviations among the population (irrespective of age or sex) and can be detected by modern methods during of the irradiation period or long after it was over, were determined in Russia.

The threshold principle of injurious effect to health is used as the basis for the EMF limits. These demands must be based on some criteria of evaluation of biological EMF effect particularities. This is the first of all the bioeffects dependence on the absorbed energy value and its distribution in the human body taking into account the possible primary exposure of crucial systems and separate organs (for example, brain while using mobile phones).

We place much emphasize on either possibility or non-possibility of cumulative processes development. This is the most important issue for determining permissible value limits as it is closely connected with possible development of remote effects. It is necessary to point out that the process of solving this problem should be carried out in conditions of chronic exposure to extremely low EMF radiation, when thermal mechanisms hardly play any leading part in development of bioeffects. We should focus on:

Another condition for chronic EMF radiation hazard evaluation is the necessity of carrying out of research on people and experiments

In our opinion, to prove our approach to EMF standardisation it is necessary to do further investigations in the following directions:

1. The investigation of possible non-thermal EMF effect mechanisms.

2. Analysis of materials used as a basis for Russian standards.

These materials (clinical investigations and animal experiments; special emphasis on neural effects) were received mainly at the Institute of Occupational Medicine RAMS, in the North-West Scientific Centre of Hygiene and Public Health (St. Petersburg), the Ukrainian Scientific

Centre of Hygiene (Kiev), the Military Medicine Academy (St. Petersburg), Institute of Cell Biophysics RAS (Pushchino) and at our Institute in Moscow.

These materials are the result of chronic EMF exposure of low intensity (10-500 μW/cm^2**).** However, all these materials can be found in scientific reports and theses.

These institutes are ready to carry out the preliminary processing treatment of these materials taking into account ICNIRP recommendations and the strict demands which sounded at every conference.

We are ready to do the summary of these materials, to select the materials that meet the basic criteria of the protocol, to discuss them in detail at Russian NCNIRP. After that we will prepare and present the report in English to WHO and ICNIRP.

We can take the responsibility for co-ordination of this work that can be done within an year.

3. EMF influence of cellular phones on the brain of their users (investigation on volunteers)

It is necessary to carry out the investigation of brain biocurrents and brain blood currents. We suppose to use the «standard» model of investigation and radiation of volunteers taking into account the experience of previous researches in other countries and in Russia.

The question of the rate of EMF short-term influence of cellular phones on different systems of the organism still remains important.

The task is to get the data on direct system reactions of the brain and system replies of the body to short-term single or repeated EMF exposure.

4. Cellular phone EMF influence on vestibular analyzer of the user (investigation on volunteers)

There is a very complex nervous receptive apparatus in the inner ear.

If sound, acceleration receptivity and equilibrium state are disturbed it can lead to serious disorders of vital activities. It is important that these analyzers are closely connected with vegetative N.S., and endocrine secretion. Besides vestibular analyzer is the brain part: nervous conduction tracts, nervous centres and nervous connections with other centres.

When we studied the radiation safety problem during piloted space flights (1964-1977) we used a successful research method estimation vestibular analyzer of human being and animals (rabbits). The method is strictly quantitative. We have registrated the value and duration of nystagmus, threshold of the adequate stimulus, the dependence of reaction on the value of stimulus (acceleration).

I have written a book about the use of this method on human being and animals in various conditions: "Vestibular reactions (Methods of study of influence of environmental various factors)". Moscow. 1970. 194p.

Earlier we have carried out the study on 200 dogs which were γ- exposed daily for 2 years in small doses (the model of the flight to Mars). We had not noticed any serious disturbances.

At present we could have carried out investigations on volunteers to estimate the state of their vestibular analyzer after EMF exposure and after the change against the initial state of brain with the help of pharmacology.

5. Prolonged 1-2 year EMF influence on the brain (investigation of vestibular analyzer of experimental animals)

As I mentioned earlier we have the experience of ionizing radiation exposure on experimental animals (dogs) for two years. Such researches can also be carried out on rabbits for 1-2 years under EMF radiation of low intensity.

Thanks to this experiment we will be able to answer the question about the state of inner ear and brain after long-term EMF exposure. **It is very important.**

Investigation of the effects of mobile phone use on tympanic membrane, skin temperature and critical flicker fusion

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Introduction

The recent large Scandinavian questionnaire investigation on mobile phone (MP) use and symptoms (Oftedal et al, 2000; Sandström et al, 2001) found several people complaining about feelings of "warms on ear" and "warms behind ear". The increase was statistically significant and for those calling more than 60 minutes per day on a regular basis about 30%
of them experienced the warmth sensation. Hocking (1998) also reported about the warmth sensation in connection with use of MPs.

Törnevik et al (1998) reported on skin temperature increases after 30 min exposure of volunteers to a mobile phone (MP). The increase was related to the component heating but the influence of RF could not be excluded. Modelling and experimental measurements have shown 1.3-2^{0} C maximum skin temperature rise after exposure to common mobile phones (Van Leeuwen, 1999).There are also some evidences of the weak tympanic membrane and brain temperature rise (Wainwright, 2000; Khudnitsky, 1999).

There have also been reports (Khudnitsky, 1998) about an increase with 2-3 Hz of the Critical Flicker Fusion (CFF) after a 2 min exposure to a mobile phone.
The aim of the present pilot study was to investigate possible heating effects on the tympanic membrane and the surface of the ear from the use of one commonly used digital mobile phone. The study also included a test of the CFF in connection with exposure to a mobile phone.

Material and Methods

Ten healthy volunteers (5 males and 5 females) participated in the experiment. The mean age was 28 years (range 23 - 34 years). Each subject was informed in detail about the intention of the study before the start of an experimental session. The experiment was approved by the ethical committee at the University of Umeå, Sweden.

The experiments comprised of temperature measurement before and after MP exposure in three experimental conditions:

1. MP not activated (Control condition),
2. active MP but connected with coaxial cable to dummy load to annihilate RF. (Battery condition),
3. MP activated (RF condition).

Each experiment protocol consisted of the following stages: a period of adaptation (5 min); determination of the basic tympanic membrane and the surface temperature of the both ears (approximately 1 min); MP exposure in one of three experimental conditions (10 min); repetition of temperature measurements (approximately 1 min). Before the experiment started as well as in the end of the 10 minutes exposure CFF was measured using common red light diode technique.

Each person participated in all three sessions. The interval between two sessions was never less than 24 hours. The order of the different experimental conditions was randomised between subjects. The right ear was always used for the exposure and the left ear for the comparison.

A BRAUN infrared ThermoScan IRT 3520 was used to measure the tympanic temperature. Skin temperature was measured using TASKO THI-700 infrared thermometer with 0.5 cm space resolution and the measurements were taken in three points on the right and left sides of the head:

1. lobe of the ear
2. mastoids (behind the ear)
3. top of the ear (scapha)

A digital MP (Ericsson GH 337) was mounted in a plastic holder and kept in contact with the subject's head during the three experimental conditions. It was oriented in normal position for use with the earphone positioned on the right ear and the microphone oriented to the corner of mouth. The antenna was located about 2.5 cm from the head, over the posterior areas of the left temporal lobe. The MP was modified with a switch on the backside to switch RF On or Off. The mobile phone emitted 900 MHz electromagnetic field pulsed at a frequency of 217 Hz with a max. output power of 2 W, and 1/8 duty cycle. The maximum SAR value for this MP was 1.1 W/kg averaged over 1 gr tissue.

Results

In Table 1 the results of the temperature measurements are shown.

The tympanic membrane temperature slightly increased after all test sessions. A temperature increase of the right tympanic membrane in comparison with the left ($<0.2^0$ C) was found ($P \leq 0.05$) for the two active conditions but not for the control condition.

Table 1. Relative changes (temp. ^oC after tests – temp. ^oC before tests) and standard deviation in the tympanic membrane and skin before and after test sessions. (n=10)

Location	Temperature increase (^oC)		
	Control condition	Battery condition	RF condition
R tymp. membrane	0.1±0.4	0.3±0.2	0.3±0.2
L tymp. membrane	0.0±0.2	0.2±0.2	0.1±0.2
R lobe	2.8±2.0	4.1±1.5	3.8±1.1
L lobe	2.0±1.9	2.5±1.6	2.9±1.4
R scapha	2.8±2.0	3.6±1.9	3.1±1.3
L scapha	1.7±1.5	2.0±1.7	1.6±1.4
R mastoids	1.1±0.8	1.5±1.4	1.7±0.9
L mastoids	0.8±1.0	1.4±1.4	0.8±0.6

R – right (exposed ear)
L - left

Skin temperature on the ear increased about 3–4 ^oC both on the left and right ear during the test sessions. However, the temperature increase was always higher for the right ear (MP covered) and for the two active conditions it was significantly higher ($P<0.05$) in comparison with the left ear. The temperature increase behind the ear was 1-2 ^oC in all test conditions, but when comparing left and right ear it was only significant in the RF condition ($P=0.009$).

Ten minutes MP use did not effect CFF. No difference was found before and after each test session.

Discussion

Our pilot study has shown that 10 minutes of MP use could lead to a 3-4 ^{o}C temperature increase of the skin on the ear. This is in agreement with earlier studies (Törnevik et al., 1998). The study indicate that the temperature increase is due not only to cover of the ear by an MP phone but also to active MP (both RF active and with dummy load). Of interest was that we found a significant temperature increase behind the ear only during RF active MP use. The temperature increase of the tympanic membrane found with active MP is relatively slight and not in the level found by Khudnitsky et al. (1998). Furthermore we could not confirm the finding from the same group that MP use influence the CFF. However, there are differences in exposure time, method of measuring temperature, localisation, type of phones and so on when comparing the results from different studies.

The observed temperature changes seem to be related mainly to component heating and to the cover of the ear by the MP. The role of RF in heating the tissues around the ear is obviously relatively slight – if any.

In view of reported symptoms among MP users and the result of this pilot study it is of interest to further study heating effects of MPs by using different techniques, taking SAR value distribution, different types of MPs and time scale into account.

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Clinical neurophysiological characteristics of persons exposed to 10 mT, 60 Hz, magnetic field during different functional conditions

Eugene Lyskov, Monica Sandström and Kjell Hansson Mild

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The aim of the present study was to investigate possible neurophysiological effects of intermittent 15 sec on/off cycle, 60 Hz, 10 µT, magnetic field exposure on patients with percievd "Electromagnetic HyperSensitivity" (EHS) as well as control subjects during different functional conditions of the nervous system. Twenty participants (15 female, 5 male, 31-60 years old, mean 45.8 ± 0.7) were invited from the group of EHS patients. Twenty volunteers (15 female, 5 male, 31-59 years old, mean 45.0 ± 0.7) served as a control group. The test protocol comprised of a set of examinations (EEG, visual evoked potentials, and electrodermal activity, ECG, blood pressure) in rest conditions and during computer work. The total duration of the test was forty minutes, divided in four 10 minutes periods: two rest periods and two periods of mathematical performance. Magnetic field and sham exposures were randomly presented during these periods resulting in four different conditions: Real-Rest, Sham-Rest, Real-Mat, Sham-Mat, respectively.

The data obtained during the different conditions of the examination showed a significant main effect of case factor (EHS vs. control subjects) on heart rate (HR) ($F_{1,80} = 20.6$; $P< 0.01$, HR spectrum ratio ($F_{1,80} = 9.5$; $P= 0.02$) and electrodermal activity ($F_{1,76} = 4.2$; $P= 0.04$), whereas EEG characteristics showed no difference between groups. Condition factor (mathematical task vs. relaxed) showed main effect on HR ($F_{1,80} = 14.8$; $P< 0.01$), HR spectrum ratio ($F_{1,80} = 7.8$; $P= 0.06$), electrodermal activity ($F_{1,76} = 56.8$; $P< 0.01$), and all spectral bands of EEG. No significant effect of the magnetic fields exposure was seen neither in ANS nor in EEG variables either for both groups.

Data obtained in the present study do not indicate that EHS patients are sensitive to low-level 60 Hz magnetic field exposure, but they have a rather distinctive physiological predisposition to sensitivity to physical and psychosocial environmental stressors.

References

Lyskov, E, Sandström, M, Hansson Mild, K*:* Clinical neurophysiological characteristics of persons exposed to 10 µT, 60 Hz, magnetic field during different functional conditions. Bioelectromagnetics, in press, 2001.

Long-term parallel monitoring of electromagnetic field exposure and physiological processes in individuals with perceived electrical hypersensitivity

Vasily Klucharev[1,2], Monica Sandström[1], Kjell Hansson Mild[1] and Eugene Lyskov[1]

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Our previous results have indicated that patients with so called Electrical Hypersensitivity (EHS) have a disbalanse of the autonomous nervous system regulation with a trend to hyper sympathotone, as measured by heart rate (HR) and electrodermal activity, and they are hyperresponsive to different external physical factors, as measured by brain evoked potentials and sympathetic skin responses to visual and audio stimulation. These data are in agreement with physiological findings from other studies on persons with perceived EHS. There is no consensus about to what extent EMF are involved in this and if so what is the most biologically relevant parameters of the EMF exposure. Current concepts of exposure assessment are based mostly on frequency-intensity-duration characteristics. The goal of this project is to find out possible correlation between the dynamic of the physiological processes and the EMF exposure characteristics for persons with EHS and persons without EHS.

