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Translation

PROCEDURAL QUESTIONS OF SETTING HEALTH SAFETY STANDARDS FOR ELECTROMAGNETIC RADIO FREQUENCY RADIATIONS

Ed. by

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PROCEDURAL QUESTIONS OF SETTING HEALTH SAFETY STANDARDS FOR ELECTROMAGNETIC RADIO FREQUENCY RADIATIONS

Moscow METODOLOGICHESKIYE VOPROSY GIGIYENICHESKOGO NORMIROVANIYA ELEKTROMAGNITNYKH IZLUCHENIY RADIOCHASTONOGO DIAPAZONA in Russian 1979 pp 2-137

[Collected papers edited by B.M. Savin, Order of the Red Banner of Labor Scientific Research Institute for Labor Health Safety and Occupational Diseases of the USSR Academy of Medical Sciences, Moscow, 1979]

CONTENTS

 [I - USSR - C FOUO]

[Text] Annotation

The collection is primarily intended for scientific workers (physicians, biologists, biophysicists, engineers) engaged in research in the field of nonionizing radiations, in particular, those involved with the development of health safety standards for radio frequency electromagnetic emissions. Along with the history of the field, also treated in the collection is the significance of the problem of setting health safety standards at the present stage of the scientific and engineering revolution; differences in approaches to the evaluation of biological effects are analyzed and procedural approaches to setting health safety standards for radio waves are also substantiated, where these approaches are based on concepts of the threshold nature of the harmful impact of a factor. Considerable attention is devoted to the treatment of experimental, clinical-physiological and public health ("industrial") study data and arguments concerning their significance in substantiating health safety standards.

The materials contained in the collection encompass a broad group of procedural issues and will undoubtedly be of definite interest to persons engaged in setting standards for other unfavorable environmental factors, as well as for instructors in health safety specialty departments and public health physicians and industrial pathologists.

Editorial Staff: *K.V.Nikonova and T.F.Gomberg*

Foreword

When solving any scientic problem, questions of methodology, as is well known, are of primary importance. Just as a thoroughly thought out theory illuminates the path of a scientific search, a refined procedure assures the success of any experimental and theoretical investigation. In this regard, the problem of the biological effect of nonionizing electromagnetic radiations is no exception. Moreover, by virtue of the complexity of the interpretation of various biological, biophysical and physical laws, which govern the final result of an exposure, these questions take on special importance within the framework of the indicated problem.

The collection offered to the readers contains a number of papers devoted to the analysis of procedural questions of setting health safety standards for electromagnetic radiations (EMI) [EMR] at radio frequencies. Reports presented to the All-Union Seminar on "Procedural Questions of Setting Health Safety Standards for Nonionizing Radiations" (Moscow, 1977) were the basis for the collection.

The inadequate level of development of the questions indicated here is one of the leading reasons for the sharp divergence in the values of the maximum permissible levels (PDU) of radio frequency radiations which have been set in various nations.

At the present time, considerable phenomenological material has been accumulated on the biological effect of radio waves. The organs, tissues, and systems which are most sensitive to certain wavelengths have been ascertained. The clinical picture of disorders and lesions which occur in people systematically exposed to high levels of microwave radiations has been described sufficiently completely. Nonetheless, it is impossible not to note that up until recently, research on the problem was conducted primarily with an eye towards accumulating individual facts. The theoretical and procedural aspects of the problem were inadequately developed. It is specifically this which has to a considerable extent determined the occurrence of two fundamentally differing approaches to setting standards for electromagnetic radio frequency radiations, in particular, the substantiation of the ultimate permissible levels of microwave irradiation.

In the majority of western European nations and the U.S., health safety standards are set by working from the concept of a purely thermal mechanism for the action of microwaves, basing the work in this case on the thresholds of damage to so-called critical organs - organs having the lowest level of vascularization and the greatest sensitivity to a temperature elevation (the crystalline lens of the eye, the cornea, testicles, etc.). The values of the ultimate permissible irradiation levels are calculated on the basis of simple thermodynamic computations. It is assumed in this case that the quantity of heat liberated during dielectric heating of tissues should be ten times less than that which the human organism is capable of absorbing in the form of radiative energy without a continuous rise in body temperature. In extrapolating for the entire body surface, this amounts to from 0.1 to 1 KW. Taking into account the indicated values, the maximum permissible level of energy flux density is set equal to 10.000 $\mu W/cm^2$ for any time interval with a duration of six minutes or more.

In contrast to the majority of foreign countries, domestic public health safety standards are based on concepts of the specific "nonthermal" effect of this kind of radiation. Despite the fact that the starting concept for setting these standards is shared by the absolute majority of Soviet researchers, in the question of which shifts in the status of physiological functions of an organism can be treated as an indicator of the harmful effect threshold of radio radiations, the opinions of the researchers diverge. Some authors feel that any reactions of the organism which occur as a response to the action of radio emissions can serve as such an indicator, while others suppose that only reactions of health safety significance are the indicator for the harmful effect threshold of radiations.

A considerable portion of the health safety standards in force in the USSR at the present time was developed more than twenty years ago, when the biological effect of radio waves had just started to be studied, while the principles of setting health safety standards for a factor were extremely poorly developed. The existing standards are in need of substantial corrections and addenda. Undoubtedly, the successful resolution of the problem of making existing standards more precise and incorporating corrections in them is possible only on the basis of the development of a unified procedural approach to the evaluation of the impact of a factor.

In recent years, especially in the field of labor health safety, serious research has been done on the development of the theoretical principles of making the environment a healthy one. One of the leading principles of the theory of the maximum permissible levels for the action of various factors in the environment is the concept of the effective threshold for the appropriate criteria of harmfulness.

As applied to problems of setting standards for radio frequency radiations, the resolution of the issue concerning the evaluation of the importance of the data of special laboratories, clinical physiology and so-called industrial studies is likewise of substantial importance. Numerous public health specialists and industrial pathologists are extremely critical of the possibility of setting the maximum permissible level for radio frequency, expecially microwave radiations, based on the data obtained from studies performed on persons exposed to radiations under industrial conditions, where there can be a successive exposure to various electromagnetic field intensities or even a combination of them with other factors. Industrial studies do not usually allow for a sufficiently precise accounting for the intensity, duration, conditions and other special features of the irradiation, which are of greatest interest from the viewpoint of the problems to be solved. In the literature, attention has already repeatly been devoted to the necessity of an exceptionally careful approach to the utilization of the results of these kinds of studies. Moreover, it is impossible not to note that over the course of a number of years, there has been a trend towards exaggerating their significance, and it is specifically this which has undoubtedly exerted a substantial influence on the specific values of the maximum permissible level of radio frequency radiations.

A detailed treatment of all of the questions enumerated above is given in the first paper of the collection "The Problem of Setting Health Safety Standards for Electromagnetic Radio Frequency Radiations at the Present Stage" (B.M. Savin).

The inadequate state of development of procedural approaches to the health safety evaluation of a factor and the principles of setting the maximum permissible levels is the reason not only for the extremely sharp differences in specific values of the maximum permissible level adopted in various nations, but also for the lack of a logical relationship between public health safety standards set in the USSR for persons professionally exposed to a given factor, as well as the population. It is specifically these questions which are treated in the second paper "The Public Health Safety Substantiation of Approaches to Setting Radio Emissions Standards" (K.V. Nikonova and B.M. Savin). Approaches to establishing the maximum permissible levels which standardize exposure parameters are also analyzed in it, as well as the requirements placed on health safety studies; questions of the biological activity of exposures with various parameters are also treated as well as the selection of health safety margin factors, the extrapolation of experimental data as applied to man and approaches to setting maximum permissible exposures for various irradiation catagories.

By working from the acknowledgement of the leading role of experimental studies in substantiating the maximum permissible levels, it is extremely important to resolve the question of study methods and evaluation criteria for experimental data. The paper of A.G. Subbota and B.A. Chukhlovin is devoted to just this question, in which the considerable personal research experience of the authors is generalized.

Since setting the harmful effect threshold is related to the determination of those exposure parameters for which there is a trend towards a replacement of purely adaptive processes by processes characterized by stress of compensatory functions, the question of evaluation criteria for ascertained changes takes on extremely great significance. The postulate advanced by the authors concerning the "imperfection" of the so-called analytical (the definition of the authors) principle of comparing indicators before and after exposure is to a well-known degree open to question. The latter, as is well known, is widely used in the study of the most diverse environmental factors. It turns out that an important role should also be set aside for this evaluation tecnique in the case of radio frequency electromagnetic radiations. Along with this, considering the poorly pronounced biological activity of a factor, it is impossible not to admit as substantiated the recommendation of the authors as regards the use of functional loads, which make it possible to more successfully ascertain hidden changes which occur. Original approaches to the evaluation of the harmfulness of a factor are treated in the paper, which provides for the study of the impact of electromagnetic radiations on animals which are conditioned beforehand to another factor or which suffer from some kind of illness or artificial breakdown in regulator mechanisms (the synthetic principle).

The paper by a group of authors (T.V. Kalyad, V.M. Nikitin and M.V. Shepelev) is of undoubted interest from the viewpoint of substantiating the significance of various research methods used in setting health safety standards for a factor; the paper is devoted to an analysis of the requirements placed on the performance of physiological studies under industrial conditions, as well as in the laboratory on volunteers. A large set of methods was tested by the authors, at times extremely complex ones, the most informative of which can be selected and recommended for more wide scale application. As the main criterion in the evaluation of the results of studies on people, it is proposed that the criterion of functional accumulation be employed. Considering the importance of cumulative processes, the use of the given indicator is enticing to be sure. Nontheless, if one works from the concepts developed by the authors in accordance with which accumulation is understood to be any changes in the level of functioning of physiological systems, then the indicated proposal raises a definite kind of objection. It turns out that the rearrangement of a level of functioning in general cannot be equated with accumulation. A rearrangement can be of an adaptive nature and directed towards the equalization of external effects, since the development of cumulative processes is evidence of the initial stage of disorders and that the organism is not coping with the load falling on it. From this point of view, the possibility of using such an indicator as accumulation in studies on volunteers is a cause for doubt.

The question of levels of functioning of the physiological systems of an organism requires a special effort at greater precision. How is a new level of functioning to be understood? Any changes in the indicators being studied or which have definite attributes (quantitative or qualitative), which distinguish them from the preceding ones?

Everything that has been said attests to the necessity of further developing the question of evaluation criteria for the results of physiological studies performed on people.

As has already been indicated above, clinical studies are of great importance for more precisely specifying the maximum permissible irradiation level. The priority as regards the detailed investigation of clinical manifestations of radio wave exposures, predominantly in the microwave band, undoubtedly belongs to Soviet authors. It is shown that the most frequent clinical forms of disorders are: vegetative dystonia, and as a special case, neurocirculator dystonia with diverse disorders of central and/or peripheral hemodynamics: neurasthenic and astheno-neurotic syndromes; various degrees of the extent to which vegetative-vascular paroxysms are pronounced, etc. However, more or less satisfactory data on the exposure levels to which these manifestations are related have been lacking up to the present time. Moreover, the majority of researchers in the U.S. and a number of western European nations deny the possibility of unfavorable consequences from electromagnetic radiations in the case of exposure to nonthermal intensities.

The paper of V.G. Artamonava and A.Ye. Vermel' is devoted to the problem of clinical studies in the light of solving questions of setting health safety standards. For the purpose of making the clinical manifestations of electromagnetic radiation phenomena more objective and studying the immediate and remote consequences of exposure to EMR, it is expedient to perform studies in accordance with specially developed programs. In this case, considerable attention should be devoted to the relationship between various changes in the health status of man with irradiation levels. The results of epidemiological studies are of special importance.

Research in subsequent years should lead to the attaining of a greater mutual understanding among scientists working in the problem area and to the elimination of substantial differences both in the treatment of the clinical changes and in the irradiation levels permitted at the present time by the standards of various countries.

In accordance with the wishes of the seminar participants, the remarks of its participants in discussions of the reports, as well as in the overall concluding discussion, have been reflected in the collection (the review paper by I.P. Sokolova and Ye.K. Lebed'). It turns out that the interested reader will become familiar with the opinion of a number of leading specialists in the problem area concerning the individual questions which were touched on.

Also included in the collection in somewhat abbreviated form is a report devoted to methods of study and evaluation criteria for the biological impact of electrical fields at the industrial power frequency (B.M. Savin, M.G. Shandala, K.V. Nikonova and Yu.A. Morozov), presented to the Soviet-American symposium on ultrahigh voltage electrical power transmission (Tashkent, 1978). An attempt was made in the report based on an analysis of existing data to reveal the reasons for the contradictory nature of opinions of Soviet and foreign authors on the question of the biological effect of a factor and procedural questions of performing experimental studies on animals were discussed; the question of interpreting the results obtained and approaches to setting standards for electrical fields at the industrial power frequency for various categories of persons is also treated.

The authors hope that the papers contained in the collection will promote the working out of a single concept of the setting of health safety standards for radio frequency electromagnetic emissions and will gratefully accept all critical remarks and proposals related to the questions under study. They will all be taken into account in compiling the procedural handbook which is planned for publication: "Procedural Recommendations for the Performance of Studies Which Have the Goal of Substantiating the Maximum Permissible Level of Radio Frequency Radiations".

Professor B.M. Savin

THE PROBLEM OF SETTING HEALTH SAFETY STANDARDS FOR RADIO FREQUENCY ELECTROMAGNETIC RADIATIONS AT THE PRESENT STAGE

B.M. Savin

The problem of setting health safety standards for electromagnetic radio frequency fields as a factor in an industrial setting and the residential environment has taken on special urgency in recent years.

The rapid development of radio communications, radar and television has led to the fact that a significant portion of the globe's population has come to be subjected to electromagnetic radio frequency radiations. At the present time, it is difficult to find a sector of the economy or sphere of human activity in which a systematic expansion of the area of application of electromagnetic energy would not be observed to accomplish the most diverse operations, from heating, welding, melting metals, the heat treatment of lumber and plastics to the creation of a high temperature plasma and the use of microwave oscillators in modern computers. The use of electromagnetic energy determines the possibility for creating fundamentally new types of technologies and production processes. It is specifically in this regard in line with the resolutions of the 25th CPSU Congress that an important place has been set aside for the further development of radio electronics and electrical power engineering in improving the technical level of production and providing for qualitative shifts in the development of all sectors of our nation's economy. This leads to an even wider dissemination of radio engineering hardware and electronic instruments, for which even higher powers will be characteristic as well as new frequency bands and generation modes.

To resolve the fuel and energy problem of the European area of the USSR and the Urals, the 10th Five-Year Plan provided for placing long electric power transmission lines at a voltage of up to 1,150 KV in service. This is responsible for the special urgency of questions of studying the biological effect of electrical fields at the industrial power frequency, both from the viewpoint of the influence of a factor on the human organism, as well as on fauna, flora and the ecosystem as a whole. There are all the reasons to assume that in the upcoming 10 to 15 years there will be a further expansion of the number of persons systematically exposed in the process of their work activity to the effect of radio emission levels of health safety significance. Along with those persons professionally involved with sources of electromagnetic radiations, an increasingly greater contigent of nonprofessionals and the populace will be subjected to their effects. In this case, the borderline between professional and nonprofessional radiation levels will be erased to an ever greater extent. Even at the present time, the irradiation levels for persons not involved in servicing radio engineering hardware prove to frequently be higher than the irradiation levels of professionals. The rise in the overall radio background will undoubtedly lead to further leveling of the differences in irradiation levels not only for the indicated two groups of workers, but also for the population. This is responsible for the necessity of a joint developmental effort for questions of industrial and public health safety.

In the situation which has arisen, questions of preventing an unfavorable effect of radio wave emissions take on special significance. It is not accidental that one of the tasks assigned by the 25th CPSU Congress in the field of health safety is the development of new techniques and means of combatting exposures to electrical and magnetic fields and radiations.