We have used 24h Holter recording (Tracker 2, Reynolds Medical Ltd UK, two channels 24 hour ambulatory tape recorder) to monitor the basic autonomous nervous system processes - ECG, HR and heart rate variability(HRV) - which are the most sensitive integral parameters of central and autonomous regulation. The EMF monitoring was done by using EMDEX II instruments. The participant wore the ECG and EMF recorders for 24 hours during a typical working day and maintained a concurrent diary of the activities during that time.

The ECG recording have been analyzed for possible transient abnormalities of neuro-cardio-vascular regulation (arrhythmia's, extrasystols etc.) and quantitative assessment of ongoing balance of sympatho-parasympathetic regulation. A standard program was used to detect and calculate pathological events as well as the dynamic of HR and HRV.

Two groups of subjects (14 persons in each) was included in the investigation. Patients with perceived EHS symptoms was selected from the Departments of Occupational Medicine and Dermatology at the Norrland University Hospital (Umeå, Sweden). Age and sex matched healthy people were used as controls.

The magnetic field recording showed the normal variation during the 24 h with low values during night time and occasionally high values were encountered in daytime. No differences were found between the two groups, neither for the mean values of the broadband recording (0.09 and 0.11 µT for the patients and the controls, respectively) nor the harmonic content (corresponding values here were 0.03 µT for both groups). We found no difference between the groups in the mean HR for the 24 h, nor was there any difference during night time. However, the HRV analyses showed that the ratio LF/HF (LF= 0.05 – 0.15 Hz, HF= 0.15 – 0.30 Hz) was higher for the patient group over the 24 h period than for the control group. The difference between the groups was in the ratio LF/HF was even larger during night time. The higher ratio indicates a higher symphaticus activity. This findings is in accordance with the results from previous clinical investigations of patients with perceived EHS.

Aspects of electromagnetic hypersensitivity.

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The Electropathological Research Center of the University of Witten/Herdecke combines an information platform for the general public, authorities and companies etc. regarding all human relevant matters of electromagnetic fields with research facilities to evaluate medical and biological effects of the latter fields. This combination led to numerous contacts with so-called electrohypersensitive persons during several years and enabled us to gather experimental data and psychosocial background of these persons who attribute their impaired health status at least in part to technical electromagnetic fields. We try to identify putative causal links between the clinical picture and the reported symptoms like fatigue, concentration failure, sleep disorders etc. and environmental factors, especially EMF.

Electrohypersensitive persons contacting the center were invited to take part in our evaluation, consisting of a detailed general and neurological anamnesis, a psychosocial questionnaire, and low intensity extremely-low-frequency field experiments. Additionally, blood samples were drawn for melatonin determination in order to evaluate the possibility of generally altered melatonin levels in the hypersensitive group.

The experiments were conducted in a conveniently designed room with reduced electrical installation and environmental EMF. Electrohypersensitive persons as well as healthy volunteers were exposed two times (with a short recreation period) to a series of ten field or sham exposure situations and were asked to guess or even to ”feel” whether or not the field was on. The 50 Hz, 10 µT fields are switched on or off at random on a stochastic basis ten times during each of the two consecutive sessions. The probability of fields being activated is 50 %. This method is normally used in sensory physiology in order to detect subliminal sensory excitations and is also effective when individual subjective symptoms appear during experiments.

Preliminary results of the up to now 37 experiments do not show significant differences in scores or ”guess probabilities” of groups of patients and controls. Nevertheless we are looking for possible correlations between scores and various parameters. The questionnaire highlights the symptoms being mainly composed of various subjective sensations like exhaustion and concentration failure and less clearly measurable disorders. Results of narrative interviews conducted by a social scientist insinuate in many cases reactions which are dominated by a special situation and intensified by mass media influences. The collected plasma melatonin samples do not show significant differences between groups of patients and healthy controls. The results do not support the hypothesis of generally changed melatonin levels in electromagnetic hypersensitive persons and do not demonstrate links between this group and the so-called ”low-melatonin-people” known in literature.

Dysregulation of autonomic control of cardiac function and shift of diurnal rhythms of blood pressure in workers exposed to RF electromagnetic fields.

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Abstract

Biological effects of exposure to low-level, non-thermal radiofrequency (RF) fields were reported in different experimental systems *in vitro* and *in vivo,* however health risks and clinical relevance of these effects remain unknown. RF radiation at non-thermal intensities is considered as a relatively weak environmental/occupational factor and its bioeffects can be in most cases effectively balanced by trigerring of adaptative, compensative and/or regenerative mechanisms of the responding physiologic systems. There are no convincing data which confirm the possibility of development of specific diseases which could be causally linked to long-term exposures in RF fields, however there exist reports on increased risk of various functional abnormalities in subjects who work in RF environment.These functional abnormalities may be, at least partially, related to bioeffects of RF exposures which develop in the central nervous system. One of the possible outcomes of such effects may be dysregulation of autonomic control of various physiologic systems, including the cardiovascular system.

Some time ago we reported increased number of slight, subclinical ECG abnormalities, accompanied by symptoms of sympathicotony in heart rate variability (HRV), lowered day/nigh ratio of blood pressure and heart rate (Bortkiewicz A et al, 1995), as well as shifts in diurnal rhythms of blood pressure and heart rate (Szmigielski S et al, 1998) in a group of 77 workers of AM radio broadcasting stations who were exposed to 0.7-1.5 MHz RFs.

In the present study a group of 38 workers of radio transmitting centres (RTC), exposed to 10-30 MHz RFs, were examined with identical cardiological tests (ECG at rest, HRV, 24-hr Holter ECG, 24-hr ambulatory blood pressure – ABP), as the above mentioned wotkers of AM radio broadcating stations. RF exposure was monitored during whole 12-hr shifts and expressed in maximal levels (E_{max}), average levels (E_{av}) and time of exposure (T_{exp}) during the shift. From these data daily exposure dose rates for the shift (D_{sf}) and life exposure dose rates (D_{lf}) were calculated. It was found that during the 12-hr shift individual workers were exposed in RF fields in series of 3-5-min. periods, counting for a total exposure time of 0.5 – 2 hr per shift. Individual exposure levels differed considerably (E_{max} from 9 to 174 V/m; E_{av} from 0.5 to 11.4 V/m) with the daily exposure dose rates for the shift ranging from 22 to 3120 $(V/m)^2$ x h. With such large individual differences in RF exposure levels the most conclusive relations between the exposure and results of cardiac tests could be obtained by multistep correlation of single parameters. Statistically significant correlation with RF exposure parameters (D_{sf} and E_{av}) was found for HRV (fast/slow component ratio), HR and BP day/night ratio and parameters of BP and HR diurnal rhythms (acrophase and amplitude, but not mean value). In general, the results indicate dysregulation of autonomic control of cardiac function with shift toward sympathicotony, a phenomenon similar to that observed in workers of AM radio broadcasting stations, who are exposed to lower frequencies of RFs (0.7-1.5 MHz).

From results obtained in these two independent studies, which used 115 RF-exposed workers, we conclude that multiyear occupational exposure to RFs may lead to dysregulation of autonomic control of cardiac function and cause increased risk of development of functional symptoms of cardiac liability. However, clinical relevance of these findings is not firmly established and an increased risk for cardiac pathology could not be established in the tested material.

Introduction

Human organism is considered as a genetically pre-programmed self-sustaining mechanism, controlled by three regulatory systems – nervous, immune and hormonal (Fig.1). These three systems, equipped with a potent set of adaptative, compensative and regenerative mechanisms, can regulate function of internal systems under different harmful environmental conditions. In fact, efficiency of the three regulatory systems of the organism and capacity of their adaptative, compensative and regenerative mechanisms determine health status of the organism and its resistance against influence of harmful environmental and occupational factors (Fig.2). There exist numerous data which indicate that long-term occupational exposure of radiofrequency (RF) EMFs may result in development of various non-specific symptoms related to funcional changes in certain systems of the body, including slight abnormalities in cardiac function.

RF energy can penetrate inside human body and induce electric currents, which may be responsible for various effects in the organism. One of these effects is non-specific stress reaction. The basic of such reaction is the interaction of energy with cells, the influence transmission of signals and reaction of sensitive targets [Jauchem, JR,1997; Swierdlow AJ, 1997]. The major place, which reacts on stress symptoms, is hypothalamus. The hypothalamus performs the control funtion for the para-sympathetic and sympathetic systems, which ones are responsible for the autonomic regulation of many organs and systems in human organism, among other things cardiovascular systems [Taylor AA, 1994]. On the other side, the hypothalamus, with its ESSOC (Endogenous Self-Sustaining Oscillatory Clock) mechanisms triggers and controls the circadian (about 24-hr) cyclic changes of most parameters of the cardiovascular system with their maxima during day-time and minima at night. Therefore, RF EMFs may be one of the factors, which influence the synchronization of different biological rhythms. Biological rhythms (circadian, diurnal etc.) are a basic property of living matter from subcellular particles to the human body. They play a very important role in everyday life in health as well as in disease [Cornelissen G et al 1996, Hayano J 1990, Thijs L et al 1992]. Fig.1 summarizes the possible mechanisms leading to development of functional changes of the cardiovascular system in EM-exposed subjects. These functional changes result mostly from dysregulation of the autonomic control of the system; by itself, the symptoms are not considered as cardiac pathology, but may pose an increased risk of development of certain cardiovascular diseases.

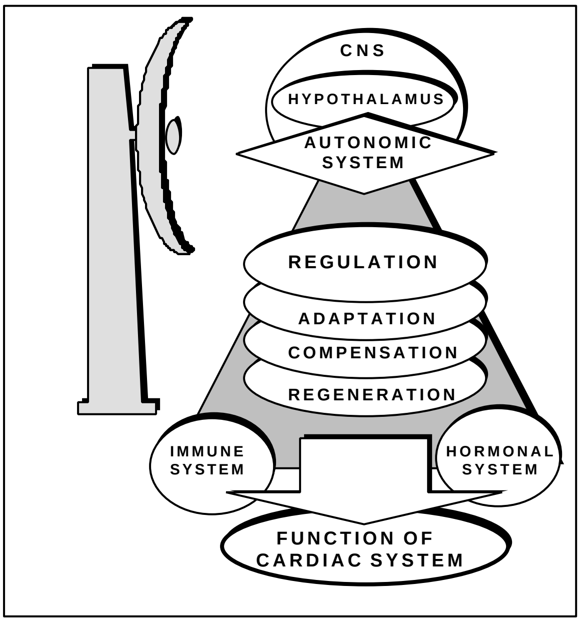

Figure 1.

Possible mechanisms leading to development of functional changes of the cardiovascular system and shifts of diurnal rhytms in subjects exposed to electromagnetic fields.

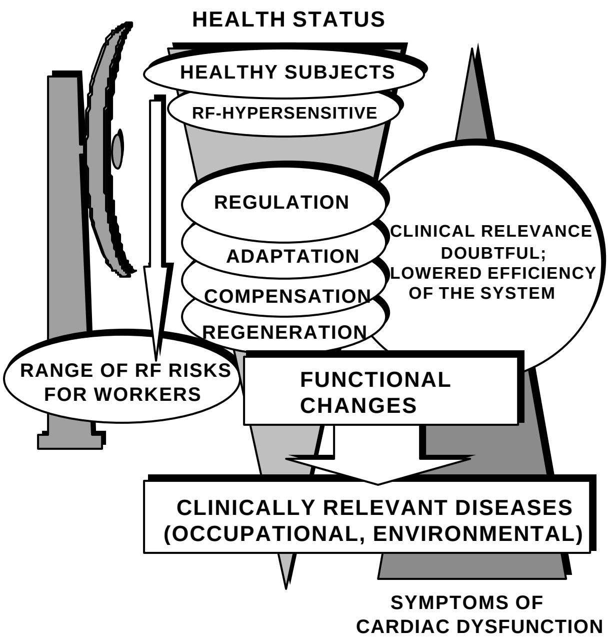

Figure 2

Development of symptoms of cardiac dysfunction in subjects exposed to electromagnetic fields.

In our previous studies [Bortkiewicz A et al 1997, Bortkiewicz A et al 1995, Szmigielski S et al 1998] we documented a dose-dependent increase in number of functional ECG abnormalities in a group of workers of middle-wave radio broadcasting stations, exposed to 0.7–1.5 MHz RFs. The most frequently found effects

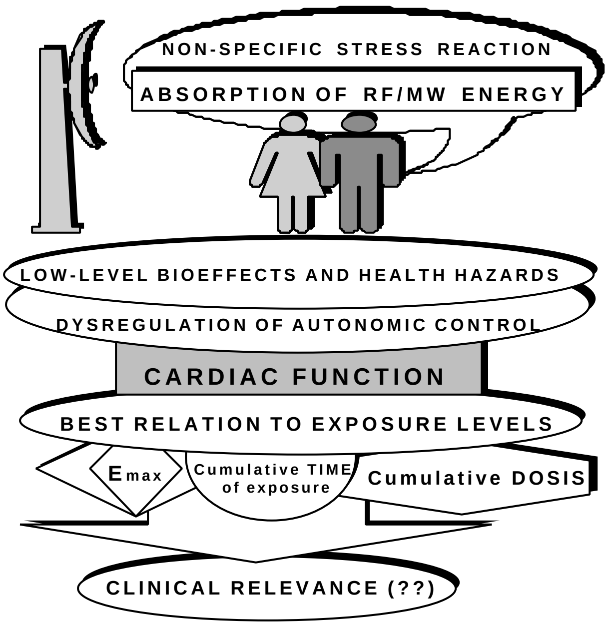

Figure 3.