The major ways of preventing an unfavorable effect from a given factor are to be considered the development of the maximum permissible level of radio frequency radiations, as well as protective measures which provide for their strict observance. It is specifically the health safety standards which are the basis and the foundation for all preventive, sanitary and environmental protection measures. It was towards this, in particular, that attention was turned at the 38th Session of the USSR Academy of Medical Sciences, devoted to questions of the development of medical science and the practical introduction of its results in the 10th Five-Year Plan in light of the resolutions of the 25th CPSU Congress.

Health safety standards can be treated as an indicator of the status of the development of one public health safety problem or another. And if the specific values of the maximum permissible level are determined, primarily, by the degree of our knowledge of the effect of a particular factor and the level of health standards theory, then the "set" of such standards is an indicator of the extent to which the questions have been worked out from the standpoint of practical interests. In this regard, the history of how the standards adopted at the present time came to be is of definite interest.

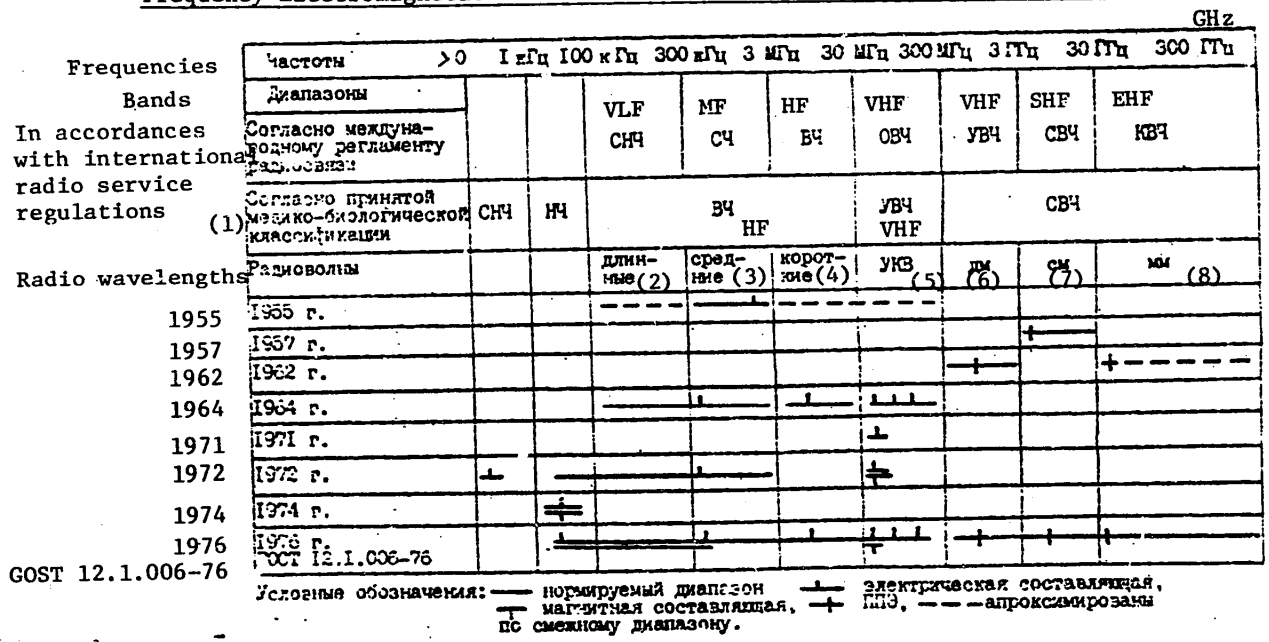
The first temporary standards for electromagnetic radiations in the radio frequency band were adopted more than 20 years ago in our country. It must be noted that during those years, the Soviet Union was the only nation in the world where the level of permissible exposure to a factor was regulated in state policy. The recommended standards encompassed a frequency range from 100 KHz to 300 MHz. In 1957, based on studies performed at the Institute of Occupational Diseases and Labor Health Safety of the USSR Academy of Medical Sciences and the Military Medical Academy imeni S.M. Kirov, standards were set for the centimeter wavelength band (Table 1). In 1962, following a few additional investigations, these standards were approximated for the band of decimeter and millimeter wavelengths. In 1964, the standards were made more precise for the 100 KHz to 300 MHz range and differential maximum permissible levels were established for the following bands: medium and long waves, short waves as well as ultrashort waves.

The maximum permissible level was made more precise in 1971. It dealt with the electrical component for the long and medium wavelength band (100 KHz to 3 MHz), as well as the establishing of differential maximum permissible levels both with respect to the electrical and magnetic components for the initial portion of the VHF band (3250 MHz). Somewhat later, based on proposals of the Khar'kov Institute of Labor Health Safety and Occupational Diseases, the maximum permissible levels were determined for the 60 to 100 KHz band.

The developmental course of the absolute maximum permissible levels for the VHF band over the period from 1955 to 1979 is shown in Table 2.

TABLE 1

Developmental Course of the Setting of Health Safety Standards for Radio Frequency Electromagnetic Radiations in the USSR



Symbols Used: The solid lines indicate the range of frequencies for which the standards are set; An upward vertical line from the solid line indicates the electrical component; A downward vertical line indicates the magnetic component; A vertical line crossing the horizontal solid line indicates the energy flux density and the dashed lines apply to approximate data based on the adjacent frequency band.

Key: 1. In accordance the adopted medical and biological classification;
2. Long waves; 3. Medium waves; 4. Short waves; 5. VHF;
6. Decimeter waves; 7. Centimeter waves; 8. Millimeter waves.

TABLE 2

Values of the Maximum Permissible Level of VHF Radiations in the Period from 1955 through 1979

Years			
1955	1964	1972	1979
30--300 MHz	30--300 MHz	30--50 MHz	30--50 MHz
5--10 V/m	5 V/m	10 V/m; 0.3 A/m	10 V /m; 0.3 A/m
		50--300 MHz	50--300 MHz
		5 V/m	5 V/m

It follows from the data in the table that over the indicated period (24 years) practically no significant changes took place in the values of the established maximum permissible levels.

The same thing occured with the standards set for microwave band radio emissions (Table 3). Approved for the first time in 1957, they practically did not change over this period of time. Only in later years were they made slightly more precise with corrections which involved the use of the indicated standards for the periodic irradiation of personnel from scanning antennas and the case of the combined effect of microwaves and soft X-ray radiation and a high ambient temperature.

In 1976, all of the maximum permissible levels which had been worked out beforehand were incorporated in GOST 12.1.006-76: "SSBT, Electromagnetic Radio Frequency Fields. General safety requirements", implemented beginning 1 January, 1977.

The establishing of regulations for the maximum permissible electromagnetic radiations in the radio frequency band has played an important part in improving the work health safety conditions for persons working with radio wave sources in various sectors of the economy. Their implementation promoted the elimination of cases of occupational pathology related to exposure to a factor. However, the standards in force at the present time are in need of further refinement and need to be made more precise. The majority of the established maximum permissible levels was recommended during those years where the biological impact of EMR had just started to be studied, because of which, the question of adequate models and principles for extrapolating experimental data from animals to man was extremely poorly worked out. Technical progress led to the introduction of new frequency bands and new radiation modes into the national economy, for which the existing standards were not designed.

The constancy of the health safety standards noted above could be due to one of the following circumstances: either the fact that the proposed maximum permissible levels were distinguished from the very start by a high degree of precision, or by

TABLE 3

Values of the Maximum Permissible Level of Microwave Radiations in the Period from 1957 through 1979

Nature of the Exposure	Years					
	1957	1962	1972	1975	1979	1979*
Continuous	3 -- 30 GHz 10 μW/cm^2 for 8 hr 100 W/cm^2 for 2 hr 1000 μW/cm^2 for 20 min	0.3--300 GHz 10 μW/cm^2 for 8 hr 100 W/cm^2 for 2 hr 1000 μW/cm^2 for 20 min	0.3--300 GHz 10 μW/cm^2 for 8 hr 100 W/cm^2 for 2 hr 1000 μW/cm^2 for 20 min	0.3--300 GHz 10 μW/cm^2 for 8 hr 100 W/cm^2 for 2 hr 1000 μW/cm^2 for 20 min	0.3--300 GHz 10 μW/cm^2 for 8 hr 100 W/cm^2 for 2 hr 1000 μW/cm^2 for 20 min	0.3--300 GHz Permissible exposure time to the field is found from the formula: T_{hr} = = D_s/P, where T_{hr} is the time in hr, D_s is the set standard dose equal to 200 μW·hr/cm^2; P = energy flux density $\leq$ 1000 μW/cm^2.
Periodic from Scanning Antennas				100 μW/cm^2 for 8 hr 1000 μW/cm^2 for 2 hr	100 μW/cm^2 for 8 hr 1000 μW/cm^2 for 2 hr	$T_{hr} = D_s/P$, where: D_s=2000 μW· hr/cm^2; $P \leq 1000$ μW/cm^2
Combined with X-ray Exposure and a High Air Temperature			10 μW/cm^2 for 8 hr 100 μW/cm^2 for 2 hr	10 μW/cm^2 for 8 hr 100 μW/cm^2 for 2 hr	10 μW/cm^2 for 8 hr 100 μW/cm^2 for 2 hr	$T_{hr} = D_s/P$, where: D_s = 200 μW· hr/cm^2; $P \leq 100$ μW/cm^2.

*Proposals for the revision of State Standard GOST 12.1.006-76.

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the fact that their further improvement did not receive the requisite attention, or finally, by the fact that the possibility of successfully resolving the indicated question was made sharply difficult by virtue of a number of factors of a medical, biological and technical nature. Just the fact alone that unified maximum permissible levels were established for extremely wide frequency band, the edge portions of which have pronounced differences in their biological effect, places the rightfulness of the first of the propositions presented above in doubt. For individual portions of a band, in particular, from 30 to 300 GHz, the standards were experimentally worked out to an insufficient degree and were essentially extrapolated from the adjacent band. Moreover, while centimeter and especially decimeter band radiations can reach vitally important organs in penetrating deep into tissue, millimeter band emissions are practically completely absorbed in the surface layers of the skin.

For the frequency bands from 1.5 to 30 MHz and from 50 to 300 MHz, the standards for which should be set with respect to both the magnetic and the electrical components, standards have been set only for the electrical component. Along with this, it has been found in recent years that in the case of large dimensions of a biological object, the energy contribution of the magnetic field component in the HF and VHF bands can be significantly greater than the energy contribution of the electrical component of the field [1]. The amount of energy absorbtion by a body which is due to the H field increases in proportion to the square of its linear dimensions. The latter leads to substantial differences in the amounts of magnetic field energy absorbtion by the body of man and small animals. Depending on the frequency band, other parameters of the external field being the same, the differences in the energy absorbtion by biological objects of different geometric dimensions can reach one, two and sometimes even higher orders of magnitude. Thus, while in the microwave band (above 300 MHz) the average and maximum specific absorbed power in a human body is usually 2 to 15 times less than in the bodies of small laboratory animals (rabbits, rats, mice), in the region of lower frequencies (less than 100 MHz) the inverse relationships are observed: a human body interacts with an external field some 5 to 30 times more than the bodies of small animals [2]. Moreover, these differences in the specific features of electromagnetic field energy absorbtion were not taken into account when substantiating health safety standards, although a significant portion of the maximum permissible level was established on the basis of experiments performed specifically on small laboratory animals.

It must also be noted that with the exception of the microwave band, the maximum permissible levels are not differentiated with respect to time, so that unjustified difficulties are frequently created in their realization under industrial conditions. However, even for this band of frequencies, the established maximum permissible levels are to a certain extent in contradiction with the general biological laws governing the response of an organism to such exposure. It is not difficult to convince oneself of this with a comparison of the permissible standards for the energy relationships at various exposure intensities and durations. Thus, in the case of an eight-hour exposure to an electromagnetic field, a value of 10 $\mu W/cm^2$ has been set as the maximum value of the energy flux density; for a two-hour exposure it is 100 $\mu W/cm^2$; and for 20 minutes it is 1000 $\mu W/cm^2$. It is not difficult to calculate that the amount of incident energy will be

4,800 μW·min/cm^2 in the first case (10 μW/cm^2 x 8 x 60 min); in the second case it is 12,000 μW·min/cm^2 (100 μW/cm^2 x 2 x 60 min), and in the third case, 20,000 μW·min/cm^2 (100 μW/cm^2 x 20 min).

Thus, the permissible energy exposure levels are not equal for the various energy flux densities. Moreover, simultaneously with the increase in the value of the energy flux density (an increase in the intensity of the effective factor), the standard norms permit an increase in the total amount of incident energy, and consequently, also in the absorbed energy. The contradiction cited above is especially clearly manifest in the "Public Health Norms and Rules when Working with Sources of High, Ultrahigh and Superhigh Frequency Electromagnetic Fields", No. 848-70, which permitted the sequential exposure of workers to two levels of electromagnetic flux densities: 10 μW/cm^2 and 100 μW/cm^2 and 10 μW/cm^2 and 1000 μW/cm^2. In the latter case, the total amount of incident microwave energy on a man during the course of a working day could reach 24,600 μW·min/cm^2, which is 50 times greater than the amount of energy permitted in the case of exposure to a field with an energy flux density of 10 μW/cm^2.

It must be noted that this same document sets the ultimate value of the energy flux density for the populace at 1 μW/cm^2. It is easy to compute that the permitted amount of incident energy should not exceed 1,440 μW·min/cm^2 in this case over the course of a 24-hour day, and 480 μW·min/cm^2 over 8 hours, which is more than 50 times lower than is permitted for persons working professionally with the given factor. For none of the factors for which standards are set is there such significant differences in the maximum permissible levels established for workers and the population.

Although GOST 12.1.006-76 "SSBT. Electromagnetic Radio Frequency Fields. General Safety Requirements" also does not provide for a variant of sequential exposure of workers at different field intensities, nonetheless it is not free of substantial contradictions as regards the quantities of permitted energy for various worker exposure times in a microwave field.

Finally, it must be noted that some of the established maximum permissible levels differ from foreign values by a factor of 1000 or more (Table 4). It is hardly necessary to prove that with all of their strictness in precluding the possibility of damaging the health of man, the maximum permissible level should not be unjustifiably stringent, since meeting them will entail unjustified economic expenditures to implement protective measures and can be a break to further technical progress.

The development of the international ties, which is accompanied by an ever wider exchange of various equipment, including generators of electromagnetic radio frequency emissions, is responsible for the special urgency of bringing the health safety standards closer together. The effective utilization of such equipment is possible only under the condition that there are maximum permissible levels of electromagnetic radiations as well as methods of evaluating and measuring them which are close in value. This kind of standardization becomes vitally essential, primarily for states which are members of the CEMA.

TABLE 4

Comparative Characteristics of Microwave Exposure Levels Permitted in Various Countries

Country	Frequency Band, GHz	Nature of the Irradiation	Maximum Permissible Level
USSR GDR Bulgarian People's Republic	0.3--300	Continuous	10 μW/cm^2 for 8 hours 100 μW/cm^2 for 2 hours 1000 μW/cm^2 for 20 minutes
		Intermittent	100 μW/cm^2 for 8 hours 1000 μW/cm^2 for 2 hours
Czecho-slovakian SSR	0.3--300	Continuous Pulsed	200 μW/cm^2·hr 80 μW/cm^2·hr
Polish People's Republic	0.3--300	Continuous	10 μW/cm^2 for an unlimited time 200 μW/cm^2 for 8 hours from 200 μW/cm^2 to 10 mW/cm^2: $T(hr)=32/(W/m^2)^2$
		Intermittent	100 μW/cm^2 for an unlimited time 1000 μW/cm^2 for 8 hours from 1000 μW/cm^2 to 10 mW/cm^2: $T(hr)=800/(W/m^2)^2$
U.S.	0.01--100	Any	10 mW/cm^2 for an unlimited time
Holland	0.3--300		for intensities above 10 mW/cm^2, a dose equal to 1 mW/cm^2·hr every 0.1 hr
England FRG France	0.3--300	Any	10 mW/cm^2 for an unlimited time
Canada	0.3--300	Any	10 mW/cm^2 for an unlimited time At intensities of from 10 mW/cm^2 to 100 mW/cm^2: $T(min)=6000/(mW/cm^2)^2$

What has been said fully applies not only to the hardware used in various sectors of the economy, but also to various radio engineering facilities such as radio and television stations, radar complexes, as well as high voltage power transmission lines. If for our country with its enormous territory, the question of the placement of radio engineering facilities is already becoming quite acute, then it is completely understandable how acute it is in those countries where the population density is high while the territory is limited.