A concept of the present study on dysregulation of autonomic control of cardiac function in workers of radio transmitting centres exposed to 10–30 MHz RFs.

included lowering of the day/night BP and HR ratio with negative correlation with RF exposure levels of workers [Bortkiewicz A et al 1997, Bortkiewicz A et al 1995]. These findings suggested that the multiyear exposure of workers in relatively strong RF EMFs may additionally lead to desynchronization of certain natural diurnal rhythms, mainly of those rhythms which are controlled by the autonomic nervous system.

In the literature there exist experimental data indicating that exposure of animals in controlled EMFs may result in desynchronization of circadian rhythms [Repacholi MH 1998, Schwartz PJ et al 1993], which leads in turn to disturbances in function of certain organs and systems.

In the present study we examined cardiac function in another group of workers exposed to RF radiation. Personnel of radio transmitting centres (RTC), exposed during work to 10-30 MHz RFs, has been monitored during the whole 12-hr shift to assess the RF exposure and thereafter underwent cardiac examination which allowed to determine parameters of autonomic regulation of cardiac function, including heart rate variability and diurnal rhythms. In this study we tried to find best possible relations of abnormalities in cardiac function with exposure parameters (maximal and mean levels of exposure, time of exposure, daily dose of exposure) to determine the proper methods of exposure assessment for medical studies (Fig.3).

Materials and Methods

Workers. For the present study, a total of 76 men aged 35-60 years, 38 working at three military Radio Transmitting Centres (RTC) (10 – 30 MHz transmitters with .... kW power outputs) and 38 at two radio line stations was selected. All subjects were employed in 4-day working cycles with 12-h shift (day), followed by 24-h rest, 12-h shift (night) and 48-h rest. There were counted 125 shifts per year as the basis for calculation of cumulated life EMFs exposure dose. Characteristic of the groups of workers (size, age, working cycle, RF exposures) are summarized in Table 1. Thirty eight subjects were considered as exposed to RFs (at maximal values for E-field intensity during working shift showing individual differences from 9 to 174 V/m), while the remaining 38 did not experience measurable exposures.

Both these group (RF-exposed and non-exposed) were matched for age, duration of employment (6 – 34 years), nutritional state and health status at $P < 0.01$.

Measurement of RF EMF exposures. For measurements of electric (E) and magnetic (H) field strengths two different types of broad-band meters were applied:

1. MEH-25 meter (Institute of Microwave Technology, Technical University School, Wroclaw, Poland), equipped with:
   1. AE-1 electric field probe (100 kHz-300 MHz) with accuracy ± 10% in the range of 2-1000 V/m of electric field strength;
   2. Isotropic 3AE-2e electric field probe (100 kHz-300 MHz) with accuracy ± 10% in the range of 0.5-50 V/m of electric field strength;
   3. AH-1 magnetic field probe (100 kHz-300 MHz) with accuracy ± 10% in the range of 0.5-250 A/m of magnetic field strength.
2. The Wandel & Golterman Radiation Meter EMR-300 (Germany), equipped with:
   1. H field probe type 10 with accuracy of ± 0.5 dB over the range of 0.03 – 16 A/m and in the range of frequency of 27 – 300 MHz. In the range of 5 – 27 MHz a calibration coefficient was individually declared for measurements for each frequency individually;
   2. E field probe type 8 with accuracy of ± 0.5 dB over the range of 1-800 V/m for the range of frequencies 100 kHz-3 GHz.

Table I. Dysregulation of autonomic control of cardiac function in workers exposed to 1-30 MHz RF radiation. Design of the study.

Groups of workers		
	Unexposed controls	**Exposed 10-30 MHz**
Number of subjects	38	38
Age	44.8 ± 8.7	45.7 ± 8.9
Working cycle	4-day, 2 x 12 hr shifts	4-day, 2 x 12 hr shifts
Exposure assessment		
Emax (V/m)	0	109.7 ± 46.8
Eav (V/m)	0	6.0 ± 3.1
DSF (V/m)2 x hr	0	1088.1 ± 937.1
DL 104 (V/m)2 x hr	0	108.2 ± 81.3
Cardiologic examinations		
1. Routine medical examination		
2. Questionnairing (risk of cardiac diseases)		
3. Routine ECG at rest (10-min recording)		
4. HRV (heart rate variability from 10-min ECG recording)		
5. Holter 24-hr ECG recording		
6. 24-hr ABP (ambulatory blood pressure)		
Analysis of results		
1. Correlation of cardiologic examinations with RF exposure levels		
2. HRV parameters (fast and slow components of the spectrum) in RF-exposed workers		
3. ECG abnormalities in RF-exposed workers		
4. Day/night ratio of BP and HR		
5. Diurnal rhythms of BP and HR		

Protocol of investigations. The investigations planned for this study comprised questionnairing oriented toward risks of cardiac symptoms, general medical examination, ECG recording at rest, 24-h Holter ECG recording and 24-h ABP (ambulatory blood pressure) recording. From these recordings several parameters were computerised, including heart rate variability (HRV), number of ECG abnormalities, day/night BP and HR, as well as parameters of diurnal rhythms of BP and HR (mean value, amplitude and acrophase of the cosinor). The intendent procedures had to be properly coordinated with the 4-day working cycle of study workers in order not to interfere with direct RF exposure. The 24-tests were performed only during the 4th day of the working cycle, starting at 8:00 a.m (Table 2). This ensured at least a 1-day rest after each last working shift before the tests and provided relatively ordinary life conditions during testing. In the case of ABP recording, all subjects were instructed to rest (sleep) in bed without any physical or mentalactivities from 10:30 p.m. to 6:30 a.m. before during the day of test.

Methods of investigations

Medical examinations. Evaluation of the health status of workers was performed by extended questionaire completed by all investigated subjects. This questionaire (constructed at the Department of Work Physiology and Department of Epidemiology, Institute of Occupational Medicine, Lodz, Poland) contained particular questions regarding the type of occupation, stress of at work, course of work shifts, life and nutritional habits, physical activity, self-evaluation of health status and family history of metabolic and circulatory diseases. Response to the questionaire was followed by anamnesis and routine physical examination performed by qualified physicans from the occupational medical staff.

ECG recording at rest. Routine ECG recordings were performed during rest in the supine position from typical leads (precordial and extremities) using the Medea system[Bortkiewicz et al 1997].

Holter ECG recording. Twenty-four-hour ECG recording (starting at 8:00 a.m. on the 4th day of the working cycle) was performed using Medilog type 3000 (Oxford, England) and Crypton 2500 (Micro-Medics, France) sets from two bipolar leads CM5 and CS1. Final results included evaluation of basic parameters of the ECG curve (heart rate, R-R period, symptoms of mild ischemia or arrythmia).

Heart Rate Variability (HRV) using Medea-HRV. At least 600 heart cycles were registered to enable HRV analysis from 512 consecutive ECG cycles (R-R periods). HRV analysis included time-related parameters: duration of R-R periods (msec.), individual standard deviation of 512 R-R periods (msec.), median and modal values of R-R, as well as parameters of frequency spectrum distribution (FSD). For analysis of FSD a fast Fourier transformation (FFT) was applied. Low frequency (LF = L1+L2 = 0.04 – 0.15 Hz), known also as Mayer wave sinus arrythmia (MWSA), and high frequency (HF = F3 = 0.15 – 0.35 Hz), known as respiratory sinus arrtythmia, components of the spectrum were differentiated and computed for each individual.

Ambulatory Blood Pressure (ABP) recording. Oscillometric 24-h ABP recording was performed using Medilog (Oxford,England) [Bortkiewicz A et al 1997, Staessen J et al 1990]. Automatic measurements of arterial BP were taken every 0.5 h during the day (6:00 a.m. - 10:00 p.m.) and every 1 h during the night (11:00 p.m. - 5:00 a.m.) for a total of 41 tests over 24 h. Systolic (SBP), diastolic (DBP), mean (MBP = SBP + DBP) blood pressure and heart rate (HR) were recorded in each test and used for calculation of diurnal rhytms. Recordings of ABP started at the same time of day (7:00 a.m.) in all studied subjects, but the first two recordings were deleted from analysis to allow adaptation to ABP recording.

Analysis of diurnal rhythms of blood pressure and heart rate. Diurnal rhythms were calculated for each individual by a least-square fit of a 24-h cosinor (Single Cosinor analysis) [Cornelissen G et al 1996, Szmigielski S et al 1998, Thijs L et al 1992], the rhythm parameters (mean value, amplitude,acrophase) were taken from the sine curve equation and used for further analysis. A total of 2-3 missing values per 24 h ABP (41 recordings) were accepted for analysis of rhythms. All recordings were checked for artifacts, beside those automatically edited by the Medilog ABP monitor. Recordings which showed a differences > 0.5 of diurnal acrophase value between two adjoining records were considered as errorneus and/or perturbed by external stimuli (e.g. excitation). Such recordings were excluded from analysis by the computer program and parameters of the rhythm were recalculated to receive final values.

Results

Assessment of RF exposure. Deatiled results of monitoring of RF exposure during 12-hr shifts in all investigated RTC workers are summarized in Table II. Analysis of data indicate that there exist large individual differences in exposure levels (Emax ranging from 9 to 174 V/m, Eav for the shift from 0.5 to 11.4 V/m) (Table II), while time of real exposure (Tex) in measurable RF fields during the 12-hr shift appeared to be relatively short and lasted from 0.3 hr (18 min.) to 2.6 hr (2 hr 36 min) with mean value of 1.72 hr (1 hr 43 min).

A comparison of maximal exposure levels (Emax) and daily exposure doses (Dsf) (for calculations see Table II) for all investigated subjects revealed a high correlation between the two parameters (Prearson's coefficient r = 0.876). Additionally, 4 subgroups of workers, which differ considerably in levels of their RF exposure can be easily identified in the present population.

Changes in ECG and Holter recordings. Abnormalities and pathological changes in ECG recordings for workers at RTC radio link stations occured quite frequently both RF-exposed and non-exposed subjects (Table III). In the whole population (exposed and non-exposed) about 60% of ECG recordings (either resting or Holter ECG) have shown more or less easily detectable deviations diagnosed as conduction, rhythm or repolarization disturbances (Table III). In general, abnormalities and pathological changes in ECG recordings were found more frequently in RF-exposed group than in non-exposed workers (28 abnormal records in RF-exposed and 18 in non-exposed, P <0.01), but in most cases the noted ECG abnormalities were listed as slight changes without clinical risks (e.g. number of extrasystoles slightly above normal levels, lowering of -ST fragment of the curve) (Table III). The most striking difference between RF-exposed and non-exposed workers was noted in the number of rhythm disturbances, including series of ventricular and supraventricular (atrial) extrasystoles (ExV, ExSV) (Table III). ExV and ExSV were detected in general from analysis of 24-h Holter ECG recordings and in most cases appeared to be short series of extrasystoles, amounting to a total of 100-400 ExV during the 24-h period recording, slightly above the upper limit accepted for healthy men of the respective age by an international group of experts [Staessen J et al 1990].

Table II. Assessment of individual exposure to 10 – 30 MHz radiofrequency fields in 38 workers of Radio Transmitting Centres (RTC), aged 45.9 ± 8.8 years, employed in a 4-day working cycle (12 hr work – 24 hr rest – 12 hr work – 48 hr rest).

Employment in RF fields (years)		**Time of exposure during 12-hr shift (hr)**		**Total time of RF exposure per month (hr)**		**Emax (V/m) during 12-hr shift**		**Eav (V/m) during 12-hr shift**		**Dose (DSF) during a 12-hr shift (V/m)2 x hr**		**Life dose (DLF) 104 (V/m)2 x hr**	
min.	2	min.	0.3	min.	11.2	min.	9	min.	0.5	min.	22	min.	1
max	34	max	2.6	max	82.3	max	174	max	11.4	max	3120	max	276
mean	21.02	mean	1.72	mean	53.24	mean	109.74	mean	5.98	mean	1088	mean	108.2
S.D.	9.68	S.D.	0.67	S.D.	20.84	S.D.	46.81	S.D.	3.13	S.D.	937.1	S.D.	81.3
Range	No. of subjects	Range	No. of subjects	Range	No. of subjects	Range	No. of subjects	Range	No. of subjects	Range	No. of subjects	Range	No. of subjects
< 10	3	0.3 – 1	9	10-20	8	< 10	1	< 2	8	< 100	8	< 5	8
10 - 15	8	1 – 1.5	0	21-40	1	10 – 50	4	2.1 – 6	10	100-500	2	6 – 50	5
16 - 20	6	1.5 – 2	11	41-60	12	51-100	11	6.1-8	5	501-1000	9	51 – 100	6
21 - 25	10	2 – 2.5	17	61-80	16	101-150	14	8.1-10	7	1001- 2000	12	101 – 200	15
26 - 35	11	> 2.5	1	> 80	1	> 150	8	10.1-12	8	2001 - 3200	7	200 - 280	4

Table III. Abnormalities and pathological changes in electrocardiographic (ECG) recordings in workers of Radio Transmitting Centres (RTC) exposed to 10-30 MHz RFs and in non-exposed workers of radio link stations.