It would be erroneous to assume that the drawbacks cited above in the field of setting health safety standards for radio frequency electromagnetic emissions were the result of a lack of the necessary attention to the indicated problem. An analysis of the subject area being worked on by the corresponding scientific staffs, just as the publications, gives evidence to the contrary. The situation which has arisen is due primarily to the underestimation of the significance of the theory of setting public health safety standards for nonionizing radiations, in particular, questions of methodology. The latter has been reflected in the lack of unified criteria for the estimation of biological effects of radio wave exposures, in the insufficiently correct evaluation of the specific significance of the data of experimental, clinical physiological and public health research in substantiating the maximum permissible levels, as well as in the inadequate level of development of the principles of extrapolating the data obtained in animal experiments to humans.

The principle of quantizing portions of the electromagnetic radio frequency emission spectrum from the standpoint of establishing the appropriate maximum permissible levels and the principle of evaluating the biological effects of radio wave exposures from the viewpoint of their health safety significance are of special importance in the entire broad group of questions related to the scientific substantiation of health safety standards for radio wave exposures. As far as the first question is concerned, it must be pointed out that the basis adopted at the present time for the partitioning of electromagnetic radio frequency radiations into standard sections is essentially a technical classification, which is close in prinicple to the classification structure of radio frequencies provided by the international radio communications regulations (Tables 5 and 6). In both classifications, each of the bands differs from the preceding one by an order of magnitude. From the viewpoint of engineering, this principle is of undoubted advantage, however, from medical, biological and health safety standpoints, it cannot be considered a reasonable one. Apparently, a more substantiated classification from the viewpoint of problems of setting health safety standards for electromagnetic radiations is one in which the basis would be the fundamental laws governing the interaction of electromagnetic radiations with a human body. In particular, if one bases the work on a purely power engineering approach to the evaluation of the influence of electromagnetic radiations, assuming that in the final analysis the biological effect is governed by the amount of absorbed energy and the specific features of its spatial distribution in various regions and structures of the body, it is an undoubted fact that the quantization of the bands should be realized primarily on the basis of the relevant indicators. The latter according to the data of biological radiometrological studies, are determined to a considerable extent by the ratio of the dimensions of the biological object and the wavelength of the incident radiation.

The results of the research which has been done provide a basis for assuming that from the standpoint of the specific features of electromagnetic field energy absorbtion, the entire spectrum of electromagnetic radio frequency emissions can expediently be subdivided into three sections or regions, for which the standard setting methodology and principles should differ substantially. Electromagnetic emissions at a wavelength considerably greater than the linear dimensions of a biological object should be included in the first; those with dimensions considerably less in the second, and in the third, those with a wavelength commensurate

TABLE 5. Classification of Radio Frequencies According to International Radio Communications Regulations

Bands	Low Frequencies (LF)	Medium Frequencies (MF)	High Frequencies (HF)	Very High Frequencies (VHF)	Ultrahigh Frequencies (UHF)	Superhigh Frequencies (SHF)	Extremely High Frequencies (EHF)
Frequencies	100-300 KHz	300 KHz-3 MHz	3-30 MHz	30-300 MHz	300 MHz-3 GHz	3-30 GHz	30-300 GHz
Waves	Kilometer	Hectometer	Decameter	Meter	Decimeter	Centimeter	Millimeter
Wavelengths	3 - 1 km	1 km - 100 m	100 m - 10 m	10 m - 1 m	1 m - 1 dm	1 dm - 1 cm	1 cm - 1 mm

TABLE 6. Classification of Radio Frequencies Used in Medical and Biological Research

Bands	Super Low Frequencies (SLF)	Low Frequencies (LF)	High Frequencies (HF)			Ultrahigh frequencies (UVCh) [VHF]	Superhigh frequencies (SHF)		
Frequencies	< 1 KHz	> 1 KHz - 100 KHz	> 100 KHz - 30 MHz			> 30 MHz - 300 MHz	> 300 MHz - 300 GHz		
Waves	Superlong		Long	Medium	Short	Ultrashort (Meter)	Decimeter	Centimeter	Millimeter
							Microwaves		
Wavelengths	> 300 km	< 300km-3 km	<3 km-1 km	<1 km-100 m	<100 m-10 m	< 10 m - 1 m	<1 m-10 cm	<10 cm-1 cm	<1 cm-1 mm

with the dimensions of a body or its individual parts. As applied to man, the corresponding frequency regions are: for the first, $\leq$ 30 MHz, for the second, $\geq$ 10,000 MHz and for the third, 30 to 10,000 MHz. Characteristic of the first region is the fact that the energy absorption level, and consequently the specific absorbed power falls off rapidly with a reduction in frequency, approximately proportionally to the square of the frequency. A distinctive feature of the second frequency range is the very rapid attenuation of electromagnetic radiation energy when penetrating into tissue. In this frequency range, practically all of the EMR energy is absorbed in the surface layers of biological structures. The specific absorbed energy in the skin does not depend on the shape or dimensions of the irradiated object. For the third range, which is intermediate in terms of the frequency, a characteristic feature is the existence of a number of absorption maxima, where a body seems to draw a field into itself and absorb more energy than arrives at its cross-section. In this case, interference phenomena are sharply pronounced, which lead to a sharp dependence of both the overall absorption and the distribution of the absorbed energy on the specific values of the wavelenths, dimensions and anatomical structure of the organs and electrical properties of the tissues.

Unfortunately, up to the present time, the specific features of electromagnetic field energy absorption and distribution considered above have not been reflected to the requisite extent in the practice of setting health safety standards, in particular, when extrapolating experimental research data from animals to man. This is related to a considerable extent both to the inadequate amount of study of the problem and to serious procedural difficulties in estimating electromagnetic field energy absorption and distribution in biological objects.

In light of modern concepts of the possibility of the specific effect of electromagnetic radiations on an organism, it would apparently be incorrect to approach the substantiation of the maximum permissible levels exclusively from power engineering viewpoints, it must nonetheless be supposed that the considerations treated above are to be taken into account when developing the appropriate health safety standards.

In dealing with the question of evaluating the biological effects of radio frequency exposures from the viewpoint of their health safety significance, it must be underscored that considerable phenomenological material has been accumulated at the present time, which attests to the great diversity of the responses of the organism to radio wave exposures. The biological effects occurring in this case can be manifest in the most diverse forms: from barely perceptible functional shifts which fall within the range of the resolving power of existing methods of investigation up to clearly pronounced morphological disturbances which attest to the development of an explicit pathology. While as far as organic disturbances are concerned there are no differences in their analysis, and they are treated by all researchers as a manifestation of radio frequency insults, as regards the evaluation of biological effects which are manifest in the form of shifts in the functional status of particular systems, much yet continues to remain debatable. Some authors consider it possible to view any reactions of an organism in response to radio frequency exposures as an indicator of their unfavorable effect and to treat them as being of health safety significance [3], while other consider it essential to differentiate the reactions occurring in this case into two independent groups: those reflecting manifestations of radio frequency sensitivity and those characterizing the development of radio frequency damage [4].

The specific features of the treatment of reactions considered above are determined not so much by differences in the mechanism of radio radiation action, as much as they are by differences in the methodological approach to the evaluation of the action of a factor. The latter have a fundamental influence on the contents embodied in the concept "harmful action threshold", which, as is well known, is the basis for the entire system of setting health safety standards [5].

Depending on the approach employed, the specific values of the maximum permissible levels vary significantly, and the differences between them can reach several orders of magnitude. It is specifically these questions which must be dealt with in more detail, since they are specifically the ones of fundamental importance in resolving questions of setting standards.

When evaluating the biological effects of radio frequency emissions, it is essential to take into account both the specific features of a given factor and the overall biological laws governing organism response to the action of various stimuli.

As is well known, the basis for any biological reactions related to the action of external stimuli is the property of everything living: irritability. This property is manifest with the action of a particular factor in the occurrence, amplification or attenuation of its activity, or in a structural change. The extent to which these reactions are pronounced can vary in the widest possible limits. It must be noted that the reactions themselves occur when the stimuli reach definite intensities, which characterize the sensitivity threshold of a particular biostructure. The sensitivity thresholds of various biostructures to exposure to specific stimuli differ substantially. Their absolute value depends not only on the biological features and functional status of the biostructures, but also on the physical properties of the stimulus, the time that it acts and the rate of rise. The threshold intensity as a function of the exposure time to a stimulus is characterized by a hyperbolic type curve and is expressed by the empirical formula:

$$J = (a/t) + b,$$

where: J is the threshold intensity of the stimulus;
t is the time that its acts;
a is a constant determined by the properties of the tissues;
b is the threshold for the case of unlimited exposure to the stimulus.

The dependence of thresholds on the rate of rise of a stimulus is expressed by an exponential curve, which reflects the development of the accomodation processes.

At the present time, considerable experimental material has been accumulated which attests to the fact that the extent to which biological reactions are pronounced with the action of radio frequency emissions obeys the laws described above [6]. It is specifically this which provides a basis for treating many biological effects of radio wave exposure as a manifestation of radio wave sensitivity.

Treating the latter as a manifestation of irritability, it is necessary to study in somewhat more detail the physiological evaluation of radio frequency radiations as a stimulus. There is no doubt at all that the given irritant belongs among the group of physical stimuli. A more complex issue is the resolution of the question of its adequacy. If we work from the definition adopted in physiology, in accordance with which all stimuli are included among the adequate ones which, first of all, act on a given biological structure under natural conditions and secondly, for the perception of which the structure is specially adapted, and thirdly, the sensitivity to which is extremely high in the structure, then there are a number of reasons for treating a rather wide spectral range of radio frequencies as an adequate stimulus, or one close to it.

Under the usual conditions of their existence, the organisms of animals and man are constantly subjected to radio frequency emissions of a rather wide frequency range. It is known that a considerable portion of the so-called natural electromagnetic radiation spectrum, which is one of the constant factors in the environment, is composed of radio frequency emissions. They are comprised of the radio emissions of terrestrial, solar and galactic origin. While the intensity of the latter is low, the intensity of the radiations related to processes occurring in the earth's atmosphere, especially during thunderstorm activity, is quite significant: it can reach hundreds of volts per meter, while the frequency characteristics of these radiations fall in a range from 10 Hz to 10 MHz [7].

A rather wide range of electromagnetic emission frequencies is of solar origin. The earth's atmosphere is a comparatively weak absorber of electromagnetic radiations at a wavelength of from 1 cm to 30 - 35 m. The level of radio emissions related to processes occurring on the sun can exceed the natural radio background level by tens, hundreds and even thousands of times. Thus, in the process of evolutionary development, every living thing has constantly come up against the action of these kinds of radiations.

At the present time, considerable experimental material has been accumulated which argues in favor of the fact that the natural electromagnetic background has exerted a definite influence on the development and vital activity of organisms, and that organisms use natural electromagnetic radiations as a source of information which provides for a continuous interaction with the changing conditions in the environment.

Research results give evidence that the most diverse organisms, starting with single cells and ending with man exhibit an exceptionally high sensitivity to electrical and magnetic fields, the parameters of which are close to the natural parameters of the fields of the biosphere [8].

Various reactions occur in an organism with the actions of electromagnetic fields of hundreds of thousands and even millions of times weaker than would be anticipated if one worked from the concepts of a purely power engineering character for the biological effects. The biological effects of weak electromagnetic fields which are unexplanable from the standpoint of purely energy interactions with the matter of living tissues can be understood from the viewpoint of their perception by receptor systems, which in contrast to technical sensors, which transform energy, react to a stimulus only as a starting mechanism.

The data of comparative anatomy and physiology attest to the fact that many organisms have special systems (structures) adapted for the perception of electromagnetic fields in the radio frequency range [9]. Their sensitivity to radio frequency exposures is not inferior to the sensitivity of other perception systems with respect to the action of adequate stimuli.

Many biological objects (fish, birds, insects) have well developed structural and functional electromagnetic reception mechanisms, the sensitivity of which to electromagnetic fields is exceptionally high. Thus, for example, the electrical receptors of fish react to low frequency electromagnetic fields with an intensity of 10^{-6} V/m, and to high frequency fields with an intensity on the order of $4 \cdot 10^{-1}$ V/m [10].

By working from the experimental data on the perception of electromagnetic fields by animals, it can be supposed that they are represented to some extent in man also. Evidence in favor of this, in particular, comes from the results of investigations related to working out the conditional reflexes with the action of extremely weak magnetic fields and electromagnetic radiations [8], as well as data on the change in membrane permeability with exposure to an electromagnetic field. As is well known, all receptor processes, regardless of which stimulus (or factor) action determines them, are manifest as a change in the plasmatic membrane permeability of the receptor. The absence of subjective perception of radio frequency emissions cannot serve as proof of the lack of reception. All interoception is essentially undisputable.

However, it must be noted that biological structures experience the influence of radio frequency electromagnetic fields not only from the environment, but also those of "somatic" origin, i.e. not only those of an exogenic nature, but also endogenic. In the life activity process in all cells, organs and tissues, electromagnetic fields constantly arise, the frequency spectrum of which, according to modern data, is rather wide and runs from fractions of a Hz up to a hundred kilohertz [11]. These fields are apparently completely adequate for nerve structures. Thus, under natural conditions, biological structures constantly experience the action of electromagnetic radiations, the frequency spectrum of which encompasses practically the entire range of radio wavelengths: from extremely long to microwaves; an exception is only the EHF frequencies - the range of millimeter wavelengths.

If one agrees that radio frequency electromagnetic radiations cannot be treated as a factor which by its nature is unusual for an organism, but are a stimulus which is to a known extent even adequate (with the exception of their coherency), then it must be admitted that it would be erroneous to treat any reactions of an organism which occur as a response to exposure to this stimulus as a manifestion of disturbances in organism activity.

The action of various environmental factors - light, sound, vibrations, accelerations, high and low temperatures, changes in the gas medium - result in extremely diverse reactions of an organism. However, up to a definite stimuli intensity level, these reactions are not treated as a manifestation of pathology. Thus, a change in the position of the body relative to the gravitational field vector, a drop in the partial pressure of oxygen when going up in altitude, a change in the temperature of the environment or atmospheric ion composition all lead to the appearance of an entire set of reactions: a change in the rate and depth of respiration, the hemodynamic or heat exchange status, etc. However, if the issue is not one of a sharply pronounced oxygen deficit or significant changes in the ambient temperature, then all of the indicated changes disappear comparatively rapidly following the cessation of exposure to the factor, something which provides a basis for treating them as a purely physiological phenomenon of an adaptive and compensatory nature.

The accumulated experimental materials make it possible to treat many biological effects of radio wave exposure specifically as a manifestation of irritability, and not as a consequence of the development of pathological processes. It must be noted that a significant portion of effects of a physiotherapeutic nature is due specifically to these kinds of reactions. Apparently, we would be making a definite methodological error if we did not attempt to differentiate these reactions from reactions which are characterized by the development of radio frequency damage. Of course this can be done only with a solid scientific foundation for the relevant criteria.

It is well known how considerable the differences are in the levels of light energy which cause visual perception and which lead to damage to the retina. Under the most favorable conditions for light perception (with maximum eye adaptation to darkness), the sensitivity of the eye is close to the physically ultimate sensitivity and amounts to about $1 \cdot 10^{-10} - 1 \cdot 10^{-11}$ erg/sec. Damage occurs to the retina though when exposed to light having an energy on the order of $4.18 \cdot 10^{6}$ erg/sec. Thus, the range of light intensities perceived by the eye is on the order of 150 dB. The same governing laws are preserved as regards the action of other stimuli. Thus, the difference in perception thresholds and pain thresholds with the action of mechanical stimuli is about 160 dB. The range of adaptive perception of sound stimuli is about 120 to 140 dB.

Thus, the ranges of various stimuli intensities which fall within the zone of adaptive perception, fall well outside the limits of 100 dB.

The shifts in the functional status which occur in the range of intensities indicated here, both within the bounds of the revelant afferent system and in other systems of an organism are to be treated as a manifestation of organism sensitivity to the given stimulus. A characteristic feature of the reactions occurring in this case is their rapid normalization following the cessation of stimulus action, the lack of cumulative effects as well as the development of accomodation phenomena in the corresponding receptor apparatus. It is specifically these kinds of effects which we frequently come up against when dealing with exposure to low level electromagnetic radiations.

The boundaries of the range of adaptive perception of radio wave radiations, just as for other stimuli, are determined on one hand by the radio frequency sensitivity threshold of the corresponding perception systems, and on the other, by the damage thresholds of individual biological structures.

For some biological structures having a low sensitivity to a given type of exposure, the radio frequency sensitivity and radio frequency damage thresholds can coincide, as a result of which, there can be practically no region of adaptive perception of radio frequency emissions. Along with this, it can prove to be quite considerable for structures which have an extremely low irritation threshold.

Based on what has been presented, the entire spectrum of radio frequency emission intensities can be broken down into three ranges: the subthreshold range, the adaptive perception range and the damage range.

In turn, the adaptive perception range is to be subdivided into three regions: the indifferent region, the region of active adaptation and the region of extreme exposures. The first of them borders the subthreshold range (their separation boundary is the threshold of radio wave sensitivity), and the third borders the damage.

Characteristic of the indifferent adaptive perception region is the occurrence of minimal functional changes which do not go beyond the limits of physiological norms and which take place rapidly both during the immediate aftereffect period and in the process of the exposure itself. Characteristic of the active adaptation region is the great extent to which the reactions are pronounced and the fact that they are sustained both during the exposure and during the immediate aftereffect period. A distinctive feature of the region of extreme exposures is the diversity of reactions, the preservation of functional changes for and extended time as well as the development of phenomena of a cumulative nature.

Working from the principles of setting health safety standards for unfavorable factors of the industrial environment which have been adopted in the USSR, in accordance with which the primary importance is attributed to pronounced functional changes in determing a harmful action, the threshold of harmful exposure falls at the boundary separating the region of active adaptation and extreme exposures. It can be characterized as that combination of standardized parameters for which changes occur in an organism which are characterized by the presence of one or a set of the following attributes:

--A qualitative realignment of the course of vital processes;

--Any quantitative changes in the status of vital processes which go beyond the limits of fluctuations in the physiological norm, corresponding to the specific vital activity conditions, and cause a reduction in the capability of an organism of realizing normal compensatory functions normal for its volume to equalize the unfavorable effect of other environmental factors or unusual psychophysiological states;

--The development of phenomena of summing the preceding exposure effects, which have the nature of cumulative ones and which lead in the case of long term exposure to the development of shifts in the status of vital processes which go beyond the limits of their permissible quantitative changes.

If one agrees with the given definition for a harmful exposure threshold, then it must be admitted that some of the established maximum permissible levels are undoubtedly too low. Moreover, if overstating the maximum permissible level conceals the danger of damage, then their unjustified stringency entails a completely unsubstantiated expenditure of funds to implement protective measures in addition to blunting the vigilance of medical workers.

The theoretical basis for setting health safety standards for radio frequency electromagnetic radiations today should be the radiobiology of nonionizing radiations, which at the present times is already an independent field of knowledge, formed at the interface of two scientific disciplines: biology and radioelectronics. Its task includes establishing the laws governing the response of living systems (at various levels of their organization: cellular, systemic, organismic) to the action of electromagnetic radiations - from quasistatic to coherent optical band radiations. The following should be cited as independent areas in it: the fields of bioradiometrology and biophysics. The first, the bioradiometrological, has the goal of establishing the laws governing the interaction of electromagnetic radiations with a biological object, in particular, establishing the quantitative relationship between the incident and absorbed electromagnetic energies, ascertaining the nature of EMR energy distribution at various frequencies within a biological object in light of the specific features of the physical properties of the tissues forming it, as well as depending on its geometric dimensions, shape, etc. The task of the biophysical area is establishing the laws governing the transformation of the biological substrate by absorbed EMR energy to other kinds of energy as a function of the electromagnetic radiation parameters, as well as ascertaining the specific features of the occurrence of biophysical processes as a function of the amounts of absorbed energy. The lack of data on the biophysics of the primary interaction of EMR energy with biostructures sharply limits the possibilities of constructing a modern scientific theory for the mechanism of electromagnetic radiation action, because of which, substantiating the health safety standards takes on an empirical nature to a considerable extent. This in turns limits the possibilities of scientific prediction. The lack of information on the specific features of energy absorption and distribution in a biological object narrows the significance of the experimental data obtained to the conditions of the specific experiment. It is quite obvious that just as the lack of sufficiently complete data on the specific sensitivity of an organism to the action of electromagnetic radio frequency emissions, this creates exceptionally great difficulties in extrapolating the data from animals to man.

In evaluating the status of the problem of setting health safety standards for radio frequency electromagnetic radiations, it is essential to deal with the state of affairs in metrology, if only briefly.

It is difficult to overestimate the role of standard setting documents, which as has already been indicated above, can be treated as an indicator of the state of development of the problem. However, the realization of their requirements depends in many respects on the monitoring capabilities. Unfortunately, the equipment produced by our industry does not make it possible to implement appropriate monitoring of the level of electromagnetic radiations. At the present time, essentially only one type of instrument (PZ-9, PZ-13) is series produced for the microwave band for wavelengths of from 1 m to 8 mm. It must also be noted that as applied to radiation conditions which exist in industry, as well as the emissions generated by radio engineering facilities, the equipment which is produced makes it possible to measure electromagnetic radiations with adequate precision in approximately 10 to 20 percent of the cases. The equipment is not designed for measuring the near field parameters of electromagnetic radiations, i.e., at work positions for complex fields, in the case of irradiation from antennas with a moving direction pattern, etc. Moreover, it is specifically these kinds of irradiation which are encountered extremely frequently in day to day practice. Moreover, the equipment has a number of serious structural drawbacks: the measurement precision is on the order of ± 30 percent, it has great size and weight, a small dynamic range and in a number of cases does not provide for direct readout of the results, etc.

An important place in reducing unfavorable effects of nonionizing radiations in the upcoming 10 to 15 years should be set aside for the development and design of hardware for general and individual protection as well as effective systems of protective measures for various groups of people.

It must be recognized as essential to improve public health law, as well as to create a network of laboratories to monitor radiation levels in industrial and public facilities for the purpose of providing for practical solutions to the problem of protecting the environment against the unfavorable action of nonionizing radiations.

It must be noted that along with the necessity of providing protection against exposure to nonionizing radiations, the question of the influence on man of conditions characterized by a lack or reduction in the natural background have taken on a well-known urgency at the present time. The answer to this question should also be abtained in the upcoming years.

The successful solution of all of the problems enumerated here is possible only based on widescale research with the participation of specialists in various fields.

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THE HEALTH SAFETY SUBSTANTIATION OF APPROACHES TO SETTING STANDARDS FOR RADIO WAVES

K.V. Nikonova and B.M. Savin

Setting health safety standards for electromagnetic radiations (EMI) [EMR] should be based on precise knowledge of the physical parameters of a factor, the actual conditions of human exposure to it as well as modern concepts of the mechanisms of the biological action of radiations in various frequency bands.

Assuring the safety of personnel subjected to the action of radio frequency electromagnetic fields (EMP), requires setting the maximum permissible irradiation levels for the entire radio frequency spectrum. At the present time, when there is still no sufficient quantity of data which reflects the laws governing the manifestation of the biological action of a factor as a function of its physical parameters, the basis for setting the maximum permissible levels can be materials on the nature and expression of biological effects due to exposure to electromagnetic radiations in a particular band or with a particular radiation mode.

The extrapolation of requirements placed, for example, on the microwave band to others is not altogether rightful, all the more if they differ substantially in frequency. Such an approach was used, in particular, in the U.S. As is well known, the American standard for irradiation in a frequency range of 10 MHz to 100 GHz is 10 mW/cm^2. For lower frequencies, the maximum permissible levels were obtained by calculations and were 200 V/m and 0.5 A/m. Such a conversion establishes only the physically equivalent quantities for the defined conditions (specifically, plane wave conditions). Differences in the nature of electromagnetic energy absorption and distribution as a function of radiation wavelength (or oscillation frequency) are ignored in this case.

The computational method of determining the maximum permissible levels based on the best studied band also cannot be considered a sufficiently correct one in the case where differences in the frequency characteristics of the subbands are formally taken into account. Accounting for the dependence of energy absorption on the frequency of the acting field cannot guarantee equality of the biological effects with equal absorption, since the specific features of the interaction of the radiation energy with the biological object are not taken into account.

It is also completely obvious that by virtue of the differences in the mechanisms of the action of high and low intensity electromagnetic fields, the maximum permissible levels cannot be determined from computed data working from the governing laws obtained by means of comparing the biological effects for various frequency bands at high exposure levels (for example, based on the data from determining the lethal effect thresholds). Calculations can be used only for a rough preliminary prediction. The basis for setting the standard for each frequency band at the present time should be experimental data on the harmful effect threshold of radiations, taking into account the results of studies which characterize the health status of persons exposed to a factor. The existing health safety standards are far from always based on the principles set forth above. In a number of frequency bands, physiological reactions of an adaptive nature have served as the basis for establishing the maximum permissible levels.

All possible exposure parameters (intensity, duration, generation mode, conditions and nature of the irradiation) should be maximally taken into account when scientifically substantiating maximum permissible levels. However, standards have been set for only the radiation intensity in the 60 KHz--300 MHz bands. In the 300 MHz to 300 GHz band, the standards also take into account the duration of the exposure along with the intensity. In this case, there is no functional relationship between the parameters for which the standards are set. The lack of energy agreement among the three levels for which standards have been set has been repeatedly underscored in the literature. The traditional approach which has grown up among us provides for utilizing the following as the standardized parameters of exposure intensity: the energy flux density (PPE), or the power density (PM) in the 300 MHz--300 GHz band, and the field intensity of the electrical (E) and magnetic (H) components of an electromagnetic field in a range of 60 KHz to 300 MHz. Such an approach is based on the notion that the work positions at SHF sources (300 MHz--300 GHz) are as a rule positioned in the radiation zone, while in the HF (60 KHz--300 MHz) and VHF (30 MHz--300 MHz) bands, they are in the near field or the induction zone where there is no definite relationship between the E and H field components. All of our work experience makes it possible to state that these parameters are far from always suitable to us. In the first case, when working with microwave sources under industrial conditions, it is necessary extremely often to make measurements in the near or intermediate fields (measurements in the direct vicinity of slots, leaky places in cabinets and waveguide channels). Secondly, in the case of large radiating antennas, the near field boundaries extend to a distant of $2a^2/\lambda$ (where a is the greatest dimension of the radiating aperture and λ is the radiation wavelength), which in practice amounts to hundreds and thousands of meters. In practice though, people are frequently subject to irradiation from high-powered sources located close together, or at points where there is an arbitrary polarization and multiple interference. In all of these cases, just as in the case of irradiation from several sources, evaluating the exposure based on the energy flux density (or the power density) is unsuitable. Thus, in particular, at close ranges from sources, there can be strong electromagnetic fields with a low or nonexistent mean power flux.

Comparative measurements performed on a 26 meter parabolic antenna in the conventional manner (using a waveguide with an open end and a power meter) and using an instrument with an isotropic sensor have demonstrated that in the case of a measurement using the first method, significantly understated results are obtained [1]. As researchers from the American Bureau of Standards point out, "The accepted concepts and standards for the level of nonionizing electromagnetic fields are quite satisfactory under definite idealized conditions. However, such conditions are rarely realized at work positions or even in experiments on irradiation" [2].

As far as using the E and H component field intensities as the parameters for which standards are set in the HF and VHF bands, then, without discussing the issue of the difficulties of measuring the total E or H vector, attention should be turned to the fact that the presence of health safety standards based on two parameters, expressed in different units (V/m and A/m), makes standards setting insufficiently flexible, since it does not allow for changing the permissible level of one component as a function of the presence or existence of the other. As a result, the permissible energy loads on a human organism differ by thousands of times. Further, the measure (parameter) for which the standard is being set should be tied rather closely to the mechanism of the harmful action. Since the danger of irradiation is governed by the field inside the object, dosimetric studies would have to be based on internal fields. However, the realization of this approach does not prove to be possible at the present time. This accounts for the understandable attempts at a compromise solution of the question. Thus, H.P. Schwan, in coming to the conclusion that criteria based on the power flux level in the case of complex fields were unsuitable, proposed the current density in tissue as the standardized indicators [3]. Working from a base value of 10 mW/cm^2 and the specific resistance of tissues at various frequencies, the author derived the following values as the numerical safety criteria: 3 mA/cm^2 for frequencies above 10 MHz; 1 mA/cm^2 for frequencies from 10 KHz to 10 MHz and 0.3 mA/cm^2 for frequencies below 10 KHz. Other authors [4], believing that it was not necessary to prove the fact that the biological effect of an exposure is governed by the energy absorbed in the tissues, propose that the amount of absorbed energy in watts per second or Joules per unit weight be used in the safety standards.

It must be noted that the proposals contained in the indicated literature do not exclude the necessity of measuring the external field, and consequently, in a number of cases the possibilities of errors related to the measurement of the energy flux density or the E and H component field intensity.

The proposal that the indicator of the amount of external field energy density be used as the standardized parameter deserves serious attention [2]. It starts from the premises that there is a relationship between the danger of an exposure and the energy absorption and that the level of the internal field is dependent on the level of the external one. The proposed parameter has a number of advantages: first of all, it makes it possible to express the intensity of electrical, magnetic and electromagnetic fields in the same units (energy per unit volume); secondly, it makes comparison possible with existing data on the energy flux density (or power density), since the values of energy density are easily related to those in simple plain wave fields; and thirdly, the given indicator can be estimated by instruments with isotropic sensors by means of measuring E^2, H^2 or the energy density of the electrical (u_E) and magnetic (u_H) fields directly.

The question of whether it is necessary to evaluate both components of the electromagnetic field or whether it is sufficient to measure one is of considerable importance from the standpoint of estimating the near fields. S.J. Rogers and R.S. King [5] believe that it is sufficient to estimate the electrical component, since human tissue has the characteristics of a resistive dielectric, and it is therefore sensitive to the electrical component of the field. P. Wacker and R. Bowman [2] also feel that the parameters E^2 and u_E are the most suitable for describing the potential danger of unperturbed fields. However, the authors make the reservation that the indicated parameters are inadequate in estimating reactive fields. According to the data of J. Lin, et al., the magnetic field, especially in the HF band, can make a substantial contribution to electromagnetic energy absorption by the human body. This makes it possible to speak of the fundamental correctness of the approaches adopted in the USSR which provide for estimating both components in the case of near fields.

Exposures to pulse modulated fields deserve special attention in the plan for resolving questions of setting health safety standards.

H.P. Schwan [7], in analyzing the reaction rates of systems to the effects of forces generated by a field, came to the conclusion that a pulsed field cannot be any more effective than a continuous one with the same average power. That is, it is impossible to increase the probability of field-force effects by means of pulses.

Along with this, some phenomena, such as electromagnetic hearing, for example, were related for a long time to the action of high peak powers [8]. However, it was simultaneously shown that with a definite pulse width, the threshold for the excitation of aural responses in man and cats is not governed by the peak power, but rather by the quantity of energy going into each pulse [9].

In papers by Soviet authors [10, 11], based on the comparative evaluation of continuous and pulsed electromagnetic radiations with a pulse repetition rate of hundreds of hertz, the great extent to which biological effects are pronounced with exposure to pulsed radiation is noted from a number of indicators. However, the differences were not so significant as to make it necessary to introduce differentiated maximum permissible levels. Data were obtained by American researchers [12] which attest to the great biological activity of pulsed electromagnetic radiations as compared to continuous radiations at comparatively low power densities (200 $\mu W/cm^2$ average; 2.1 mW/cm^2 peak).