	Whole population (N = 76)	*RF-exposed workers (N = 38)*	*Nonexposed Controls (N = 38)*	*Stat. sign.*
Total number of workers with ECG abnormalities (standard and/or Holter)	46 (61.0%)	28 (74.0%)	18 (47.0%)	$\chi2 = 4.46$ $P < 0.05$
General Assessment of ECG recordins				
Normal (0)	30	10	20	
Slight abnormalities without clinical risks(1)	30	18	12	
Moderate disturbances, incl. lowering of –ST (2)	12	7	5	$\chi2 = 11.72$ $P < 0.01$
Pathological changes with clinical risks (3)	4	3	1	
Predominant types of abnormalities and pathological changes in ECG recordings				
Conduction disturbances	19	12	7	
Intraventricular	5	3	2	
Intra-atrial	4	3	1	
RBBB	7	4	3	
Other	3	2	1	$\chi2 = 17.34$ $P < 0.01$
Rhythm disturbances	28	19	9	
ExV	21	14	7	
ExSV	7	5	2	
Repolarization disturbances (incl. lowering of ST)	16	10	6	

NS – not significant (chi-square test, P > 0.05);
RBBB – right bundle branch block;
ExV – ventricular extrasystoles;
ExSV – supraventricular extrasystoles;
ST – S-T fragment of the ECG recording.

Heart Rate Variability (HRV*).* Analysis of HRV, based on computation of 512 consecutive ECG cycles from resting recordings revealed significant lowering of low/high (LF/HF) component ratio (F1+F2/F3 and F2/F3) in RF-exposed subjects, compared to non-exposed controls ($P< 0.001$). The lowering of the low/high ratio resulted mainly from higher values of the respiratory sinus arrythmia (RSA) component of the frequency spectrum (0.15-0.35 Hz, expressed as F3), being an indicator of parasympathetic nervous system tonus. The F3 component of HRV spectrum has shown a significant negative correlation with RF exposure level of workers, expressed as the daily exposure dose (Dsf) ($F = 18.47$, $r = -0.447$, $P < 0.01$), similar to the negative correlation between Dsf and HRV slow/fast component ratio (Fig.6).

Analysis of ABP recordings. Analysis of 24-h ambulatory blood pressure recordings has shown that the average values of systolic and diastolic arterial BP for both investigated groups were within limits considered normal for healthy men (Table IV). High standard deviations (9 - 11 mmHg) indicate that exist indviduals with BP values exeeding upper limits of the normal range (Table IV). In fact, elevated values of BP during day, night and/or 24-h recording were found in six workers (16%) in the RF-exposed and in three subjects (8%) in the non-exposed group, but the difference was not significant. Systolic BP during the day was about 15 mm Hg higher than during the night (Table IV). The day-night difference in diastolic BP reached 10-12 mm Hg, and this resulted in BP day/night ratios of 1.10-1.20. The day/night ratios, both for BP and heart rate (HR), differed significantly between RF-exposed and non-exposed groups at $P<0.01$ (Table IV) and showed significant correlation with individual exposure levels (Dsf) .

Diurnal rhythms of BP **and HR.** In all investigated subjects the diurnal rhythms of BP and HR were well preserved and easily calculable (Fig.4).

The working in a 4-day cycle with alternate day and night 12-h shifts is not a normal situation and may lead to desynchronization of natural diurnal rhythms, e.g., in body temperature, heart rate, blood pressure, autonomic regulation and certain biochemical parameters [Muller JE et al 1994, Taylor AA 1994]. A typical result of desynchronization of these diurnal rhythms appears to be lowering of their amplitude, shifts of the acrophase (time of maximum) and changes in the time relation of dependent rhythms [Hayano J 1990]. Analysis of systolic blood pressure values in healthy male (aged 35 years), between 0:00 and 9:00 p.m., revealed well preserved rhythm with two maxima during day-time and one minimum during night-time (Fig.8). The least-square fit of a 24-h cosinor (Single Cosinor analysis) flattens the maxima and minima and allows to calculate individual rhythm parameters - mean, amplitude and acrophase (Fig.4).

Table IV. Analysis of 24-hr ambulatory blood pressure (ABP) recording and parameters of diurnal rhythms in workers exposed to 10-30 MHz RFs.

Parameter analyzed	**Total population of workers (N = 76)**	**Exposed workers (N = 38)**	**Non-exposed workers (N = 38)**	**Stat. sign.**
SBP 24-hr (mean) (mm Hg)	130.4 ± 9.8	128.6 ± 10.4	132.4 ± 9.2	NS
DBP 24-hr (mean) (mm Hg)	83.4 ± 8.8	84.6 ± 8.3	82.4 ± 9.1	NS
SBP day (mm Hg)	138.4 ± 10.7	137.4 ± 11.3	139.2 ± 10.3	
DBP day (mm Hg)	89.3 ± 7.8	88.4 ± 8.3	91.2 ± 7.6	
SBP night (mm Hg)	123.9 ± 7.7	123.5 ± 7.2	124.5 ± 8.3	P<0.01
DBP night (mm Hg)	77.4 ± 6.8	78.6 ± 6.6	76.4 ± 7.1	P<0.01
SBP day/night ratio	1.13 ± 0.06	1.11 ± 0.05	1.15 ± 0.06	
DBP day/night ratio	1.12 ± 0.05	1.09 ± 0.04	1.14 ± 0.05	
HR 24-hr mean	77.5 ± 7.2	78.4 ± 8.6	76.3 ± 6.6	NS
HR day	84.1 ± 8.4	83.5 ± 9.4	84.2 ± 8.2	NS
HR night	72.3 ± 6.4	74.2 ± 7.3	70.3 ± 5.4	NS
HR day/night ratio	1.15 ± 0.08	1.11 ± 0.07	1.18 ± 0.09	P<0.01
Parameters of diurnal rhythms				
SYSTOLIC BLOOD PRESSURE				
24-hr mean value (mm Hg)	126.1 ± 7.1	126.5 ± 7.0	125.4 ± 7.2	NS
Amplitude (mm Hg)	15.4 ± 3.2	14.0 ±3.8	17.4 ± 2.6	P<0.01
Acrophase (grades)	210.4 ± 22.7	199.6 ± 27.5	228.6 ± 20.1	P<0.05
DIASTOLIC BLOOD PRESSURE				
24-hr mean value (mm Hg)	85.3 ± 4.9	84.6 ± 4.8	87.1 ± 5.1	NS
Amplitude (mm Hg)	11.4 ± 3.2	9.8 ± 3.6	12.3 ± 3.1	P<0.01
Acrophase (grades)	205.4 ± 25.1	186.4 ± 28.4	231.3 ±23.5	P<0.05
HEART RATE				
24-hr mean value	78.1 ± 8.1	77.3 ± 7.8	78.4 ± 8.8	NS
Amplitude	14.6 ± 6.4	11.4 ± 5.4	18.3 ± 7.2	P<0.01
Acrophase (grades)	184.8 ± 23.6	168.3 ± 22.4	208.5 ± 24.2	P<0.05

SBP – systolic blood pressure; **DBP –** diastolic blood pressure; **HR –** heart rate.

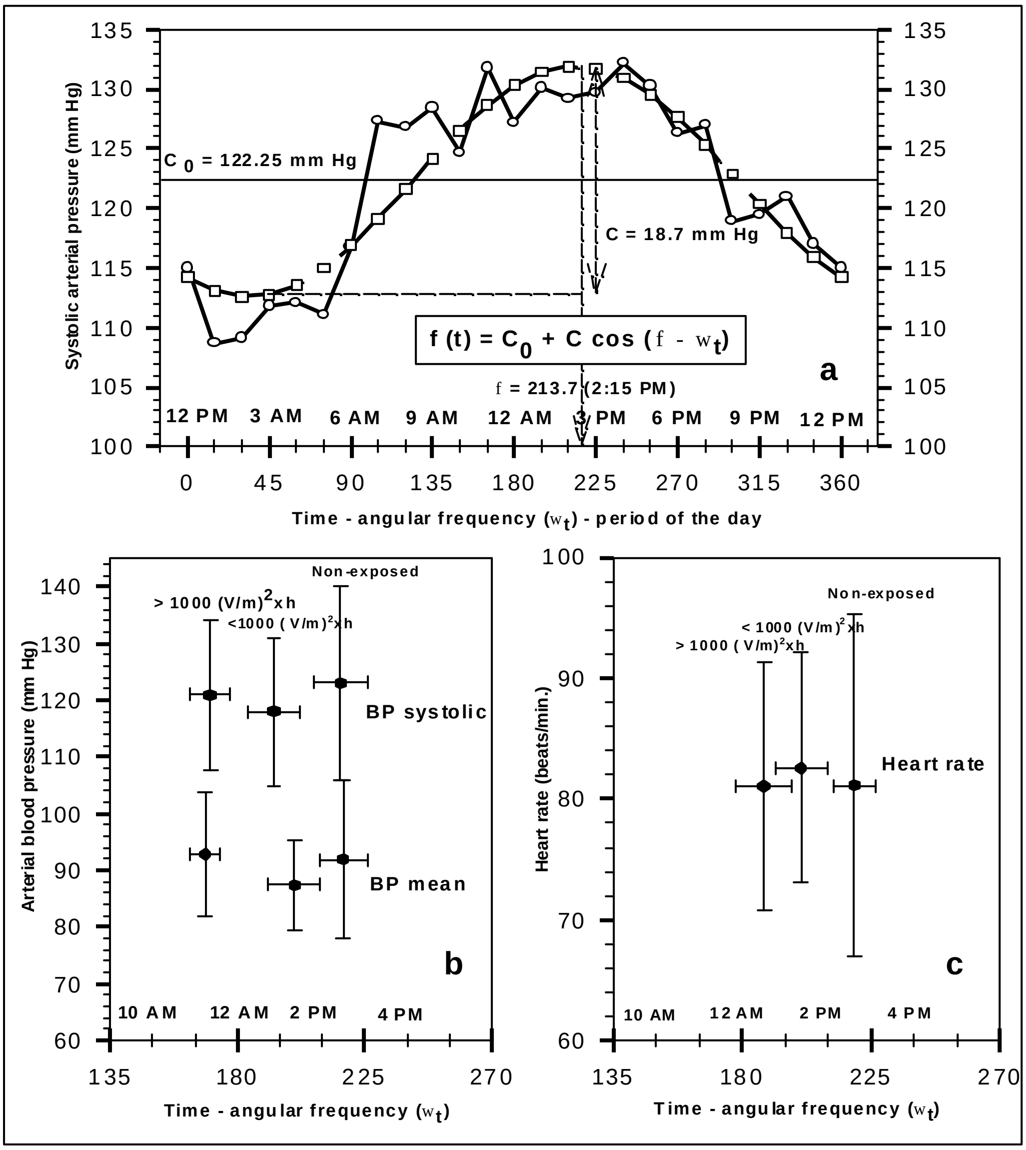

Figure 4. Diurnal rhythm of systolic blood pressure in a 35-year old healthy workernot exposed to EM fields (a) and in the RF-exposed group of workers(b and c).

For unexposed workers the acrophase of all BP rhythms was about 220^0 (3:00 p.m.) (Fig.4 b). In RF-exposed workers amplitude and acrophase of diurnal rhythms of BP differed significantly from values observed in unexposed subjects (Fig. 4b). Amplitude of rhythms was lower in the exposed and showed negative correlation with individual RF exposure dose (Dsf) (Fig.4). Acrophase of rhythms was shifted to about 180^0 - 195^0 (11:00 a.m. - 1:00 p.m.) and again, and showed negative correlation with individual RF exposure dose (Dsf).

The course of HR rhythms was in general similar to that of BP rhythms, but acrophase of the HR rhythms in both investigated groups were shifted to the left by about 30^0 (2 hr) and ranged from 165^0 to 210^0 (11:00 a.m. - 2:00 p.m.). Significant differences ($P < 0.01$) for amplitude and acrophase of HR rhythms were noted between RF-exposed and non-exposed groups (fig.4 b,c)

Discussion

In the present study, workers at radio transmitting centres (RTC) and radio line stations were diagnosed from the point of view of presence of functional disturbances of the circulatory system and increased risk for development of ischemic heart syndroms. All investigated subjects were qualified by occupational medical services as a fit for work at permissible intensities of RF EMFs.

The main results of our experiments revealed that there existed two types of changes in the investigated subjects. First, quite frequently in the EM-exposed workers there appeared various subclinical abnormalities in ECG recordings. Second type of changes was desynchronozation of diurnal rhythms of ABP and HR. The diurnal rhythm of BP is a major source of BP variability. ABP recorded in EM-exposed workers has shown repeatedly the liability of both SBP and DBP, being closely related to the activity of the subject [Bortkiewicz et al 1995]. The fall of BP at the rest time and a rise at the time of activity appears to be the most marked and persistent changes over the 24-h ABP [Bortkiewicz et al 1995]. Some authors conclude that the oscillations in the autonomic drive directed to the heart may be important in genesis of diurnal rhythms of cardiac function [Hayano J 1990, Taylor AA 1994]. In fact, day-to-night oscillations of sypathetic and parasympathetic nervous system activity were observed by spectral analysis of HR and BP [Muller JE et al 1994]. Generally, different experimental dates indicate that diurnal rhythms of cardiovascular activity have their origin in the central nervous system [Cornelissen G et al 1992, Hayano J 1990, Muller JE et al 1994].