It turns out that at the present time when evaluating pulse modulated radiations, it will be the most correct to assign the major significance to average field levels. It is not excluded that at definite peak power values and pulse widths, the maximum (peak) levels can make their own independent contribution to the biological effects of radio frequency exposures. In these cases, it can prove necessary to measure the average and the peak levels. Taking into account the trends in the development of modern radio electronics, it is extremely important to further improve the precision in the matter of the role in biological effects of pulse width and amplitude, the ratios of the maximum and average field levels at which the effects of the maximum levels exceed the effects of the average level as well as the role of the pulse repetition rate. The clarification of the indicated questions will make it possible to make the appropriate corrections in the standards set with respect to the average level; as far as setting standards with respect to the maximum (peak) level, then it is apparently expedient to use it only in the case of one-time or infrequently repeating pulses.

As is well known, studies performed for the purpose of establishing safe irradiation levels for man, as a rule, are complex and include the health safety evaluation of the conditions of exposure to a factor, the clinical physiological examination of the health status of persons subjected to the irradiation and the experimental study of the biological effects due to the influence of electromagnetic fields in various frequency bands. Without posing the problem of clarfying the role and place for various kinds of studies in establishing the maximum permissible levels, we will only deal with the requirements placed on health safety investigations.

It is specifically the health safety studies which determine the conditions necessitating the setting of standards. Clinical and health safety parallels are drawn based on their results, the correctness of the conclusions of which depends in many respects on the quality of the health safety data. The results of health safety studies are incorporated in the parameters of the experiment.

Based on what has been said, it is apparent that health safety studies should provide the most complete possible characteristics of the industrial environment being studied. Their results should contain data on the radio frequency band, the irradiation mode, the nature of the irradiation, the intensity, the duration of the exposure, on the presence and levels of other unfavorable factors (X-ray radiation, unfavorable meteorological conditions, noise, chemical contaminants), as well as on the conditions and level of intensity of the work.

Obtaining precise and detailed data necessary for resolving questions of setting health safety standards entails definite difficulties in a number of cases. Thus, the environmental physiologist is not always able to evaluate all of the steps in a production process or all of the ways the radiation acts on a person, not to even mention the difficulties related to the unsatisfactory metrological support for the studies which have the goal of determining particular parameters of radio frequency exposures. Moreover, as the results of analyzing the materials of health safety and clinical physiological studies to substantiate health safety standards for individual frequency bands of electromagnetic emissions over the last 10 years, attention has been primarily devoted only to that factor which is being studied and is considered the major one. All of the deviations ascertained in the health status of workers are not always justifiedly linked to exposure to that factor. In this case, the possible role of other factors in the production environment is completely ignored. Such an approach can lead to serious errors. This is all the more true since clinical manifestations related to exposure to radio frequency electromagnetic radiations do not have any specific attributes.

Because of the nonspecific nature of the functional changes which occur with the influence of radio waves on man, and the difficulties of establishing the etiological role of the various industrial and every-day factors in their origin when working out the maximum permissible levels of electromagnetic radio frequency emissions, a great role is assigned to experimental studies. In this case, the question of extrapolating the data obtained in experiments on animals to man becomes of exceptionally great importance. Differences in the reactions of animal and human organisms to exposure to a factor can be due both to differences in energy absorption and distribution and the specific features of the organization and functioning of "critical" organs and systems. The biophysical studies and calculations of electromagnetic energy absorption by models of different sizes and shapes [13] which have been performed at the present time make it possible to derive coefficients for definite conditions and using them, derive equivalent exposure levels for man and animals in terms of energy absorption. As far as the second factor is concerned which determines approaches to the extrapolation, the species specific sensitivity, the question of its role in organism responses to irradiation deserves considerably greater attention than has been devoted to it up to the present time. There are only individual papers specially devoted to the comparative evaluation of human and animal organism reactions to radio frequency exposures. The purpose of the investigations of American authors [14] was to search for an organism which could serve as a reference standard in studying microwave exposures. The reactions of dogs, rabbits, rats and various small organisms down to the simplest ones were studied in this case. An organism which would possess definite and reproducible characteristics in the case of microwave irradiation was not found. A.G. Subbota and B.A. Chukhlovin [15], based on an analysis of data in the literature as well as their own, came to the conclusion that it is necessary to use predominantly large animals in experiments, where the animals are comparable to man in terms of the geometric dimensions of the body and the level of organization of the functional activity of the major systems. In the opinion of S.M. Michaelson, an answer to the question of whether it is better to use many objects or one to two (and which ones) to predict human reactions has as yet not been obtained; a systematic study of several types of animals is needed.

It goes without saying that special studies which make it possible to evaluate changes in functions while taking energy absorption into account are needed to resolve the question of the comparative sensitivity and vulnerability to damage of animals and humans. Only with sufficient knowledge of two factors - energy absorption and sensitivity of individual systems of an organism - is it possible to develop scientifically substantiated extrapolation factors.

Along with questions of extrapolating experimental data when converting from harmful effect thresholds to maximum permissible levels, it is very important to also solve the problem of the value of exposure margin of safety factors. The purpose of introducing the latter, as is well known, is assuring the reliability of health safety standards. As applied to various physical and chemical factors in the industrial environment, the value of margin of safety coefficients will fluctuate from a few units up to 100 or more.

No serious research of an experimental or theoretical nature has been done to determine health margin of safety factors as applied to radio frequency exposures. However, individual proposals have been put forward on the given question. Thus, in 1974, it was proposed for the entire microwave band, where exposure intensity is estimated in power density units, that a health margin of safety factor of 10 be used, as is most frequently employed in public health safety practice. For lower frequency bands, where the intensity of electromagnetic fields is estimated by the intensity of the E and H components, working from the same factor of 10 and acknowledging that biological effects are due to energy, a margin of safety factor of $\sqrt{10} \approx 3$ was proposed. However, taking into account the fact that workers may simultaneously be exposed to both electrical and magnetic fields, the opinion was advanced that it is expedient to increase this quantity by a factor of $\sqrt{2}$ times, i.e., when setting the standard for a factor with respect to the E or H field intensity, it was recommended that a health margin of safety factor of 5 be established.

In the opinion of V.A. Zhuravlev*, the cumulative level of radio frequency effects in an organism should be adopted as the criterion for determining the value of health margin of safety factors on analogy with other areas of setting health safety standards. Experiments performed to compare the total energy of fractional lethal doses and a one-time dose as well as an analysis of data in the literature allowed the author to come to the conclusion that microwaves have a small cumulative capacity, and to propose the following as the specific values of the margin of safety factors for a single threshold dose for man: for professionally exposed persons - 10; for nonprofessional exposure during production - from 20 to 50; and for the populace - 100.

We are inclined to believe that the health margin of safety coefficients should be differentiated taking into account the exposure categories (professional, nonprofessional, exposure of the population) and the biological effectiveness of the exposure. The latter can be determined from the frequency characteristic of the radiation, as well as the generation conditions or the conditions of irradiation of an object.

There is doubt that it is correct to use a cumulative indicator as the main danger criterion, since radio waves have a poor cumulative effect, because of which it is difficult to anticipate substantial differences based on this test with different exposure characteristics and since the governing laws obtained at the lethal dose level hardly reflect the actual danger of a factor under industrial conditions. It turns out that at the present time, the use of the chronic effect threshold for systematic exposures and the acute effect threshold for one-time exposures is the most justified at the present time as the main danger criterion. The following should be taken into account as supplemental indicators: the ratio of the acute action threshold to the chronic action threshold, which characterizes the development of effects of a cumulative nature, as well as the rate of rise of the curves which reflect the dependence of the biological effects on the intensity and time of an exposure.

Exposures to continuous and pulsed (with a pulse repetition rate of more than 100 Hz) microwave radiations in a frequency range of 500 MHz to 10 GHz can be considered to be the most well studied. The results of analyzing experimental data on the characteristics of biological effects of the indicated exposures makes it possible to consider their use justified when the standard is set for a health safety margin factor of 10 for professional groups. It is expedient to estimate the danger and the selection of the health safety margin factors when setting standards for microwave radiation in other frequency bands and exposure modes based on the indicator of their relative biological efficiency (OBA) [RBE]. The latter should be expressed as the ratio of the harmful effect threshhold for the exposure for which the standard is being set to the harmful effect threshold of the most well studied microwave radiation. For frequency bands and

*See Page 103 [62] of this collection.

exposure modes characterized by a higher biological efficiency (RBE > 1), it is recommended that higher safety margin factors be employed, and vice-versa, for lower efficiencies (RBE < 1), lower safety margins be used. It turns out in this case that the differences in the biological efficiency of exposures is to be considered substantial and requiring differentiation of the safety margins which are introduced if the differences in the harmful effect threshold amount to a factor of no more than 3. Smaller differences are actually incorporated in the possible experimental error. For the same reason, absolute values of the health safety margin factors should not be less than 3.

The possibility of utilizing the given proposal when substantiating the maximum permissible levels for electromagnetic radiations at a frequency of less than 300 MHz, or another approach which takes into account the specific features of the parameters for which standards are being set, requires further theoretical and experimental work.

The authors consider it expedient to use unified approached to setting standards for radio frequency emissions for various categories of persons, and taking into account the comparatively poor biological efficiency of a factor, consider supplemental safety margin factors of 2 - 3 to be sufficient for nonprofessional exposures and 4 - 5 sufficient for the population. What has been said in no way precludes the possibilities of finding and using other procedural approaches. The issue can involve, for example, modeling under experimental conditions the particular features characterizing groups of personnel for which standards are being set. However, the main methodological principle should be observed in all cases which provides for the use of the appropriate harmfulness criteria in setting the health safety standards. Health safety standards being set for various categories of persons should not be a set of quantities which are not related to one another, where these quantities reflect the specific features of approaches to the substantiation of maximum permissible levels in institutions for various specialties. They should follow from the overall laws governing the interaction of radio frequency electromagnetic radiations with biological objects.

It is obvious from what has been said that the process of experimentally substantiating the maximum permissible levels is composed of the following steps:

--Evaluating the functional status of critical organs and systems under conditions of acute and chronic exposure;

--Determining the harmful effect thresholds: the acute effect threshold and the chronic effect threshold based on an analysis of the data obtained;

--The extrapolation of the data obtained on animals to man, i.e., the determination of the harmful effect thresholds for man;

--Substantiating the health safety margin factors;

--Proposals for the standard values, which follow from the results of the experimental study.

For final recommendation, it is necessary to make corrections which follow from an analysis of the data on the health status of the irradiated contingents of persons. It stands to reason that such data can be obtained by means of clinical environmental physiological comparisons under conditions where it is possible to make such comparisons and where the data being obtained meet the requirements placed on the materials used for resolving issues of setting health safety standards.

It must be stated that as a result of acumulating the scientific data, in the future we will be able to predict the biological effects of electromagnetic radiations in new frequency bands and under new exposure conditions. To make health safety standards predictable is an important goal, of special importance in the age of the scientific and technical revolution. To achieve this goal, it is essential to do fundamental research into the dependence of biological effects on the parameters of exposure to a factor.

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METHODS OF STUDY AND THE EVALUATION OF EXPERIMENTAL DATA IN SETTING HEALTH SAFETY STANDARDS FOR RADIO EMISSIONS

A.G. Subbota and B.A. Chukhlovin

Experimental data which characterize the threshold levels of the unfavorable action of a factor are of considerable importance in substantiating the health safety standards for radio frequency electromagnetic fields (EMP). It must be noted that up to the present time, the question of the organs and systems which are the most sensitive to exposure to a given factor cannot be considered finally resolved, something which naturally makes it difficult to select adequate methods of study. In the beginning of the 1960's, a number of American authors, working from concepts of the thermal mechanism of damage, numbered the crystalline lens of the eye among the most sensitive organs to exposure to electromagnetic fields, in particular, in the microwave band. For this reason, they recommended opthalmoscopy as well as the determination of ascorbic acid content and glutamine in the crystalline lens as the most informative procedures [1].

In the opinion of the majority of Soviet authors, the greatest sensitivity to the given kinds of radiations is exhibited by the central nervous and cardiovascular system. The unfavorable effect of a factor has been estimated based on indicators for a change in the functional status of specifically these systems [2].

It should also be pointed out that many authors have studied the status of a number of other systems rather deeply (digestive, hematogenesis, endocrine, etc.) as well as individual vital activity indicators for an organism. An analysis of published literature provides a basis for thinking that among the research methods being used, only a few are sufficiently informative for purposes of setting standards, where some of them can be used only for limited species of experimental animals. Thus, for example, to substantiate the maximum permissible levels of electromagnetic microwave radiations, it is expedient to perform experiments in the form of chronic trials with large animals, in particular using dogs, for which the vital important organs are located at approximately the same depth as in man [2]. To evaluate the status of the higher nervous activity, the use of I.P. Pavlov's method of conditional reflexes is justified (recording symmetrical reactions), while for the cardiovascular system, it is necessary to determine the arterial and venous pressures, as well as take electrocardiograms and kinetocardiograms.

The methods of I.P. Pavlov and Heidenhain of studying the secretor function of the stomach using ventricles, as well as the evacuator motor activity of the stomach and the absorption of some substances in an isolated loop of intestine are rather sensitive exposure to radio waves.

Gas exchange indicators studied using Douglas--Holden's method can also be treated as informative ones, as well as certain kinds of exchange: carbohydrate (based on the blood sugar level and reactions to the sugar "load"), protein (based on the content of overall protein or protein fractions in blood serum), mineral exchange (based on the K, Na, and Ca content in blood serum, Ca in tissues), etc.

Biochemical techniques directed towards the study of hormones primarily responsible for the mobilization of energy reserves and the adaptation of an organism to extreme exposures have become rather widespread in recent years. In the opinion of a number of authors, hematogenesis status indicators (the overall clinical analysis of the blood, the study of the osmotic resistance of erythrocytes) and the biological immune protection system of an organism (phagocyte activity of neutrophyls, blastotransformation of lymphocytes, the level of the immunological response to an antigen stimulus) can also be informative [2]. To ascertain the mutagenic action of radiations, special cytogenetic techniques using blood cells, bone marrow, the epithelium of the cornea of the eye, etc. are finding application.

To estimate the overall status of an organism, such indicators of vital activity as the reproductive capability (fertilization, fetal development, fertility, and the characteristics of progeny), a change in body weight, as well as the ability of the irradiated organism to train to handle physical loads have also been studied [3-5].

However, it must be emphasized that even correctly chosen methods still do not fully guarantee the correctness of the scientific research to substantiate the maximum permissible radiation levels. No less important really but an even more complex issue is the question of selecting criteria for evaluating research results. Because of the fact that when an organism is exposed to radio emissions, as a rule, two to three types of reactions develop - physical and pathological - the question of which of them is to be the governing factor in setting the health safety standards for exposure takes on special significance. At the present time, no one any longer has any doubt that adaptive reactions cannot be used for setting standards for electromagnetic radiations, since they characterize only the radio sensitivity and are more evidence really of the presence of the reserve capabilities of maintaining homeostasis in the organism. It can be considered that the basis for establishing standard levels should be those reactions which go outside the range of usual physiological fluctuations in the homeostasis process. In this case, it is necessary to take into account the fact that with repeated irradiations, the development of adaptation phenomena may be observed with respect to the exposure, where this development is manifest in the gradual attenuation of changes in step with the repetition of the electromagnetic exposures.

As applied to the central nervous system, the main health safety indicator for the unfavorable impact of a factor is to be considered a disturbance of higher nervous activity. In this regard, the task of an investigator engaged in determining the threshold levels of the harmful effect of electromagnetic fields on the central nervous system should be reduced to establishing the values of the intensities and time parameters of the radiation exposures for which disturbances occur in the conditioned reflex activity. In this case it is necessary to use a rather wide assortment of stimuli, which are perceived by different analyzer systems.

It is significantly more difficult to determine the initial attributes of functional disturbances in the blood circulation system, since up to the present time there has been no clearcut experimental model for cardiovascular illnesses

TABLE 1.

The Disadaptive Effect of Centimeter Wavelengths (λ = 12.6 cm; "Luch - 58" Equipment) from Data of a Study of Arterial Pressure (AP) in Rabbits Adapted to IR Radiation with an Energy Flux Density of 350 mW/cm^2

Conditions of the Trials	Number of Trials	Arterial Pressure Drops Over 2 Hours mm Hg, M ± m	Significance of the Differences When Compared to the Background p	Remarks
Series 1				
Starting data (3 days of observation)	15	4.9 ± 0.5	--	--
1st and 3rd IR Radiation sessions with an energy flux density of 350 mW/cm^2. Rectal temperature rise of about 1.1° C	15	15.3 ± 1.8	< 0.01	--
4th - 6th sessions of IR Radiation exposure at the same parameters	15	4.7 ± 0.7	> 0.5	Adaptation to IR Rays
8th-10th sessions of IR Radiation with the same parameters, for 1 day prior to each of them, irradiation at centimeter wavelengths (energy flux density = 1 mW/cm^2, λ = 12.6 cm, 30 min. exposure)	15	17.6 ± 2.3	< 0.01	Disadaptation
Series 2				
Starting data (4 days of observation)	28	4.0 ± 1.3	--	--
1st-4th sessions of IR Radiation with the same parameters	28	19.0 ± 1.8	< 0.01	--
5th - 8th sessions of IR Radiation with the same parameters	28	6.1 ± 0.6	> 0.25	Adaptation
9th - 12th sessions of IR Radiation. Each of them was preceded by microwave irradiation with an energy flux density of 50 mW/cm^2 (λ = 12.6 cm; exposure of 30 min.). Interval of one day.	24	19.5 ± 2.4	< 0.01	Disadaptation

Notes: 1. The value of the arterial pressure gradients characterizes the peak to peak value of the swings of the arterial pressure in the carotid artery characteristic of man when he is exposed to radio emissions. Based on an analysis of data in the literature, it can be thought that the most substantial in this case are persistent electrocardiogram changes, which attest to the presence of myocardial hypoxia, in conjunction with overall hemodynamic changes. Functional changes which disappear rapidly are to treated as a manifestation of the radio wave sensitivity of the organism.

The harmful effect indicators of radio frequency emissions on the digestive system can be such changes as long-term depression of gastric juice liberation in the nervous reflex phase, dissociated disturbances of the acidification and digestive strength of the juice, as well as a reduction in the absorptive capability of the intestine (based on the level of glucose absorption). These kinds of changes can be treated as a manifestation of a singular gastric neurosis.

An objective indicator of the unfavorable influence of a factor on the biological immune protection mechanisms of an organism is a persistent reduction in the phagocyte activity of neutrophyles, a slowdown in the blastotransformation of lymphocytes, depression of the organism's capability of antibody formation, as well as a decrease in the bacteriocidal properties of the blood, etc.

Among the biochemical indicators, decisive significance should be assigned only to those which confirm the corresponding clinical picture. In and of themselves in isolation they cannot serve as a criterion for an unfavorable effect, taking into account the pronounced variability of many of them in the vital activity process of an organism [6].

Depression of gas exchange indicators, disturbance of endocrine regulation, etc. should also be considered sufficiently informative for the determination of harmful effect thresholds of electromagnetic radiations on an organism.

Thus, setting the threshold levels for harmful exposure to electromagnetic fields should be based on the estimation of a set of indicators for the change in the functional status of a number of systems of the organism. However, it must be noted that the solution of this problem, which is based on the analytical principle of comparing indicators obtained before and after an irradiation exposure, cannot be treated as the optimal one. As drawback to the indicated approach is the fact that in this case, the internal processes which take place in the irradiated organism are not revealed.

Experience with experimental work shows that more complete information on the effect of electromagnetic fields can be obtained when using a different principle, which can be designated the "synthetic" principle. The latter provides for the study of the particular indicators against a background of exposure to extreme factors, with the influence of which the system being evaluated is brought to the upper limit of its functioning. Under natural conditions, such kinds of changes occur in the thermal regulation system. When it is hot, this system is loaded in one direction, and in a cold (in the winter), it is loaded in the other. Against the background of substantial differences in the stress on this system, an additional load on it because of exposure to an electromagnetic field will be accompanied by unequal shifts in its functional status indicators, something which makes it possible to estimate the degree of the unfavorable impact of a factor.

where it is measured every 30 minutes for 2 hours. The radiation exposure occurred in the interval between the first and subsequent measurements.
2. M is the mean arithmetic value of the arterial pressure gradients and m is the mean arithmetic error.
3. The Student-Fisher t criterion was used.

As is well known, the initial functional status of an organism depends not only on seasonal temperature fluctuations in the environment, but also on previously sustained illnesses, the degree of training for physical loads and the like. In this regard, when setting the harmful effect thresholds for electromagnetic fields, it is extremely important to correctly simulate the actual situation of multiple factor exposures in the experiment.

The following two experimental schemes were used successfully in our research. In the first case, an animal which was trained to any extreme factor (heat, physical loads, etc.), was subjected to a low intensity electromagnetic field, and then again exposed to the extreme stimulus, to which the organism had been previously adapted. In this case, it was established by how much the previously acquired immunity of the organism to this stimulus was disrupted by the electromagnetic field and how long traces from the electromagnetic irradiation remained. Trials on dogs demonstrated that when exposed to an electromagnetic field with an intensity of one mW/cm^2, the disruption of the adaptation to a high temperature environment can continue for up to three days.

Similar results were obtained in trials using rabbits, which were trained to high temperatures by means of infrared rays. The results of these studies are cited in Table 1. It can be seen from the table that the loss of adaptation effect as regards arterial pressure is quite distinct. The data cited here are indirect evidence that microwaves actually have a nonthermal effect. If they were to cause only a thermal effect, just as infrared rays, the elevated resistance to high temperatures which was achieved should have been preserved (there would have been a positive transfer of the adaptation to microwave heating). However, as follows from the data given in the table, no such phenomena were observed. Similar effects were detected in trials using rabbits, adapted to microwaves at a different wavelength (Table 2), as well as with dogs. For the latter, electrocardiograms, respiration and rectal temperature were recorded in addition to the arterial pressure [7].

The data of Table 2 show that the immunity developed to one wavelength is not accompanied by increased immunity to another. On the other hand, when exposed to decimeter wavelengths, a decrease in immunity is observed. Thus, radio waves in this band disrupt adaptive responses developed for exposure to centimeter wavelengths. The latter provides a basis for stating that the mechanism for their action and the response of the counteraction differ for each of the indicated wavelength bands.

A second variant of the experiments provided for conducting studies on animals with an artificially disrupted activity of the regulator mechanisms or after the animals had sustained some kind of illness. The results of these kinds of trials, performed on dogs who sustained radiation illness, are cited in Table 3. It can be seen from the table that the microwave exposure not only reproduces some of the radiation sickness symptoms, but also causes additional changes: in the form of trophic disturbances (ulcers) in the region of the knee and foot joints.

TABLE 2. The Disadaptive Effect of Decimeter Wavelengths (λ = 60 cm; "Volna" Equipment) from the Data of a Study of the Arterial Pressure in Rabbits Adapted to Centimeter Wavelengths (λ = 12.6 cm; "Luch-58" Equipment)

Conditions of the Trials	Number of Trials	Arterial Pressure Gradients over 2 hr mm Hg, $M \pm m$	Significance of the Differences when Compared with Background, p.	Remarks
Initial data (4 days of observation)	20	6.7 ± 4	-	Background
1st-4th sessions of cm wavelengths (λ = 12.6 cm; energy flux density = = 50 mW/cm^2; 30 min exposure). Rectal temperature rise of 1.3° C	20	23.4 ± 2.3	< 0.01	-
9th-11th sessions of cm wavelengths with the same parameters	15	6.8 ± 0.6	> 0.5	Adaptation
12th - 15th sessions of cm wavelengths with the same parameters. For one day before each session, irradiation with dm wavelengths (λ = 60 cm, energy flux density = 1 mW/cm^2, 30 min exposure)	20	11.5 ± 1.2	< 0.01	Slight disadaptation
16th - 19th sessions of cm wavelengths of the same parameters, for 30 min before the session, irradiation with dm wavelengths (energy flux density = 1 mW/cm^2)	20	33.8 ± 2.8	< 0.01	Pronounced disadaptation
21st - 22nd sessions of cm wavelengths with the same parameters; prior to each of them, irradiated by the same cm wavelengths with an energy flux density of 1 mW/cm^2.	10	6.4 ± 0.8	> 0.5	-

TABLE 3.

Specific Features of the Impact of Microwave (λ = 10 cm; Energy Flux Density = 5 mW/cm^2; 30 Minute Exposure) on the Organism of a Dog Which Has Sustained Radiation Sickness

Indicators Being Studied	Back-ground	After Micro-wave Ir-radiation	After an X-ray Radiation Dose of 200 r: Peak of the Rad-iation Sickness	After an X-ray Radiation Dose of 200 r: 3 months Later	Micro-wave Ir-radiation	Significance of the Differences When Compared p: 2-4	p: 4-6
1	2	3	4	5	6	2-4	4-6
Conditioned motor reflexes:							
a) Latent periods in sec	2.8	3	45	7.2	56.2	0.01	0.5
b) Number of hits on the pedal	3.2	3.4	1.4	3.2	0.2	0.01	0.05
Conditioned secretion reflexes (quantities in drops)	14.4	18.2	5	16	6.4	0.01	0.5
Maximum arterial pressure, mm Hg	139	143	147	138	148	0.01	0.5
Number of leukocytes	9,250	6,810	2,250	2,540	4,450		
Trophic disturbances					Sores in the region of the knee and foot joints		

Note: Each figure in columns 2 - 6 is the average of five trials.

As has been shown in the studies of various authors, some of the symptoms of previously sustained illnesses can reoccur in dogs with an artificially induced myocardial infarct, which was achieved by means of tying off one of the coronary arteries or by endocrine system insufficiency which was created by removal of the hypophysis or the thyroid gland. It is obvious that the partial reoccurrence of a previously sustained illness (or function insufficiency) should also be treated as an indicator of a damaging effect.

The question of the threshold levels for the unfavorable action of radio frequency emissions is closely related to the estimation of the significance of exposure parameters, and primarily, to the intensity (P) and duration (T) of the irradiation. As was shown in paper [8], the same effect can be observed with substantial differences in the intensity, but with different exposure durations. Achieving different effects as a function of the exposure intensity and time occurs when the following conditions are observed, defined by the formula:

$$T = W/kP$$

Where T is the exposure time in minutes;
W is the incident energy density, $mW \cdot min/cm^2$;
P is the radiation intensity, mW/cm^2;
k is an experimentally determined coefficient which shows how many times the radio wave efficiency increases with an increase in the energy flux density.

The circumstances treated here attest to the necessity of both standardizing the conditions for the performance of experimental studies and working out unified criteria for estimating biological effects, without which it is impossible to have a sufficiently rigorous substantiation of the threshold levels of the unfavorable effect of radio frequency electromagnetic radiations.

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METHODS AND CRITERIA FOR EVALUATING THE RESULTS OF STUDIES ON VOLUNTEERS IN RESOLVING QUESTIONS OF SETTING HEALTH SAFETY STANDARDS

T.V. Kalyada, V.N. Nikitina and M.V. Shepeleva

Studies of the physiological laws governing the interaction of the organism of man and electromagnetic radiations should occupy an important place in solving the problem of the biological effect and substantiating the maximum permissible levels of nonionizing radiations.

The study of these laws will make it possible to estimate the biological effects of the action of a factor at the level of a quite complex, highly organized biological system, such as the human organism. Some authors believe that the property of perceiving weak electromagnetic fields occurs only at the level of complex, highly organized biological systems, and it is possible that this property is fully manifest only in the human organism [1]. The study of the biological effect of electromagnetic fields on the human organism has the advantage that its results in resolving questions of setting health safety standards can be used directly without any corrections related to the extrapolation to man of experimental data obtained with animals.

The experimental study of the biological effects of low intensity electromagnetic fields makes it possible to ascertain the physiological systems most sensitive to electromagnetic fields in various portions of the spectrum and establish the threshold values of the radiation parameters for various reactions of an organism.

Under conditions of long term exposures, which is possible only at low irradiation intensities, it is possible to trace the development of shifts of an adaptive and cumulative nature, which can be manifest, in particular, by a change in the level of functioning of individual physiological systems. The study of the genesis of functional changes in the human organism with the action of electromagnetic radiation or in combination with other factors in the industrial environment makes it possible to compare the concept of possible paths for the development and the nature of formation of adaption reactions, as well as clinical manisfestations related to the exposure to the factor. This in turn serves as a good basis for the development and organization of a system of prophylactic measures directed towards preventing the unfavorable effect of electromagnetic radiations.

An extremely limited amount of research drawing on volunteers has been done at the present time to study the biological effect of radio frequency electromagnetic emissions.

Some of them are related to the determination of the threshold levels of microwave radiations which cause a perception of heat in man. It has been determined that with exposure to 10 cm wavelength waves, this effect occurs at 10 mW/cm^2 [2], and with exposure to 3 cm waves, at 1 mW/cm^2 [3].

Visual, aural, tactile and other effects caused by radiation have been described [4]. N.I. Matuzov, in studying the area of the projection of the blind spot and adequate optical chronaxy in the case of microwave irradiation at an intensity of 1 mW/cm^2, noted an elevation in the irritability of the visual analyzer [4]. S.F. Libikh later demonstrated that lower intensities caused an expansion of the scotoma while higher doses caused a contraction [5].

Sound perception with the action of microwaves has been described in detail by a number of authors [6]. A similar effect has been observed with exposure to lower frequency electromagnetic fields at 60 Hz to 15 KHz [7]. When men have been irradiated with a microwave field at an intensity of 1 to 3 mW/cm^2, a disruption of coordination of movements has been noted [8]. When studying reactions to a moving object (RDO), it has been determined that microwave irradiation with an intensity of 1 mW/cm^2 increases the reaction precision, something which can be viewed as a stimulating effect of weak microwave energy doses. Extremely interesting is the fact that changes in the indicators for response to a moving object show an onset only after four to five days of exposure. The same thing has been observed when studying the hemodynamics of volunteers with dosed exposure to microwaves [9]. In this case, irradiation at an intensity of 1 mW/cm^2 has led to an increase in almost all hemodynamic indicators (with the exception of pulse pressure and systolic volume). The effect of radiation with an energy flux density of 3 mW/cm^2 caused a reduction in the indicators being studied. In the case of combined exposure to microwave and VHF electromagnetic fields, no changes were detected after 5 exposures, but after 10, the depressive action of the factor was noted. Also noted was a rise in the extent to which biochemical changes were pronounced in step with the increasing number of exposures [10].

In the authors' own research, in the case of exposure to electromagnetic fields of low intensity, no substantial shifts in the reactions being studied were noted in the first four to five days of irradiation. Only in subsequent days was a realignment of functions at a new level of activity noted.

Some researchers in the case of inadequate repetition of the exposures have not obtained reliable measurements, and in a number of cases have drawn the insufficiently substantiated conclusions that low intensities are biologically insignificant.

The results of published research attest to the fact that different systems of the organism respond to the action of a factor in different ways. Thus, a study of functional shifts in the blood system of man in the case of microwave irradiation (1 mW/cm^2) established that after the first exposure session, phagocytosis intensity fell off. When the number of exposure sessions was increased up to 5 to 10, as well as during the aftereffect period, the studied indicators for irradiated animals did not differ from the control values.

Studies of the gas exchange status of volunteers exposed to microwave irradiation at an intensity of 3 mW/cm^2 demonstrated that in the first days of exposure, oxygen consumption increased among the test subjects. In step with the repetition of the exposures (seven days), the response reactions smoothed out.

This served as the basis for concluding that there was adaptation to the action of the factor. However, after 9 to 10 sessions of irradiation, just the opposite reaction was observed, i.e., a decrease in oxygen utilization [11].