Analysis of ECG recordings, received during our studies, points a variety of minor and more serious abnormalities and even pathological changes appearing quite frequently in both groups of workers. Close to 75% of RF-exposed workers showed various disturbances in condustivity, rhythm or repolarization, but in most cases only slight ECG abnormalities, without clinical relevance and risks have been identified. In fact, all types of abnormalities and pathological changes in ECG appeared more frequently in RF-exposed workers than non-exposed group ($P < 0.01$), but no particular form of ECG abnormalities could be identified as responsible for the difference between exposed and non-exposed subjects. Therefore, we cannot draw firm conclusion about higher risk of functional cardiac disturbances related to occupational exposure to RF. We cannot point the predominating types of these disturbances, which could be determined in the exposed group, too. Nevertheless, there exists a clear tendency for a higher number of mild rhythm disturbances (mostly small series of atrial extrasystoles, amounting to a total of 100-400 ExV during 24-h Holter recording) in RF-exposed workers. This tendency may be explained as the result of the functional dominance of the sympathetic system in autonomic regulation of cardiac function in multiyear employees exposed to RF. On the other side, other results obtained in the present study do not confirm the presence of sympathicotonic regulation of cardiac function in RF-exposed workers. Particulary, no convincing symptoms for predomination of sympathicotonic regulation were found in analysis of HRV, including parameters of ECG frequency spectrum distribution, being considered as an objective method for evaluation of sympathetic-parasympathetic components in neurovegetative regulation of cardiac function [Bortkiewicz A et al 1997, Bortkiewicz A et al 1995].

Statistically significant changes, between RF-exposed and non-exposed group, were found for their diurnal rhythms of BP and HR. A group of RF-exposed workers has shown considerable shifts in their diurnal rhythms of BP and HR. Mean 24-h values for systolic blood pressure (SBP), diastolic blood pressure (DBP), mean blood pressure (MBP) and HR did not differ from those recorded in non-exposed subjects employed at the same working pattern, but the day/night ratios and amplitude of the most rhythms were significantly lower. Additionally, the acrophase of the rhythm was shifted to earlier hours of the day. Analysis of individual amplitude and acrophase values revealed their strong negative correlation with maximal RF exposure levels experienced during working shift. In view of these results it may be concluded that multiyear occupational exposure in RF EMFs can desynchronize autonomic neurovegetative control of cardiovascular function.

RF-exposed and non-exposed workers were employed on the same working pattern (a 4-day cycle which included two 12-h working shifts and one of the four days in the cycle with reversed activity - night shift) and such working pattern was continued for the whole period of employment (6-34 years). Therefore, all investigated subjects should be considered as adapted to a particular working environments, which may generate modified course of physiologic rhythms, including diurnal rhythms of BP and HR. Neverthless,the differences observed between RF-exposed and non-exposed subjects can be attributed to influence of EMFs. Both groups were matched with regard to age, duration of employment, nutrtional stage, health status, level of physical activity, quality of sleep and timing of the sleep-wake transition. A link between EMF exposure and change of diurnal rhythm of BP and HR is additionally confirmed by a strong correlation of amplitude or acrophase values with individual RF exposure levels.

At present we cannot offer a resonable explanation for mechanisms responsible for changes of diurnal rhythms of BP and HR in workers exposed to RF EMFs. There exist no sufficiencely direct evidences to confirm the hypothesis that observed desynchronization of autonomic regulation of cardiovascular functions is a result of EMF exposure. But in the available literature there exist experimental date indicating that exposure of animals in controlled microwave fields may result in desynchronization of circadian rhythms, which leads in turn to disturbances in the function of certain organs and systems [Schwartz PJ et al 1993]. These results were never confirmed in epidemiological and medical investigations of humans exposed to electromagnetic fields. Results of the presented study supports, for the first time, the possibility that occupational RF exposure may desynchronize diurnal rhythms of BP and HR, generated by day/night oscillations of autonomic regulation systems.

In conclusion, it is our strong feeling that occupational exposure to RF fields increases the risk of disregulation of autonomic control of cardiac function. Such dysregulation is manifested by changed ratio of high/low fractions of HRV, increased number of functional ECG abnormalities and lowered day/night ratio of BP and HR. Additionally, shifts of diurnal rhythms of BP and HR (lowering of amplitude, earlier occurance of acrophase) confirm the tendency for dysregulation of the autonomic control. However, the clinical relevance of the RF-related dysregulation of autonomic control of cardiac function and its influence on the possible increase of risks of cardiovascular diseases is not known; further studies for assessment of this possibility are needed.

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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 health examination 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 allowable values (7000 V/m^2/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 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 in the control. A tendency to an 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 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 group, (%).

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 cardio-vascular 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
Cardio-vascular 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 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 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
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 groups**	**Age structure (%)**	**"Expected" number of pathologies for 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 groups**	**Age structure**	**"Expected" number of pathologies for 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

Biochemical findings are shown in Table 8. The table illustrates the differences observed between the compared groups. Thus, the basic group subjects had a significantly higher ß-lipoproteid level as compared to the control. 76% of the basic group were revealed to have ß-lipoproteid 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 milk acid, piruvic acid and glucose concentration, as compared to the control. Four subjects with glucose levels exceeding physiological standards also belonged to the basic group. Thyol 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 ± 0.33	10.27 ± 0.83	8.03 ± 059	< 0.1	< 0.05
Cholesterol, mmol/l	6.54 ± 0.20	7.05 ± 0.31	6.64 ± 0.20	NS	NS
β-lipoproteids, g/l	6.73 ± 0.20	6.51 ± 0.51	5.45 ± 0.2	< 0.01	< 0.1
Milk acid, mmol/l	1.1 ± 0.04	1.16 ± 0.29	0.89 ± 0.05	< 0.01	NS
Pyruvic acid, µmol/l	115.0 ± 3.0	122.6 ± 7.5	98.6 ± 6.0	< 0.05	< 0.05
Glucose, mmol/l	4.4 ± 0.09	4.16 ± 0.16	3.64 ± 0.09	< 0.01	< 0.05
Blood SH – groups, mol/l	23.67 ± 0.71	23.15 ± 1.25	27.76 ± 1.15	< 0.01	< 0.05
Blood SS – groups, mol/l	2.82 ± 0.14	2.05 ± 0.21	1.89 ± 0.22	< 0.01	NS
SH/SS, units	9.42 ± 0.59	11.3 ± 1.1	12.93 ± 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). The table shows that testosterone levels in regulators are lower than 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 (experimental group), in previously, EMF-exposed persons (special group) and in control persons

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

Findings analysis 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 mW/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, that is, 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. The 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 n=70	Last examination n=70	t
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	Heartache	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/m^2 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/m^2 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

- Performed studies suggest the identity of health disturbances among the workers exposed to low intensity HF and SHF EMR.
- The disease induced by electromagnetic radiation is clinically manifested in vegetative dystonia syndrome with peculiar complaints, and disturbances in central nervous system, cardiovascular system, reproductive system and gastrointestinal tract; and in blood biochemical parameter changes.
- Revealed changes are persistent in character and do not disappear after ceasing the EMF exposure.
- 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 thyol disulphide changes – are the symptoms of ageing syndrome.
- 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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Occupational and residential health monitoring on people exposed to electromagnetic fields in RF range. Clinical observations of 12 patients exposed to EMF.

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The treatment of changes in the state of health of people that have been exposed to electromagnetic radiations of radio frequencies represents an exclusive complexity by virtue of a number of reasons, and the basic ones are:

1. Impossibility to give a legible definition to measure pathological influence of electromagnetic fields on an organism.
2 Polymorphism of clinical developments.
3 Stage and undulating course of the disease
4 Illegibility in a number of cases of the hygienic characteristics of working conditions, which impedes the analysis and comparison of observations and literary data.

Not incidentally in this connection, there is no common opinion on the opportunity of treatment of clinical developments incipient at activity of electromagnetic radiation, as "Radioundular illness " or “Illness of electromagnetic saturation of an organism”. In Russia there is now an official point of view concerning the influence of electromagnetic fields of ultrahigh-frequency on an organism of a man, that has found reflection in the order "About the order of carrying out of pre-stress and periodic medical examinations of the workers and medical rules of the tolerance to an occupation " (order N90, dated 1996). According to this order the diagnosis is stated as follows: diseases, connected with action of radiation of a radio-frequency range of super high frequencies, with a syndromal decoding:

1 Vegetative dystonia;
2 Asthenic syndrome;
3 Astheno-vegetative syndrome;
4 Subthalamic syndrome.

In this case we have to estimate the action of electromagnetic fields on an organism from a clinical point of view as a syndrome. The above mentioned syndromes are unspecific and can be also observed for many other diseases without connection to the influence of electromagnetic radiation, as defines the difficulty of this disease diagnostics. It is particularly true for the cases of chronic low-intensive action of electromagnetic radiation. For the acute influence of electromagnetic radiation there is a more or less apparent connection between the fact of action and disease development.

In this report an attempt is made to show:

1 There is a similarity in clinical developments of acute and chronic influence of electromagnetic fields on a human organism.

2 There is an opportunity of excretion to some extent of specific syndrome-complex.

3 It is possible to reconsider an attitude toward formulation of the diagnosis with an excretion not of the stages, but the variants of clinical current of the disease, connected with an action of electromagnetic fields, which is possibly connected with the requirements of an irradiation (irradiation geometry, its duration, attitude of the body axis to the magnetic and electrical amounting).

In non-regular conditions of work, during the repair of radio equipment a man, 25 years old, was exposed to super high-frequency radiation with power density exceeding 15 mW/cm^2 within 20 seconds. The bottom of the trunk up to the loin, left-hand lateral area of the trunk and the face were exposed. Entering the clinic, the diagnosis was formulated as a disease connected with the action of electromagnetic fields of ultrahigh frequency with syndromal decoding:

1 Asthenoneurotic syndrome;

2 Syndrome of a vegetative dystonia with paroxysms of mainly sympathoadrenic type and hyperventilation syndrome.

At the moment of exposure the patient felt warmth in the places of influence. During the next 8 hours the subjective frustration of primary response were developed, such as: headache in occipital and temporal areas, rotatory vertigo, nausea, blanket delicacy, the heightened sweating, feeling "of labored respiration", there was a single-pass vomiting after nutrition reception. After three days decreasing of attention appeared, the patient became forgetful. There were two attacks of a type of: with a compressive headache in temples and nape, and the feeling of "indentation of eyes in orbits" as a background, the alert reaching the level of pavor appeared. All that was accompanied by the feeling "of labored respiration". The attack came to an end by a plentiful emiction.

Entering the clinic, on the fourth day the patient complained at: compressive headache in nape, which began at 3 o'clock at night and accompanied by the feeling of “indentation of eyes in orbits”, rotatory vertigo incipient periodically, blanket delicacy, irritability, decreasing of attention, infringement of dream (difficulties of falling asleep, frequent night awakenings), pain in interscapular area and loin while moving. During the clinic period there were three attacks of a type as described above. The complaints basically were on blanket delicacy, irritability, defective memory, and feeling of "air shortage".

After the neurological examination it was possible to point out the following basic syndroms: 1. Asthenic development, such as decreasing of memory, absent-mindness, emotional lability; 2. Weakly expressed vestibular syndrome 3. Syndrome of increasing of nervous - muscle excitabilities; 4. Weakly expressed syndrome of pyramid deficiency; 5. Syndrome of vegetative dystonia. The clinostatic test showed out the obvious clinostatic deceleration indicating the infringement of vegetative providing. The body thermometry showed the change of thermoregulation biorhythm with a reduction of difference between the morning and evening temperature of a body up to 0.1 - 0.2 degrees. On the 28-th day the primary hypotonic reaction with rapid pulse (arterial pressure in average 100 and 60 mm of mercury column, pulse 86-94 per minute) was replaced for hypertonic and slow pulse (arterial pressure 150 and 90 mm, pulse 62-68 per minute). The change of a coefficient Cerdo has shown the change of vegetative tone on the 24-th day from sympathic to parasympathic.

The blood clinical analysis has revealed the increase of absolute lymphocytosis and some decrease of thrombocytes. On the 23-rd day coagulogramm has revealed the activation of the 1 phase hemocoagulation with rising trombinogenesis and conservation of thrombocytes function, the absence of ingibition pathology. The level of hormones of a thyroid gland on the 17 day was within limits of norm. The activity of blood cholinesterase icreased a little. Thermovideografy (thermodiagnostics) done on the 9 day after electromagnetic field influence has revealed thermohyperfunction of a thyroid gland, supraclavicular lymphatic clusters, attributes of infringement of the peripheric circulation of the inferior extremities and spondylosis of the lower department of the spine. The electroencephalography done on the 23 day has shown moderate changes of bioelectric activity of a brain, showing diffuse changes of irritative character with a defeat of mesodiencephalon structures, with increasing of a level of activation of a reticular formation with a background of high emaciation of cortex neurons, decreasing and instability of a blanket function state of a brain.

The following group of clinical observations has been related to the 60-70-es years, with the subsequent dynamic observation during more than 20 years. The first case as a matter of fact refers to the so-called mixed action of superhigh-frequency radiation. At the begining there was an acute defeat by a potent blanket irradiation, which caused a short-term loss of consciousness and subsequent ataxia. In the future the patient continued to work in the circumstances of irradiation of flux energy density 100 $\mu W/cm^2$ during 60 % of operating time. The second patient was exposed to an irradiation about 4000 $\mu W/cm^2$. during 35-40 % of operating time within 7 years. The third case is connected with an irradiation by an electromagnetic field of 5-7 kW in a pulse regime during 13 years. And, at last, the fourth patient for 4 hour every day during 10 years was in the zone of action of superhigh-frequency radiation with power density of 100-200 $\mu W/cm^2$.

For the best comparison the changes of a state of health are grouped together as well as in the first observation according to the systems. Changes of central nervous system were examined as the astheno-vegetative syndrom in 3 cases, subthalamic syndrome - in 1 observation. As for the cardiovascular system the basic developments were submitted by: 1. vegeto-vascular dystonia of a hypotonic type with transformation during 2-3 years in a hypertonia -1 case. 2. changes of ECG treated at the begining as a myocardial dystrophy later in 2 cases were shown as progressing coronary deficiency with the outcome into an infarct of myocardium at the age of 40 and 45. 3. The forming of ischemic heart disease of the high class per 39 years - 1 case.

Blood analyses: during 23 years the clinical analysis of blood was carried out and was defined transient, and in one case proof cytopenia of a different degree of expressiveness increasing in time or undulating. The level of leucocytes of blood varied from 4.8 up to 2.1 on 10 in 9-that degree per liter, the thrombocytes were in limits 156-150 on 10 in the 9-th degree per liter. The infringements of a lipide exchange were submitted by augmentation of a level of a cholesterin in blood almost in 2 times during the first 3-4 years from the beginning of observations (from 3.9 till 8.84 mmole per liter).

Taking into account the above stated, the plan of 2 stages medico-ecological monitoring was designed. The basic positions of this plan are the following. The first stage is intended to excrete the group of hazard. For this purpose the complex medical examination of minimum two groups will be carried out. A basic group consists of persons with suspicion on an opportunity of development of this disease, connected with action of electromagnetic fields and the second group - control. The examination includes questionnnare and clinico-laboratory examination intended on detection, from our point of view, of specific syndrom-complex and comparison with the group of control.

Simultaneously with it the hygienic estimation of conditions of stay of these groups will be carried out. The second stage is carried out in a clinic for detailed study of persons of the basic group with suspicion on development of the disease, connected with action of electromagnetic fields. The purpose of this stage is to carry out differential diagnostics of detected changes in a state of health and interpretation of them as a disease, connected with an action of electromagnetic fields.

This plan of 2 stages medico-ecological monitoring was tested during the investigation of a state of health of the population, living in conditions of a high level of electromagnetic fields. The basic group lived in the zone, where the level of electromagnetic radiation ultrahigh-frequency was 12-263 $\mu W/cm^2$ and radiation level 150-170 MHz - 7-8 V/m, the control group lived in the conditions, where the level of superhigh-frequency radiation was 5.40 + 2.30 $\mu W/cm^2$. The basic complaints were on blanket delicacy, prompt fatigability, decreasing of memory, sharp change of mood, uneasiness. There was a reliably significant difference in comparison with the control group. The basic differences in structure of a detected pathology between these groups expressed in predominance for the persons of the basic group of vegetative dystonia syndrome and astheno-vegetative syndrome with reliably significant difference. There was a reliable difference in quantity of thrombocytes (in the basic group it was less). The elongation of bleeding time of the persons of the basic group in comparison with the control one was observed. A level of fibrinogenum and prothrombin index was lower in the basic group. In the structure of illnesses of the persons of the basic group acute resperatory-virus diseases, herpetic infection and allergosis considerably predominated, that allowed to presume a state secondary immunodeficiency of the examined basic group. There was reliably significant augmentation of immunoglobulins M and G in blood of the examined persons of the basic group in comparison with the control one. The significant augmentation of the level of hormones of a thyroid gland of the examined basic group in comparison with the control one was fixed reliablly.

Taking into account, that the basic syndrome was represented by the syndrome of a vegetative dystonia, that is why for the individual analysis it was taken as the basic one. The combination of syndromes of vegetative dystonia and thrombocytopenias is significantly predominated in the basic group. The syndrom of vegetative dystonia in a combination with thrombocytopenia and leukopenia, and as variants: vegetative dystonia plus thrombocytopenia and attributes of coagulopathy or syndrom of vegetative dystonia, the changes of blood and hyperplasia of thyroid gland were only of the examined basic group.

As a result of examinations of the first stage the group of hazard in 10 people was chosen, which could have the development of the disease, connected with the action of electromagnetic fields. The carrying out of careful differential diagnostics in clinic conditions allowed diagnosing the disease, connected with the action of electromagnetic fields ultrahigh frequency for 7 out of 10 patients. For more visual comparison of all cases all detected changes also presented according to the systems.

* In central nervous system the changes were represented by the following syndroms: 1. Astheno-vegetative syndrom - 3 cases; 2. Asthenoneurotic syndrom - 2 cases; 3. Neurasthenic syndrom - 1 case; 4. Hyperventilation syndrom - 6 cases.

* The changes of cardiovascular system in 4 cases were treated as a vegeto-vascular dystonia of a hypertonic type.

* System of blood: in 4 cases the syndrome of thrombocytopenia and in 2 cases a transitional thrombocytopenia were found out.

* System of a hemostasis: the syndrom of coagulopathy was revealed in 7 cases.

* Changes of immune system corresponded the activations of autoimmune processes in all cases.

* The hyperplasia of thyroid gland - 1 case.

Conclusion

Thus, the clinical observations allowed us to find out possible specific symptom-complex of the disease, connected with the action of electromagnetic fields.

The nervous and the cardiovascular system, system of blood and hemostasis, thyroid gland, immune system are involved at this disease. The current of disease is in stages and undulating. The degree of involving in pathological process of introduced bodies and systems is various and apparently depends on conditions of irradiation, energy exposure and area of irradiation, genetic determinacy of a type of organism reaction.

During an acute irradiation it is possible to choose the period of primary reaction, which differs by a direction of changes in intimate - cardiovascular system and system of blood from the subsequent period and from changes at chronic low-intensive influence. Probably during chronical low-intensive irradiation there are also similar changes as well as during the acute irradiation in the period of primary reaction, but we shall skip them as these changes during the chronical action are not so bright, and most people do not ask for medical care in this period.

We record changes in the state of health during chronical action already in the second phase of disease. Probably, it also explains an inconsistency of observations introduced in the written works. Especially frequently the conflicts are in the treatment of changes of blood system. In our point of view it is connected with undulating changes, which are altering as during any disease by the periods of compensation and decompensation.

We consider irregular to regard the syndromes, viewed today in the official definition of the diagnosis, as the stages of this disease: initial - vegetative dystonia, asthenic syndrome, moderately expressed astheno-vegetative syndrome, expressed subthalamic syndrome. Probably, these syndroms correspond to the clinical variant of current: mainly with a defeat of nervous system, system of blood (hematological variant) or mixed. This question requires further development. The possible formulation of the diagnosis: "Radioundular illness" or
"Illness of electromagnetic saturation of an organism":

I 1. Acute:
   1) Initial Phases;
   2) Secondary phases.
  2. Chronic:
   1) Initial Phases;
   2) Secondary phases.

II. Syndromal decoding:
  1. Psychovegetative syndrome;
  2. Syndrome of a vascular dystonia;
  3. Syndrome of lymphocytosis with subsequent cytopenia (transitional or stationary value);
  4. Syndrome of consumption coagulopathy;

5. Syndrome of hyperplasia of thyroid gland without disturbance or with disturbance of function.

III. Clinical form:

1. Cerebral;
2. Cerebral - hematological;
3. Hematological.

IV. Stage:

1. Decompensation;
2. Compensation.

V. Cause:

1. Stationary;
2. Progressing;
3. Remittent.

And, at last, surveying one of the aspects of antropogeneous ecological system, in which the man and technical product, manufactured by him - the electromagnetic fields – operate, it is possible to state, that as a result of unfavorable influence an electromagnetic radiation the autoecology of the man varies. This conclusion is received by the results of the carried out research work, which has shown the changes of central nervous, cardiovascular and endocrine systems, system of blood and hemostasis. Moreover it is possible to propose that the electromagnetic fields are potentially capable to be the factor of man-made selection weakly controlled today.

As it was said above, the electromagnetic radiation leads to infringements of vegetative nervous system. Systems, which actively participates in adaptive reactions of an organism. It is expected, that people having initial deficiency of vegetative nervous system (constitutional or acquired), the infringements under the influence of electromagnetic fields will be more expressed. It is shown, that there is a genetic association of vegetative crisises with antigenes Cw6, B12, B35 of system HLA. From our point of view this question must be investigated from interdisciplinary positions involving geneticists.

Health surveillance of RF/MW exposed personell – adequacy of methods used and the need for protocol unification

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RF/MW sources are nowadays widely used in numerous aspects of modern life, making the number of occupationally and/or residentially exposed subjects constantly increasing. Under the circumstances, it does not come as a surprise that health consequences of such exposures have become one of the major concerns of not only scholar, but of the general public as well. Responding to that, clarification of mechanisms underlying health impact of RF/MW exposures have earned a priority status in modern radioscience. However, few major obstacles exist before achieving results beyond doubt. In addition to the well-known problems of extrapolation from cellular and/or animal models to humans, scarce and inadequately designed epidemiological studies, limitations of a whole-body SAR concept etc., a question of adequacy and accuracy of health check methods will be pending as long as the patterns of RF/MW influence on human health are not completely understood. A lack of an uniform, internationally accepted RF/MW health surveillance protocol poses as a major problem both in research work and in everyday practice, since substantial differences arise in the extend and methodology of health checks performed by different researchers and/or practitioners, making their results very difficult, sometimes even impossible to compare.

The aim of this paper is to present our design of a health survey of RF/MW occupationally exposed personnel in order to initiate the discussion on accuracy and adequacy of methods included and, above all, to urge the need for unification of RF/MW health check protocol on the international level.

The health survey protocol, presented in the following text, was designed within the framework of the ongoing Croatian prospective epidemiological study on health impact of long-term RF/MW occupational exposure. This study is additionally supported by the Concerted Action PL973038 from the European Commission INCO-COPERNICUS Program in Brussels, Belgium.

The survey is aimed at two major goals. The first one is identical to the goal of any health check performed by a physician: to gain the insight into the general status of the examinees. The second, more specific goal, was to sort out the examinees whose findings call for further medical attention, both in terms of more frequent checking of their health status and in terms of more specialised diagnostics to be applied.

The survey includes the following items:

1. standard haematology (*whole blood count*, *differential white blood count;* data on the latter used not only as a haematological parameter, but also as a piece of information substantial for the correct interpretation of cytogenetic tests performed via lymphocyte cell cultures; *coagulogram*)

2. standard biochemistry *(glucose blood level, glucose tolerance test, lipoproteins, cholesterol, triglycerides, iron, UIBC, TIBC, haptoglobin, hepatic enzymes);*
3. estimation of *potassium^{+}, calcium^{+} and sodium^{+} blood levels*;
4. estimation of *catecholamines' blood levels* as well as of the excretion of *vanillylmandelic acid in urine* ;
5. estimation of *serotonin and melatonin blood levels*;
6. standard immunology (*blood levels of immunoglobulin A, M and G*);
7. cardiovascular examinations- *standard clinical examination, ECG, 24-hours Holter monitoring, BP,* peripheral blood flow status (*widefield nail-bed capillaroscopy on both hands);*
8. lung function testing *(FVC, FEV_1)*, standard chest radiography;
9. ophtalmological examinations (*vision, fundus, orthoscopy, applanation tonometry, nictometry*);
10. examination of audition abilities (*tonal audiometry*), equipose tests;
11. EEG;
12. psychological testing;
13. cytogenetic testing (*conventional structural chromosomal aberration analysis*).

Out of the methods listed, technique used for the estimation of morphological and functional status of peripheral blood flow will be further discussed.

Results of other authors (1,2), as well as those of own research (3,4,5), suggest that the pattern and the extend of radiolesions of target tissue depends, among other, upon the perfusion of a target area. A considerable portion of radiation damage is caused not only by changes in hemostasis and neurohumoral regulation of blood flow, but also by the primary lesions of the blood vessel wall, in particular of the endothelial cells.

Capillary system offers the fastest visually accessible response to radiation. The early sign of the exposure is vasodilatation, macroscopically presented as erythema. It is a logical pattern of "self-defence" of an irradiated tissue, aimed at cooling the target area. The skin reaction to irradiation can actually be described as the inflammatory one, presented by the essential characteristics on any inflammatory process : *rubor, calor, dolor, tumor* and *functio laesa.* Therefore, soon after irradiation, oedema of endothelial cells can be noted. The further process of hydroscopic degeneration of endothelocytes can ultimately lead to the complete luminal obturation. In an attempt to restore the damage, reactive proliferation of the endothelial cells is initiated.

In general, endothelial cell cycle has a slow turnover, lasting from 2 months up to 2 years. It appears, however, that there are endothelial cell subpopulations with much shorter cell cycle, i.e. with a much higher proliferation index, which makes endothelium unequally radiosensitive (6). Thermal sensitivity of proliferating endothelial cells is considerably higher than these of the resting ones, which can accelerate and intensify cytocidal radiation impact (7).

A considerable part of radiation damage to the endothelial cells is also attributed to the changes of cytomembrane, the latter being capable of causing even cell death. Necrotic elements are eliminated by desquamation, resulting in the formation of wide interspaces in the endothelial layer as well as in the denudation of a basal layer. Subsequently, capillary vessel wall becomes considerably more permeable than regularly, allowing for plasmatic and sometimes even corpuscular leakage into the interstitium.

At this point, capillaroscopy is the only non-invasive technique enabling direct monitoring of capillary vessels at the accessible localisations, nailfold being thereby used most frequently. Dispite limitations in the scope of the technique, its major advantage is that it allows for the detection of initial changes of the small blood vessels, preceding any clinical expression.