The results of many years of industrial experimental research, performed in the Leningrad Institute of Occupational Diseases and Labor Hygiene have demonstrated that the study of the interrelationships between the physiological functions of man and a physical factor in the industrial environment can be accomplished both under actual production conditions and in a laboratory experiment with simulated production variations of the exposure or variations specified by the theoretical studies. Physiological studies of man, in our opinion, should be based on paraclinical research techniques which have become widespread in medicine. Even the term "paraclinical" emphasized their integral relationship with conventional clinical investigation techniques. The use of these techniques under conditions of human labor activity has expanded the possibilities for evaluating the functional status of an organism working under conditions of the unfavorable action of factors in the production environment. In choosing the methods for functional studies, one should work primarily from the clinical manifestations of exposure to a factor and the nature of the pathology. The major feature of the procedural approach in evaluating functional changes is the comprehensive nature of the studies, which makes it possible to establish the presence, nature and extent to which deviations in the functions being studies are pronounced. In this case, the choice of the specific research methods is determined primarily by the task posed by the research. Thus, for example, the frequent task of estimating the reactions of any one system makes it possible to more deeply investigate the choice of adequate methods which thoroughly reveal the functional activity of this system. Tasks of a wider scope require the choice of methods which make it possible to evaluate the functional status of the systems most sensitive to the action of a factor, where these systems are functionally interrelated.

Physiological investigations should be carried out in different variants, both under conditions of relative quiet and under conditions where functional loads are applied to more fully evaluate the system being studied. In this case, to obtain comparable data, the studies should be performed under strictly identical, standard conditions.

The analysis of accumulated material obtained as a result of evaluating the functional status of an organism working under conditions of exposure to electromagnetic fields attests to the expediency of performing these kinds of studies and makes it possible to note the major requirements placed on their performance. For physiological studies in a production environment, it is necessary to carefully select both the main and control groups of subjects. The work conditions of the groups being compared should be identical in terms of the nature of the work process, and the characteristics of the industrial environment with the exception of the electromagnetic factor. The conformity of the groups should be observed both with respect to such indicators as sex, age, length of service, etc. The study should be performed on healthy persons, and in the same seasons of the year if the work is carried out over a number of years. The groups of study subjects should be segregated according to various attributes, such as for example, frequency band, irradiation conditions and intensity, the combination of exposures, etc.

On of the major trends in the study of the functional status in the organism of workers is to be considered the statistical physiological assessment of the various homeostatic systems of the organism, i.e., the evaluations of the levels of their functional activity, which are produced during the process of environmental exposure, including the exposure to the factor being studied.

The functional systems under study can be physiologically characterized by means of determining their indicators recorded in various ways prior to the start of the work process under conditions of relative quiet. For a deeper assessment of the functional capabilities of the physiological systems being studied, adequate functional loads should be employed.

When performing such research, sufficiently large contingents of workers under conditions of exposure to electromagnetic fields and appropriate control groups have been selected, something which has made it possible to comparatively evaluate the data obtained in different groups with various lengths of service and to characterize the dynamics of the functional realignment of the systems of the organism in the process of exposure to the factor being studied.

From standpoints of modern physiology, the transition of physiological systems from one functional level to another can, on one hand, in the case of adaptation, be accompanied by increased performance of the functional system, and on the other, by a reduction in its performance as a result of fatigue and functional exhaustion.

Physiological studies of workers can also be accomplished during the execution of production operations during the course of a work day. It is well known that the work process generates a definite dynamic stereotype, characteristic of various professional groups. In those cases where the production activity is realized under conditions of unfavorable exposure to a particular factor in the production environment, one can anticipate disturbances of the developed stereotype or the one being developed.

A third extremely important trend in research is the study of biological rhythms. As our research has shown, workers under conditions of irradiation are capable of changing the diurnal periodicity of their physiological functions.

Experimental studies using low intensity electromagnetic fields on volunteers, nct previously exposed to radio waves, guarantee complete exposure safety, and consequently, the permissibility of a detailed study of the factor.

Persons included in a laboratory experiment should be practically healthy. The preliminary assessment of the physiological indicators of the functions under study provides for a rather homogeneous selection of volunteers according to typological features and adequacy of the reactions to the procedures being employed and the experimental situation.

The first step in an experimental study consists in extinguishing the orientation reactions and the adaptation of the test subjects to the experimental conditions. This period continues for no more than five days. The extinguishing of the orientation reactions is determined by the relative stability of the indicators being recorded. This step should be executed in precise time wise accord with the experimental model. The next step in the investigations, being a continuation of the first, should provide for the capability of a comparative assessment of the parameters being studied with imaginary and real irradiation of various test subjects.

Concurrently with the major experimental group, the research is performed on persons not exposed to irradiation, i.e., only with imaginary exposure to the factor. Such control is especially expedient during long term experiments and has the goal of ascertaining the presence of cumulative effects. In this case, the duration of the research with exposure to the factor being studied should be no less than 20 days. Such a formulation of an experimental study makes it possible to ascertain the threshold values of electromagnetic fields based on the criterion of functional accumulation of a biological effect, which is of great importance in substantiating standard values.

Each experimental study should be performed during definite hours, under strictly monitored, fixed meteorological conditions, while maintaining the specified irradiation parameters. Each experiment begins with a preliminary 20 to 30 minute adaptation of the test subject to the microclimatic conditions in the laboratory should be optimal. Then, the physiological parameters of the functions being studied are recorded in a definite sequence so as to avoid possible functional loading by one method on the sequentially recorded indicators for another function. Repeated recording of the indicators is accomplished in a set sequence: immediately after terminating the radiation and during the recovery period. The daily exposure is determined in each specific case either by the industrial time wise models for the irradiation or by the theoretical tasks of the research. Investigations of physiological systems can be carried out during the irradiation process. In this case, to avoid artifacts when recording indicators, it is necessary to preclude the possibility of contact between the metal sensors and the human body during general irradiation or with parts of the body exposed to local electromagnetic fields.

Based on an analysis of data in the literature and experience with their own research, the authors consider it possible to recommend the following methods for functional studies of volunteers:

--Electroencephalography;
--Methods of evaluating various analyzer systems (visual, aural, temperature);
--Psycho-physiological tests;
--Mechanical cardiography;
--Rheoplethysmography;
--Occlusion and simple plethysmography;
--Study of heat regulation, etc.

To assure the compatibility of work results, not only the procedural approaches to the performance of industrial and experimental studies should be standardized, but also the set of physiological instrumentation used in them.

Up to the present time, no unified principles have been developed for evaluating the impact of an environment, including electormagnetic fields, on functional systems of an organism. It is well known that the physiological substantiation of the recommended maximum permissible level of industrial environmental factors should be based on definite physiological criteria. One of these criteria, in our opinion, when evaluating the threshold effect of electromagnetic fields in experimental studies on volunteers can be the cumulative biological effect which is manifest in a change in the level of functioning of the systems of the organism which are most sensitive to long term exposure.

When resolving questions of setting health safety standards, the results of experimental research must be interpreted correctly, for which it is essential to compare them with data in the case of imaginary exposure and with control group data, as well as with the data obtained from practically healthy persons during industrial observations, with the obligatory comparison to clinical manifestations of exposure to the factor.

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THE TASKS AND PLACE OF CLINICAL RESEARCH IN SETTING HEALTH SAFETY STANDARDS FOR ELECTROMAGNETIC RADIO FREQUENCY EMISSIONS

V.G. Artamonova and A.Ye. Vermel'

The impact of radio frequency electromagnetic fields on the human organism has been studied for a long time, though changes in the functional status of organs and systems in people exposed to a given factor nonetheless are frequently treated far from the same way by various authors. The reason for this lies, on one hand, in the inadequate knowledge of the mechanism for the action of electromagnetic radiations, and on the other hand, in the absence of unity in the interpretation of the reactions observed in this case.

As is well known, the basis for establishing the maximum permissible levels of radio frequency exposures is the ascertaining of the harmful thresholds. In the USSR, decisive importance is attributed in this case to functional changes, in contrast to a number of foreign countries where the major role is assigned to morphofunctional disturbances.

Noting on the whole the definitive achievements of domestic medicine in the study of the clinical picture of radio frequency exposures, it is necessary to note at the same time that a whole series of questions relating to the problem continue to remain insufficiently worked out up until now.

In analyzing the literature devoted to the study of human organism reactions to exposure to low intensity electromagnetic fields, attention is drawn to the extraordinarily large number of search investigations directed towards ascertaining both the clinical shifts and the changes in the individual laboratory indicators. The estimated indicators also include those such as subjective reactions to the irradiation, status indicators for the higher nervous activity and cardiovascular system, digestive organs, kidneys, endocrine organs, as well as the organs of vision and hearing. The influence of electromagnetic fields on EEG's and EKG's, gastric secretion, the morphological composition of the blood, individual biochemical indicators, immunity status, reproductive function and the overall morbidity has been described in detail [1-6].

It must be noted that the clinical significance of the data cited in various papers is not of the same value. A significant number of the ascertained shifts cannot be treated solely as a manifestation of pathology. Some of them can be treated as responses to an external stimulus (the electromagnetic field), i.e., belong among the indicators of radio sensitivity, or themselves reflect the development of phenomena of an adaptive nature.

Undoubtedly, a characteristic feature of the development of radio damage is the occurrence of functional disturbances in the central nervous system, in particular, the hypothalamus and in reticular formation. These disturbances are manifest as clinical syndromes, which vary in frequency and the extent to which they are pronounced, but are close to each other in essence and number among neuroses with varying degrees of vegetative disorders [4]. This includes vegetative dystonia (and as a special case, neurocirculator dystonia with various disorders of central and peripheral hemodynamics), as well as neurasthenic or astheno-neurotic syndromes, differing degrees of vegetative-vascular paroxysms and some others.

Despite the unanimous opinion of domestic clinical specialists and physiologists concerning the functional nature of the disorders enumerated above, various researchers do not give the same interpretation to the physiological reactions and clinical syndromes which develop in persons exposed to radio waves. It must be pointed out that even in the question of the rightfulness of the concept "radio frequency illness", there are various points of view. In essence, there are no uniform diagnostic principles for the detectable changes, there is no clear cut understanding of the timewise pathology of the impact of an electromagnetic field on the human organism, and public health and safety conditions as well as the influence of other factors in the industrial environment on the health status of people working when exposed to electromagnetic fields are not always correctly taken into account.

Everything that has been said causes well known difficulties in comparing data obtained by different researchers, since there are no overall criteria for estimating the observed clinical reactions, and reliable demonstrations of the relationship of these reactions to the influence of the factor being studied are frequently lacking. As an example of the not altogether successful treatment of the detected clinical changes, one can refer to the review published in 1977 devoted to the influence of microwave band electromagnetic fields on the human cardiovascular system [7]. In this review, such phenomena as the "muting of heart sounds, the shifting of its boundaries and systolic noise" are cited as proof of the negative impact of an electromagnetic field on the cardiovascular system. All of the enumerated attributes are not proof of cardiac pathology. They are encountered with a very high frequency among healthy people, and moreover, ascertaining them is of an extremely subjective nature. The use of such criteria leads the author to an extremely free treatment of the concept of myocardial dystrophy and to an arguable explanation of the influence of electromagnetic fields on vascular tone. It is also no accident that some foreign authors point out that the drawbacks to the work of Soviet researchers are the "limited statistical analysis of the collected data, the lack of adequate control and quantitative evaluation of the material" [8].

It follows from what has been said that an important task of clinical research at the present time is the creation of a standardized system of examining people exposed to electromagnetic radiations, and the development of uniform principles for evaluating the reactions of the human organism to the indicated exposure.

Along with this, the successful resolution of numerous clinical problems proves to be possible only given a combining of efforts by clinical specialists in various institutions in our country, i.e., with the organization of widescale clinical research within the framework of a unified comprehensive program. This program should make it possible to resolve the questions posed above in a comparatively short time, and in particular, to collect a maximum of information and make the interpretation of the obtained data objective.

These kinds of clinical studies are widespread at the present time and assist in the operationally timely solution of many complicated problems. It was specifically because of the clearcut manner in which cooperative research was set up in the U.S. that they were successful in their time in solving many problems of berylliosis in a short period of time. Wide scale international clinical studies are underway in our time. For example, the effectiveness of various chemotherapy schemes for certain neoplasms as well as the epidemiology of cardiovascular illnesses, etc. is being studied in the plan of the Soviet-American medical program.

Since the creation of a standardized system of examining workers is of decisive significance in the conduct of cooperative research, it is exceptionally important to establish the critical organs and systems which are the most sensitive to electromagnetic radiation esposure, as well as to choose the main clinical and laboratory indicators which objectively reflect human reactions to the action of the factor being studied.

To assure the capability of comparing data obtained under different industrial conditions, it is necessary to take into account the characteristics of radio frequency emission as a whole with all other factors in the production environment. In this regard, the parameters of the electromagnetic exposure and frequency range, nature of the radiation (continuous or pulsed), nature of the exposure (constant, intermittent; overall, local), the intensity, duration as well as the possible impact of other production factors (noise, X-ray radiation, the temperature factor, labor intensity, etc.) and those of a nonproduction nature (social and everyday living conditions, etc.) must be indicated in the public health and environmental physiology characteristics which are obligatory for any occupational pathology and clinical investigation.

As has already been noted, the interpretation of clinical shifts which take place under the influence of low intensity electromagnetic fields poses definite difficulties. The developing functional changes on the part of the central nervous system, which are manifest in diverse neurotic syndromes, do not have any kind of specificity, while their appearance is one of the most frequent responses to the action of multifarious stimuli of an exogenic and endogenic nature. As is well known, the development of a neurosis can be the consequence of conflict situations in domestic life and in production, as well as exhaustion, unfavorable meteorological conditions, intercurrent injections, the result of exposure to diverse physical or chemical factors, etc.

Naturally, the lack of specific radio wave damage marker criteria among the cited clinical reactions makes a precise etiological diagnosis of the observed functional changes difficult. Along with this, it has been noted that these changes, which are usually of the same type, occur only among workers who have a long length of service and are exposed to electromagnetic radiations at levels exceeding the maximum permissible levels.

The careful dynamic observation of the test contingent of persons and the choice of the appropriate control groups of people working under similar conditions, but not exposed to electromagnetic fields, are of great importance in understanding the role of radio frequency emissions in the development of particular clinical reactions.

Taking into account the nature of the physiological reactions and the clinical shifts which develop, it is necessary to select the most informative research techniques when creating a standardized system of medical examination of persons subjected to electromagnetic radiations. In this case, it is expedient to break them down into obligatory and facultative. To be included among the first is the detailed clinical examination (by a neuropathologist, therapist and oculist). Working from the specific features of changes in the nervous system when exposed to radio frequency electromagnetic fields, special attention must be devoted in the clinical status to ascertaining the attributes of vegetative dysfunction. In this regard the data on patient history should contain information on the ability to endure unfavorable microclimatic exposures (cold, heat, a stuffy room), accelerations (trips in a car, swing, hammock, boat), the extent to which vegetative reactions are pronounced in the case of agitation (nasal vasomotor lability, hyperhydrosis and hypothermia of the hands, heartbeat), with the precise time when these disturbances appeared (starting in youth or in later years; the months).

Attention should be devoted to the presence or absence of vegetative shifts during the neurological examination: in the dermal vascular response to mechanical and chemical stimuli, sweating, and studied data on the orthoclinostatic reflex. To more precisely specify the status of the higher functions of the central nervous system and make the neurotic and asthenic manifestations objective, it is expedient to conduct studies of the bioelectric activity of the cerebrum (EEG) using functional loads as well as study the reaction thresholds of a number of analyzer systems.

The extent to which vegetative vascular dystonia is spread among persons exposed to electromagnetic fields determines the necessity of studying overall (central) and regional (cerebral) hemodynamics. In developing programs, it is necessary to precisely specify the specific methods recommended for investigating various hemodynamic indicators (mechanical cardiography, isotope studies, dye tracing, rheoencephalography, etc.). The measurement of arterial pressure in the brachial arteries, the determination of the size of the vessels in the fundus of the eye and EKG examination are to be numbered among the obligatory methods of studying the cardiovascular system.