An ordinary capillaroscopic image reveals hairpin-like capillary loops, each consisting of an ascendant, apical and descendent portion, and lying in the nail-bed in the plane form. This plane is almost coinciding with an optical plane of a stereomicroscope, which makes the nail-bed a preferable locus for capillaroscopic examination. Within the standard performance, also oblique collecting veins and subpapillary venous plexus are clearly visible.

Capillaroscopic changes noted in the postirradiation period, follow the above described pattern of events typical for microvascular radiolesion. Therefore, the first change of the capillary shape to be seen in the postexposure period is vasodilatation. In the advanced stage, zones of stenoses of capillary lumen are to be expected. Due to the increased permeability of a capillary vessel wall, plasmatic and corpuscular extravasations can be visualised. Degeneration of an endothelial cytomembrane could account for the presence of fragile capillary structures, visualised as capillarorexies and consequent microhematomas. In the terminal stage, target area becomes avascular and fibrotic, an image described sometimes as a "Moon surface".

According to our own experience (5), capillaroscopy is a method of high sensitivity (95%, respectively), of satisfactory, but less specificity (80%, respectively) and of high positive prediction (86%). However, its scope is limited to an acceptable screening test, since agents other than radiation could provoke similar pattern of reaction of a small blood vessels. Nevertheless, such a diagnostics allows for the detection of initial changes of peripheral blood vessels, making this simple, easy-to-perform method of inestimable value in the preventive medicine.

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Assessment of immunotropic effects of long-term exposure to radiofrequency and microwave radiation.

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Long-term exposure in radiofrequency (RF) and microwave (MW) fields can influence function of the immune system, but the available data on the immunotropic potency of RF/MW radiation are still full of uncertainties and controversies.

Depending on conditions of exposure, frequency and modulation of the radiation, as well as on animal species used in the experiments, various symptoms of either stimulation or inhibition of certain immune reactions have been reported. E.g. Guy et al. (1985) in the life-time exposure of rats to MWs (pulsed 2450 MHz, SAR 0.15-0.4 W/kg) found lowered response of blood lymphocytes to mitogens (phytohaemagglutinin – PHA), while Smialowicz (1984) after exposure at the same wave frequency, although at higher power intensities (SAR 1 – 5 W/kg) reported increased mitogenic response of lymphocytes. In more recent experiments, Veyret et al. (1991) found enhancement or lowering of humoral immune response in mice exposed to 9.4 GHz at SAR 0.015 W/kg, depending on the carrier wave modulation.

Epidemiological investigations of workers exposed to RF/MW radiation did not confirm existence of a measurable shift in the immune status of the investigated populations, despite numerous reports on fragmentaric and/or poorly documented abnormalities in single immune parameters which were found in small groups of RF/MW-exposed workers (e.g. changed number of blood lymphocytes, lowered levels of serum immunoglobulins, weaker response of blood lymphocytes to mitogens).

It has been stressed that in the available literature there exist no reports on complex assessment of function and responsiveness of the immune system, all investigations were aimed to evaluate selected, fragmentaric reaction of the system and/or functional response of immunocompetent cells in RF/MW-exposed subjects. Therefore, at the present state of knowledge it is not possible to conclude about the possible immunotropic potencies of RF/MW radiation, as assessment of the immunotropic potency requires a general insight into the whole complex immune network, taking into advance the immune status of the host prior to the exposure. Modern concepts of human immunity are based on the well established model of the organism which acts as the genetically determined system, supervised and controlled by the neuro-endocrine-immune network. The three systems (neural, endocrine and immune), with their homeostatic regulators (neurotransmitters, neuropeptides, hormones, growth factors, cytokines, lymphokines, angiokines and antibodies) form a self-regulatory model, which uses a joint set of modifying factors (BRM – biological response modifiers) for their proper function and regulation [Besedovsky et al.(1977), Hadden (1987), Deschauxs et al. (1995)]. The above neuro-endocrine-immune network with its BRM-based model of self-regulation opens a new insight into the possible immunotropic potencies of RF/MW radiation. Except of direct influence of the radiation on components of the immune system (e.g. on immunocompetent cells, release of cytokines or monokines by these cells, cell-mediated or humoral reactions), there exists also a possibility of indirect influence on the immune system by RF/MW-induced modifications of functions of the neural and/or endocrine systems. Such possibility should be considered in case of existing data on influence of long-term exposures in relatively weak RF/MW fields on certain brain functions, including abnormalities in EEG records, behavioural effects and/or dysregulation of autonomous neural control of internal organs.

Table I. MICROWAVE RADIATION and the IMMUNE SYSTEM.

Authors	**Effects**	**Exposure conditions**	**Clinical relevance**
Chou, Guy et al.,1985	Slightly lowered mitogenic response of lymphocytes to mitogens (PHA) *in vitro*	Life-time exposure of rats, 2450 MHz, pulsed, SAR 0.15 – 0.4 W/kg	??
Smialowicz, 1984	Increased mitogenic response of lymphocytes to mitogens (PHA) *in vitro*	rats, 2450 MHz, continous and pulsed SAR 1 – 5 W/kg	??
Veyret et al., 1991	Enhancement or lowering of humoral response (antobody levels), depending on modu-lation of carrier wave	mice, 9400 MHz, SAR 0.015 W/kg	??
Stankiewicz et al., 2000	Different response of human lymphocytes to exposures *in vitro* , depending on pulse modulation of the wave	human lymphocytes, 1320 MHz, continous and pulsed (5 μsec), 10 W/m^2) SAR 1 W/kg	??
Several publications (1965 – 1995) from the Soviet Union and East European countries	Reports on fragmentaric and/or poorly documented abnormalities in single para-meters of the immune system: shifts in blood picture; lowered serum Ig levels; weaker response of lym-phocytes to mitogens in microcultures.	Laboratory examina-tions of relatively small groups of workers exposed to RF/MW radiation, frequently without comparison with valid control groups	No evi-dence for exis-tence of shifts in immune status of exposed workers

Efficiency of the immune system, expressed as the immune status, is crucial for development, growth and survival of the organism, including its procreative potency, antiinfective and antineoplastic resistance, supervision of the metabolism, genetically-determined quality of tissues, as well on proper course of regenerative processes. Numerous factors which can modify efficiency of the immune system (enhance or lower), including factors which are able to correct the deficient immune functions, are now recognized as immunotropic factors. Various immunotropic factors with suppressing, stimulating and/or correcting potencies, including pharmacological substances, hormones, antibiotics, stressors and radiations are a subject of extensive experimental and clinical investigations.

All immunocompetent cells originate from haemopoietic stem-cells, although development and differentiation of single types of immunocytes run on various pathways. Most of the effector cells (B lymphocytes, NK cells, K cells, monocytes, macrophages) differentiate in bone marrow and reach full maturity in confrontation with antigenic stimuli in peripheral lymphoidal organs (lymph-nodes, spleen, Peyer nodules) under influence of numerous cytokines, hormones and growth factors. In contrary to the above effector cells, maturity of the multipotential immunoregulatory-effector population of T lymphocytes depends on microenvironmental and hormonal influences of the thymus. Inside of the thymus, in confrontation with a wide exposure to histocompatibility I and II class antigens and in cooperation with numerous thymic hormones and cytokines, undergoes maturation and selection of T lymphocytes. Finally, the immune system receives cells which are able both to recognize tissue signals and to initiate and regulate the proper immune response. The thymus is most active in the early phases of life of the organism, including its foetal and neonatal development, when the immune system is equiped with a population of multipotent T lymphocytes. However, during the whole life, despite of progressive involution of the thymus, this organ still has an ability for temporary enhancement of its hormonal and/or lymphopoietic activity, even at the advanced age, depending on requirements [Bertho et al. (1997)]. Such enhancement of activity of the thymus allows for quantitative and qualitative modification of the population of T lymphocytes and appears to be an important immunotropic factor, resulting in higher efficacy of the whole immune system [Tridente (1985), Clarke et al. (1986),Dabrowski et al. (1990)].

In the available literature there exist no valid informations about the possible influence of RF/MW exposures on function of the thymus and on maturation or selection of T-lymphocytes in this gland. It would be important to know whether or not RF/MW radiation can change the above mentioned ability of the thymus for temporary enhancement of its hormonal and/or lymphopoietic activity in mature organisms and influence the resulting immunotropic effect.

Table II. Main functions and responsibilities of the immune system for homeostasis of the organism.

Type of the immune response	***Function of the immune system***	***Immune cells and transmitters engaged***	***IMMUNOTROPIC factors***
IMMUNE COMPETENCE	Anti-infective, anti-neoplastic RESISTANCE PROCREATIVE potency	phagocytic cells antigen-presen-ting cells (APC) TCD4 effector cells monokines lymphokines	macrophage activators activators of lymphopoiesis and lymphocyte functions thymic extracts
IMMUNO-GENICITY	Supervision of METABOLISM Proper course of REGENERATIVE PROCESSES Supervision of genetically-determined QUALITY OF TISSUES		

The most important phase in the process of maturation of T lymphocytes appears to be rearrangement and transcription of genes (in the 14^{th} and 7^{th} human chromosome) which programmate structure of the glycoproteic heterodimer antigenic receptor TCR [Boehmer (1996)]. The receptor complex TCR/CD3, together with the co-recognizing molecules CD4 and CD8, allows to reach the complex ability of T lymphocytes to recognize clonal antigenic specifity with own antigenic histocompatibility HLA class I (lymphocytes CD8) and class II (CD4). Such receptor complexes allow to differentiate the population of T lymphocytes into inductive-cooperative TCD4 and effector (cytotoxic and suppressive) TCD8 cells. In this order T lymphocytes participate in the sequence of immune response.

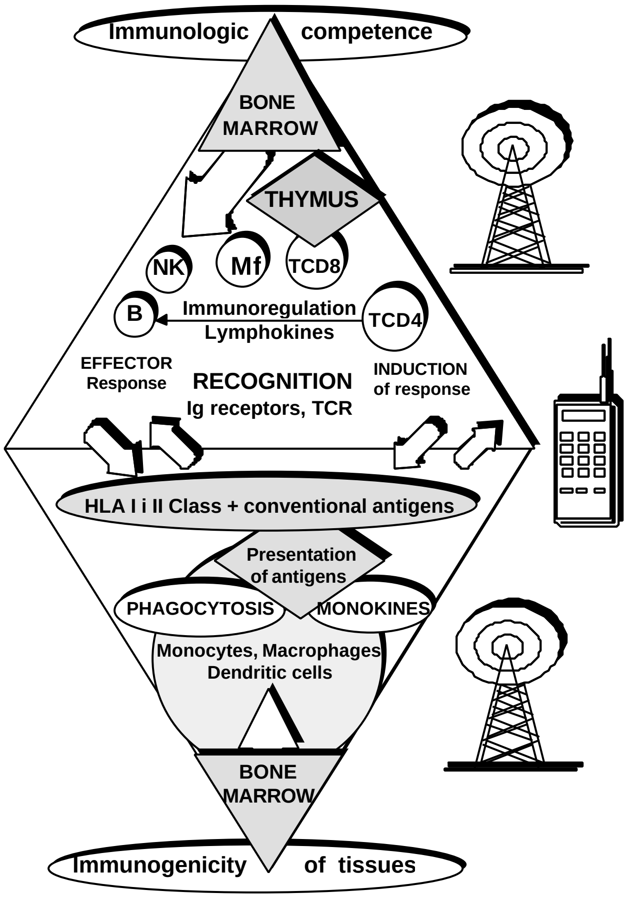

Figure 1

Schematic organisation of the human immune system.
Note matching and cooperation of the two sites of immunity – immunogenicity of tissues and immunologic competence.

Antigen-presenting cells (APC) (monocytes, macrophages, dendritic cells) via expression of HLA II class antigens (sometimes modified by conventional antigens) stimulate for the response the respective TCD4 cell. Depending on its functional fenotype, the inductive-cooperative TCD4 lymphocytes recruit into the chain of immune reaction suitable immunocytes, which determine the type of the response. In general, the lymphokine prophile of Th1 lymphocytes (IL-2, IFN-gamma, TNF-beta, IL-3, GM-CSF, TNF-alfa) stimulates cellular, suppressive and cytotoxic mechanisms of the immune response (e.g. TCD8 cells, NK cells), while humoral response of B lymphocytes is stimulated by Th2 lymphocytes (IL-4, IL-5, IL-6, IL-9, IL-10, IL-13) [Mosman and Sad (1996)].

The effector phase of cell-mediated immune response (TCD8 lymphocytes) is triggered by specific antigenic stimulus, presented in couple with histocompatibility antigens class I (HLA-A, -B, -C). These antigens are a stable element of expression of most of the tissues of the organism. However, development of the effector phase depends on the preceeding inductive phase, which is initiated in specific conditions of tissue injury by presentation of HLA class II antigens by APC to TCD4 cells. Therefore, at the normal immune status there exist no possibility for improperly addressed and/or uncontrolled by TCD4 lymphocytes devlopment of autoaggressive or allergic cell-mediated or humoral reactions [Dalgleish (1986), Dabrowski et al. (1990)].

The above presented multi-step organization model of the immune system is a fenotypic expression of the genetic programm of immunity, which is composed of two complementary parts – the first is responsible for immunogenicity, while the second for recognition and reaction to immunogenic signals. Genes which are responsible for immune response are localized in the 6th chromosome (major histocompatibility complex – MHC) and programmate HLA class I and II antigens. Genes which programmate structures of antigenic receptors of T lymphocytes are localized in the 14th (alpha chain) and 7th (beta and gamma chains) chromosomes. Additionally, genes responsible for immunoglobulins are localized in the 14th (heavy chains), 2nd (light kappa chains) and 22nd (light lambda chains,) chromosomes. Any factors which cause injury of these chromosomes would result in deficient immunogenicity and/or immune competence and in turn, lower considerably the immune status of the organism.

The above described organization and structure of the immune system, with its division into immunogenicity and immune competence and differentiation of the competence from the supervising level of immunoregulatory inductive-cooperative TCD4 lymphocytes, down to a variety of effector cells (TCD8 lymphocytes, B lymphocytes, NK and K cells, monocytes, macrophages, granulocytes, mast cells) allows for localization of abnormalities and/or deficiencies in the system and for assessment of the role of these anomalies for proper function of the whole system and for its efficiency. It is worth to remember that all changes (both positive and negative) which will influence the high levels of the pyramid of immune competence (e.g. function of TCD4 cells) would in turn cause secondary effects at lower levels of the competence (e.g. in TCD8 or NK cells). Therefore, the higher would be localized the target for possible interaction with RF/MW radiation, the more pronounced would be different anomalies and deficiences in the whole immune system. On the other side, direct interactions at the peripheric effector elements of the immune competence would have much weaker consequences for the efficieny of the whole immune system. Additionally, it is worth to remember that functional efficieny of the immune system is not only limited to anti-infective and anti-neoplastic resistance, based on cell-mediated and humoral reactions. Of equal importance in immune response appear to be providing proper tolerance for autologic tissues and neutral external structures, as well as supporting with a variety of cytokines, hormones and growth factors the process of tissue repair and regeneration [Georgiev and Albright (1996), Dabrowski (1998), Schwartz and Cohem (2000)] .

Assessment of the immunotropic potency of RF/MW radiation has to be based on the above presented modern concepts of organization and structure of the immune system and allow for valid determination of the immune status of the exposed host. It has to be taken into advance that both stimulation and inhibition of certain immune reactions can be evoked in RF/MW-exposed subjects and that the final effect may strongly depend on the efficiency of immunity before the exposures. Therefore, it is logical to predict large individual differences (at least in human studies) in response to long-term RF/MW exposures with single subjects who may respond with considerably more pronounced (either positive or negative) shift in efficiency of the immune system that an average value for the whole group. Thus, except of analyzing mean values for the whole investigated groups, it is adviced to search for „exceptional responders” and count the frequency of such responders.

It is proposed to apply two ranges for assessment of the immunotropic potency of RF/MW radiation in investigations of exposed workers – basic (or screening) evaluation of immune status, followed by specialistic immunodiagnostic methods used only in selected subjects.

Basic evaluation of immune status should be based, except of general medical examination and routine laboratory tests, on:

1. Questionnairing (or interview) which includes frequency of infections and use of antibiotics, occurance of allergic symptoms, anaemias, tissue distrophias, autoaggressive diseases, neoplastic diseases and other deficiences of the immune system;
2. Blood picture with differential count of leukocytes;
3. Serum levels of immunoglobulins (IgA, IgG, IgM, IgE);
4. Delayed hypersensitivity to various antigens in skin tests;
5. Quantitative analysis of subpopulations of peripheral blood mononuclear cells (PBMC), including T lymphocytes (TCD4 and TCD8), monocytes (CD14), B-lymphocytes (CD19) and NK cells (CD56).

Specialistic immunodiagnostic methods which allow to diagnose type of immune abnormalities and localize the abnormalities on the scheme of organization and structure of the immune system, should be used only in subjects select from the set of basic evaluation of immune status. These methods include:

1. Neurologic, endocrine, ophtalmologic*, oto-rhinolaryngologic* and haematologic (including bone marrow biopsy) examinations and laboratory tests;
2. Microculture of peripheral blood mononuclear cells (PBMC) with determination of:
3. Spontaneous transformation of lymphocytes in 72-hr culture;
4. Mitogenic response of lymphocytes to phytohaemagglutinin (PHA), concanavalin A (Con-A) and pokeweed mitogen (PWM) or lipopolysaccharide (LPS);
5. Con-A-induced suppressor activity of T lymphocytes (SAT);
6. Lymphocyte-monocyte cooperative index (LM);Saturation of interleukin-2 (IL-2) receptors on T lymphocytes;
7. Activity of monokines (IL-1, IL-1ra) and selected lymphokines (e.g. IL-2, IFN, IL-6, IL-8, IL-10) in culture supernatants;
8. Flow cytometry of peripheral blood mononuclear cells (PBMC) with detailed fenotypic characterization of immucompetent cells;
9. Analysis of cell cycle of stimulated lymphocytes in culture (optional);
10. Immunogenetic investigations (optional).

* Optalmologic and oto-rhilaryngologic examinationations are proposed, because certain dystrophic changes and chronic inflammatory states of the organs of vision and hearing (e.g. chronic conjunctivitis, recurrent keratosis, dystrophia of the optic nerve, some forms of hypacusis, tinnitus, Menier’s syndrome) may result from functional abnormalities of the immune system.

Table III. Assessment of immune status in workers exposed to electromagnetic fields.

Range of assessment	***Methods proposed***
BASIC EVALUATION OF IMMUNE SYSTEM	QUESTIONNAIRING (INTERVIEW) directed to: frequency of infections; use of antibiotics; occurance of allergic symptoms; anaemias; tissue dystrophias; autoaggresive diseases; neoplastic diseases; other deficiences of the immune system. BLOOD PICTURE with DIFFERENTIAL COUNT SERUM LEVELS OF IMMUNOGLOBULINS DELAYED HYPERSENSITIVITY IN SKIN TESTS QUANTITATIVE ANALYSIS OF SUBPOPULATIONS OF PBMC (TCD4, TCD8, CD14, CD19 and CD56).
SPECIALISTIC IMMUNO-DIAGNOSTIC METHODS	Neurologic, endocrine, ophtalmologic and haematologic (with bone marrow biopsy) EXAMINATION and LABORATORY TESTS MICROCULTURE OF PBMC with determination of: • spontaneous transformation of lymphocytes; • mitogenic response of lymphocytes to PHA, Con-A and PWM • Con-A-induced suppressor activity of T cells (SAT); • lymphocyte-monocyte cooperation (LM) • saturation of IL-2 receptors on T cells • activity of monokines (IL-1, IL-1ra) and selected ILs in culture supernatants FLOW CYTOMETRY OF PBMC with detailed fenotypic characterization of immunocomptent cells ANALYSIS OF CELL CYCLE of stimulated lymphocytes (optional) IMMUNOGENETIC INVESTIGATIONS (optional)

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Magnetic Field Exposure of Train Engineers

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Abstract

This study represents one specific objective of the project "Improvement of methods of exposure assessment for MF from electric traction with regard to coronary heart diseases" in the frame of the European INCO-Copernicus Program.

Magnetic fields (MF) on electrified transport systems are generally lower than international limits. However, recent epidemiological studies showed that MF from AC and DC powered transport may be associated with possible health hazards (Balli-Artunes et al., 1990; Floderus et al., 1994; Alfredsson et al., 1996; Ptitsyna et al., 1996; Pfluger et al., 1999; Pfluger et al.).

Epidemiological data on DC powered trains in Russia showed a 2-fold increase in the risk of coronary heart diseases (CHD) in the job category of engineers in electric locomotives (EL), as compared to drivers in electric motor unit trains (EMU). In line with results on Russian engineers, increased risk of myocardial infarction was found among Swiss railway occupations; moreover, engineers of Swiss EL show a tendency of high mortality at early ages (Pfluger et al., 1999; Pfluger et al).

Biological and epidemiological studies evidence that frequency and intensity "windows" MF, interaction with DC-fields and other MF aspects can be important for exposure assessment. (Morgan and Nair, 1992; Valberg, 1995). However there were lack of adequate measurement information and adequate practical methods to describe exposure aspects other than TWA (time weighted average). We developed a set of improved methods, algorithms and software to quantify the following aspects of complex-spectra "real world" MF: variability in different frequency ranges, including DC fields, amplitude-frequency dependence, polarization and intermittency. Necessary measurement information that allows adequate characterization of the above mentioned exposure aspects was received by using a computer-based waveform capture system (sampling rate up to 200 Hz).

We performed measurements in workplaces of engineers on Swiss AC (16.67 Hz) and Russian DC electrical trains. MF in DC and AC trains shows complex combination of static and varying components. We did detailed analysis and comparison of MF spectral characteristics in DC and AC trains in 0-50 Hz range. Exposure comparison show some consistency of the power spectra among MF measured in Swiss and Russian trains in the range 7-15 Hz. Polarization structure of measured MF was defined and quantified. It was also found that intermittency in the scale of units of seconds is a characteristic feature of all kind of trains.

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Do MF fields influence on locomotive engine drivers?

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An increased rate of coronary heart diseases was recently found among Russian engine drivers of electric locomotives (EL). Presumption that this adverse effect might be associated with elevated magnetic field exposure was a starting point of the international project IMMORTALITY. The general goals of the project included monitoring of DC-ELF MF in different types of possible biological responses to specific exposure conditions. The aim of the present study was to investigate possible deviations in basic physiological markers (e.g. heart rate, heart rate variability, blood pressure, EEG, performance of cognitive task) in conditions of whole-body, 30 minutes exposure to combined DC and 12 Hz magnetic fields, emulated EL environment.

Fifteen healthy volunteers participated in experiments. Subjects were informed of project aims and experimental procedure. Each participant was exposed to both real and sham exposures and served as his own control. Consequence of sham and real exposures was randomized, and interval between them was not shorter than 48 hours to exclude possible cumulative effects. Sessions began at 11.00 or 13.30. Experiments took place in the whole-body exposure facility consisted of a system of orthogonal coils with size 3.90x2.25x2.25 m. Signal generators and power amplifiers provided the generation of DC and AC components along fixed orthogonal directions. The following exposure was considered as ”EL” – 12 Hz: 3; 2.5; 2 mT in Z; Y and X axes respectively. DC: linearly polarized (Y-axes) with flux density regularly varied from 40 μT to 20 μT with the intermittance steps 30 μT lasting 90 sec each. Non-energized coils provided sham exposure. Natural non-homogeneity of the earth field did not exceed of 1.5 μT and homogeneity of the generated field did not exceed 10%. Performance of Memory and Attention tasks, blood pressure measurements, heart rate and eight channels EEG records were obtained before, during and after exposures. Dynamic of systolic and diastolic pressure, mean values of heart rate and heart rate variability spectrum, spectral power of alpha, beta, theta, delta bands of EEG, and error rate and reaction time in cognitive performance have been calculated.

Small but significant differences between responses to real and sham exposure was observed in mean values of heart rate during exposure (67.5 vs. 69.7 bpm). This transient effect disappeared after exposure. There were no other exposure-related differences in observed psychophysiological parameters. Data do not conflict with main project hypothesis. However, mor pronounced CNS and ANS ”stress” responses would be expected, in context of possible links between MF exposure and chronic cardiovascular disorders.

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Chromosomal aberrations in peripheral lymphocytes of train engine drivers

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Cytogenetic surveillance of groups of individuals is justified if they are exposed to potential carcinogens and/or mutagens in their work environment. An increased level of chromosomal aberrations has been suggested to predict elevated cancer risk. Studies on Swedish railway employees have indicated that train engine drivers have an increased cancer morbidity and chronic lymphatic leukemia. The drivers are exposed to relatively high magnetic fields, ranging from a few to over a hundred µT, mean values for the working hours being in the range 2-15 µT. In vitro experiments have suggested that MF exposure may cause chromosomal aberrations. To see if MF exposure has a genotoxic effect, we performed a pilot study on 18 nonsmoking male engine drivers. The results showed a significant difference in the number of cells with chromosomal aberrations between the drivers and two control groups, one consisting of dispatchers and the other of office workers. The study has now been expanded to other groups of 30 engine drivers and 30 referents (policemen). We report here results from both the pilot study and the follow-up study.

Methods. The local occupational health units collected blood samples by venipuncture immediately after the work shift. From each sample, two lymphocyte cultures were established within 24 hours. In the pilot study, all slides were analyzed in Umeå, Sweden.
In the follow-up study, a laboratory in Helsinki, Finland scored half of the slides from each subject, while the other half was analyzed in Umeå.

Results

In the pilot study, the mean rate of cells with aberrations (gaps included or excluded) was higher among the engine drivers compared with the reference groups. The difference was statistically significant in comparison with the office workers, the engine drivers having about four times as many cells with chromatid breaks ($p<0.01$) and cells with chromosome breaks as both control groups ($p<0.05$). Of the 18 engine drivers, 14 (78%) showed at least one cell per hundred with chromosome-type aberration compared with two of seven (29%) among he dispatchers and five of sixteen (31%) among the office workers. In the follow-up study, the engine drivers had more cells with chromatid breaks, and chromosome-type breaks and exchanges than the policemen did, but the differences were statistically significant only for chromosome exchanges ($p < 0.05$). Eighteen engine drivers (60%) had two or more cells with chromosome-type aberrations among the analyzed cells compared with nine (30%) of the policemen; the corresponding numbers of subjects with three or more cells with chromosome-type aberrations were 10 and 4, respectively.

Discussion

Both studies showed a significant increase in the number of cells with chromosome aberrations among the engine drivers in comparison with respective reference groups. The pilot study was based on a few individuals and only seven concurrent non-exposed controls (dispatchers), which made the interpretations uncertain. The result of the second study, however, supports the hypothesis that exposure to EMF at mean intensities of 2-15 µT may induce chromosomal damage.

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