Besides those included among the obligatory methods, one should also include the description of the status of the transparent media of the eyes, the study of lipid exchange and the study of the morphological composition of the blood.

The set of facultative tests can be determined by the specific features of each production environment, the scientific interests of the researcher and the possibilities for using particular techniques. These can include the study of a series of biochemical indicators, the evaluation of the hormonal status, the status of the organism's immunological activity, etc. When selecting both the obligatory and facultative tests, one must take into account the possibility of using them during mass studies. The analysis of the data obtained requires the observance of a strictly correct approach.

One of the important tasks of clinical research is the study of the remote consequences of long term exposure to low intensity electromagnetic fields. The high frequency of functional neurological disturbances, in combination with vegetative dystonia in the form of disturbances in the regulation of vascular tone and extracardial functional disturbances, makes it necessary to carefully study the prognosticative significance of the indicated disturbances and their role in the origin of certain general somatic illnesses: primarily hypertension and chronic ischemic heart disease, as well as the impact of long term exposure to electromagnetic radiation on the development of certain involutional processes, including cataractogenesis. These questions, and in particulat, the role of the physical factor being studied in the development of hypertension and coronary pathology are discussed in our literature [9-10]. However, the conclusions of these papers are still to treated only as preliminary, since they are based on a comparatively limited amount of clinical data. The clinical study of the remote consequences of exposure to electromagnetic radiations is of exceptionally great importance at the present stage, primarily for checking the substantiation of existing health safety standards and the effectiveness of the protective measures being taken.

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INFORMATION ON THE ADDRESSES TO THE SEMINAR

I.P. Sokolova and Ye.K. Lebed'

Some 39 persons took part in the discussion of the issues raised at the seminar concerning the methodology of setting health safety standards for nonionizing radiations. It is appropriate to present the opinions of the rather large group of scientists on the most urgent questions of the problem under discussion.

The problems posed for environmental physiology science in light of the resolutions of the 25th CPSU Congress and the 16th USSR Trade Union Congress were reflected in the address of deputy chief public health physician of the USSR, candidate of the medical sciences A.P. Zaichenko, in which the importance of a more rigorous scientific substantiation of maximum permissible levels was underscored in light of rapid scientific and technical progress. The author of the paper especially emphasized the necessity of taking into account the time factor when setting standards, the importance of bringing the viewpoint of specialists in occupational and public health safety closer together for the purpose of developing unified standards which take into account both occupational and nonoccupational exposure. This same question was reflected in the speech by professor M.G. Shandala, in whose opinion "It is impossible to establish regulations for nonoccupational exposure without knowing occupational conditions, and vice versa". M.G. Shandala believes that all environmental factors can be broken down into two groups: those inherent in nature and the fundamentally new ones. In the case of the former, he considers it necessary to evaluate not only excess exposure which leads to definite reactions of an organism, but also underexposure, which is likewise fraught with various unfavorable consequences. In evaluating such factors, it is proposed that three levels be established: optimal, ultimate (or maximum) permissible and the minimum necessary. In speaking about the responses of an organism to exposure to electromagnetic factors, the author singles out four zones: the zone of primary (or evolutionary) adaptation; the zone of compensator reactions or secondary adaptation; the zone of reparative regeneration and the zone of pathology.

M.G. Shandala feels that the maximum permissible levels for occupational exposure should fall in the range of compensator reactions, and for the irradiation of the populace, it should fall within the range of primary adaptation.

In the opinion of professor B.M. Savin, such an approach is not a real one given the hardware state of the art. The maximum permissible levels for the populace should go beyond the range formed by the natural background, since otherwise we will not in essence be able to do anything which adds to the natural exposures. For this purpose, a more detailed study of the range which M.G. Shandala called the zone of compensation is necessary. This range can be extremely great and change depending on age, health status, etc. B.M. Savin also indicated the necessity of a specific determination of the reactions, the threshold of which will be the basis for setting the maximum permissible levels, once again underscoring the fact that in this case, simply an action threshold or sensitivity threshold cannot be used, since the latter completely depends on the sensitivity of the study methods employed.

Doctor of the medical sciences A.G. Subbota turned the attention of seminar participants to the fact that nonionizing radiations encompass an enormous range of the electromagnetic spectrum, and that only a few bands have been studied sufficiently well at the present time out of this entire spectrum. This is evidence of the necessity of organizing wide scale research in the radiobiology of nonionizing radiations. The author of the paper noted fundamental differences between radio frequency electromagnetic emissions and other factors in the environment:

--Limited penetration into tissues, which leads to the fact that all of the shifts via the mechanism of chiasma of the afferent paths are directed towards opposite portions of the central nervous system and are realized on the side of the body opposite to the irradiated side; this is evidence of the necessity of taking into account the worst case exposure variant in the physiological plan along with the irradiation parameters when developing standards;

--The impossibility of using a number of physiological methods which require contact between metallic elements (for example, electrodes) and the body of man or animals, as well as the change in field distribution in the organs as a function of the direction of irradiation;

--The impossibility of extrapolating data in a number of cases from animals to man because of differences in the geometric dimensions of the bodies and the species differences in physiological functions.

Professor Z.V. Gordon turned attention to the fact that the term "radiobiology" as applied to nonionizing radiations is not a successful one, since it is traditionally related to ionizing factors. She underscored the lack of health safety standards in a number of nonionizing radiation bands and the necessity of a more differentiated setting of standards for the radio frequency range. In this case, Z.V. Gordon grants that the laws which have been sufficiently well studied in one band (for example, the dose dependence of biological effects) must be extrapolated to others, since the engineering cannot wait while we "go through" all the bands.

The address of V.S. Blumental was devoted to the question of the health safety evaluation of intermittent exposures. The author feels that breaking exposures down into continuous and intermittent without indicating the pulse width and repetition rate parameters does not make it possible to determine the true degree of danger of the latter. Moreover, determining the type of irradiation (continuous or intermittent) requires in a number of cases that special oscillographic analyses be made of the field. A procedural approach to estimating radar emissions, based on an accounting for the energy characteristics of the field and organism reactions to the intermittent nature of the exposure. The concept of effective intensity is introduced for this purpose:

$$P_{eff} = P_{avg}\gamma(K),$$

where: P_{avg} is the average value of the intensity of the intermittent irradiation;

$\gamma(K)$ is a factor which takes into account the organism reaction to the intermittent nature of the exposure, and which depends on the pulsation coefficient K: $K = \alpha_m/\alpha_{avg}$, where α_m is the magnitude of the periodic responses of the organism in the steady-state mode when a pulsed field acts on it; α_{avg} is the magnitude of the organism response when intermittent radiation acts on it, the carrier frequency and average intensity of which are similar to the corresponding parameters of the pulsed field.

The determination of the coefficient γ requires the performance of special medical and biological studies.

The following are essential for the instrumented determination of irradiation levels using the proposed approach:

--The measurement of the average value (over the exposure period T) of the intensity P_{avg};
--Measuring the level of the instrumentation response to the pulsed action of the field, P_m;
--Sequentially determining: $K = P_m/P_{avg}$, $\gamma(K)$ and $P_{eff} = P_{avg}\gamma(K)$.

An intrument is needed for the measurement of P_{avg} which has inertial properties which are chosen from the condition $\Theta_{avg} \geq T/\sigma$, where σ is the permissible value of output signal pulsation.

An instrument is needed for the measurement of P_m, the transfer function of which is similar to the generalized transfer function of the organism.

In view of the fact that a number of the circuits of the instruments cited here coincide, in particular, the RF, amplifier and readout circuitry, it is expedient to design one all-purpose instrument, which correspondingly has two operational modes.

An analysis of the dependence of the average and effective intensities on the duty-cycle of the irradiation for different values of the relative pulse width (τ/Θ) shows that with a reduction in the pulse width, the values of P_{eff} approach the average intensity, and with an increase, they approach the peak value.

To determine K and P_{eff}, it is necessary to know the time constant of Θ. Since this parameter characterizes the dynamic properties of an organism, it should be determined on the basis of the corresponding medical and biological data.

In the opinion of candidate of the physical and chemical sciences V.M. Chibrikin, estimating the intensity of an electromagnetic field based on the energy density could be used if a thermal mechanism were the basis for the biological effect. It seems more correct to the author to speak of specific effects or resonance ones. From the viewpoints of acknowledging the resonance mechanism of an exposure, the utilization of a dosage approach in setting standards is the subject of criticism, since not only the energy characteristics of an exposure are important, but also its timewise distribution and the possibility of matching the biological rhythms of an organism. In doubting the expediency of estimating the total field energy ($U_{tot.}$), V.M. Chibrikin devoted attention to the differing sensitivity of biochemical reactions to E and H fields: biochemical processes which are of an ionic nature respond to an electrical field, and those of a radial nature, react to a magnetic field. In dealing with the question of extrapolating experimental data, the author emphasized the nonuniformity of the comparison of exposures on animals of different kinds by virtue of the differences in the depth of energy penetration.

Candidate of the biological sciences V.M. Shtemler turned the attention of seminar participants to the fact that at the present day, the energy interaction of electromagnetic fields with an organism are the most obvious. From this viewpoint, it is rightful to speak of a uniform mechanism for the action of E and H field components, since any alternating magnetic field, in accordance with the law of electromagnetic induction, induces an electrical eddy field in body tissues which should interact with tissues in accordance with the same laws as an ordinary electrical field at the same frequency. Another matter is that the magnetic component of an electromagnetic field can in principle cause some specific effects which are due to the magnetic interactions themselves, with which one must also deal. In particular, it has been demonstrated theoretically and experimentally that it is possible for constant and low frequency magnetic fields to influence the rate of free radical reactions in chemical systems. However, the biological role of these kinds of interactions in the radio frequency band remains unclear at the present time.

In evaluating the cyclical nature of exposures with respect to the circadian rhythms of the organism, V.M. Shtemler noted that it can be of importance if any one system or any one reaction is analyzed. In practice though, the issue is one of many systems and reactions, the rhythms of which do not coincide, and for this reason, it is as if the response of the organism as a whole is the resultant of the exposure of numerous systems.

V.M. Shtemler emphasized that the comparison of exposures to electromagnetic fields for animals of different species is rightful if one works not from the external field, but from the internal fields created in the biological object. Based on the data of American researchers, the author of the paper calculated the irradiation parameters in electromagnetic fields of different frequencies, which provide equal average values of the internal electrical field, current density and absorbed energy for man and animals of different kinds (see the Table).

Candidate of the medical sciences V.A. Zhuravlev in his address noted the existence of substantial differences in the set standard levels for radio emissions adopted in different countries. These differences reach three to four orders of magnitude. The author noted that the principles of determining the duration of microwave irradiation based on integral values of the incident energy (CSSR, Polish People's Republic), as well as setting norms for intermittent exposure (Polish People's Republic) deserve attention. In the opinion of V.A. Zhuravlev, pronounced but reversible functional changes should be the basis for the development of maximum permissible levels. By assigning great significance to health safety margin factors in setting the maximum

TABLE

The Exposure Parameters Necessary to Provide for Equal Values of the Internal Electrical Field, Current Density and Absorbed Energy Density in the Body of Man and Certain Animals

The Calculation for Equivalent Spheroidal Models of Man and Animals

a) Energy Flux Densities for a Plane Electromagnetic Wave, in mW/cm^2 *. The Direction of the E Field Is Parallel to the Long Axis of the Body

Frequency, MHz	Average Man, 70 kg, 170 cm	Dog, 32 kg 90 cm	Rabbit, 3.0 kg 40 cm	Rat, 0.32 kg 20 cm	Mouse, 0.02 kg 7 cm
20; Quasistatic approximation range	1.0	3.6	5.0	5.3	8.0
70; Maximum absorption for man	1.0	7.5	18.0	18.5	30.0
130; Maximum absorption for a dog	1.0	0.53	2.0	2.7	4.7
300; Maximum absorption for a rabbit	1.0	0.57	0.13	0.24	0.67
600; Maximum absorption for a rat	1.0	0.85	0.26	0.04	0.23
1,700; Maximum absorption for a mouse	1.0	1.0	0.4	0.12	0.02
10,000; Quasioptical approximation range	1.0	0.9	0.45	0.17	0.06

* Calculation made from the data of "Radiofrequency Radiation Dosimetry Handbook (Second Edition)" by C.H. Durney, C.C. Johnson, P.W. Barber, et al., 1978, Departments of Electrical Engineering and Bioengineering, the University of Utah, Report SAM-TR-78-22.

TABLE, continued

b) The "Isolated" E Field Intensities (V/m) in the Quasistatic Approximation Frequency Range (≤ 20 MHz)

Exposure Conditions		Average Man	Dog	Rabbit	Rat	Mouse
Long axis of man and animal parallel to the E field	Free Space	1	2.27	2.38	2.14	2.71
	Subject on a conducting plane	1	2.51	2.65	2.34	3.10
Long axis of man and animal perpendicular to the E field	Free Space	1	0.95	0.95	0.95	0.95
	Subject on a conducting plane	1	0.89	0.88	0.90	0.85
Long axis of man parallel to E field, while animal perpendicular	Free Space	1	11.4	11.4	11.4	11.4
	Subject on a conducting plane	1	28.5	28.5	28.7	27.3
Long axis of man perpendicular to E field, while animal parallel	Free Space	1	0.190	0.198	0.178	0.225
	Subject on a conducting plane	1	0.078	0.083	0.073	0.097

c) The Isolated H-Field Intensities (A/m) in the Quasistatic Approximation Frequency Range (≤ 20 MHz)

Exposure Conditions	Average Man	Dog	Rabbit	Rat	Mouse
Identical orientation of the long axis of man and animal in the H field	1	1.06	2.3	5	12
Long axis of man parallel to H field, while animal perpendicular	1	0.75	1.65	3.5	8.5
Long axis of man perpendicular to H field, while animal parallel	1	1.5	3.25	7	17

permissible levels, he believes that the level of cumulative radio frequency effects in an organism should be taken as the criterion for determining the values of the latter. His own research and analysis of the literary data in this field showed that microwaves have a small cumulative capability, which indicates the possibility of employing safety margin factors in a range of from 2 to 10.

In ascertaining three major exposure categories (occupational, nonoccupational in the working zone and irradiation of the populace) and admitting the necessity of setting microwave radiation standards based on a uniform threshold dose for man, V.A. Zhuravlev proposes that the following health safety margin factors be used: 10 for occupationally exposed persons; from 20 to 50 for nonoccupational irradiation in industry; and 100 for the populace.

In entering the discussions on the report of A. G. Subbota and B.A. Chukhlovin, "The Choice of Study Methods and Principles of Evaluating Experimental Data when Setting Radio Emission Standards", professor M.I. Rudnev emphasized the fact that when working out the maximum permissible levels of radio emissions, changes of a functional nature are to be taken as the basis, where methods of studying integral indicators, such as, for example, behavioral reactions and the like should occupy first place in the set of experimental methods.

In giving a positive assessment of the proposals of the conferees, the author of the paper considers it expedient to devote more attention to the study of the status of hormonal functions, the cardiovascular system and remote consequences. He also underscored the necessity of further work on questions of the significance of various organism reactions and the quantitative evaluation of the ascertained changes.

Professor A.A. Kasparov in his address emphasized the importance of standardizing procedural questions when working out health safety norms. He devoted special attention to evaluation criteria for the harmful effect of a factor. He recalled that such criteria in toxicological practice are the extent to which the deviations are pronounced, the stability of the changes and the presence of hidden changes which are ascertained by means of functional loads. Professor A.A. Kasparov emphasized that the most acceptable approach to nonionizing radiations must be determined on the basis of analyzing existing data, and also noted the importance of creating a regulating document for working out the maximum permissible levels.

Doctor of the medical sciences B.A. Chukhlovin supported the proposal of A.A. Kasparov concerning the necessity of working out procedural recommendations. This document can be written on the basis of existing procedural guidelines using materials obtained in recent years. In the opinion of B.A. Chukhlovin, a careful analysis of existing data will make it possible to make a substantial contribution to the resolution of such questions as the selection of research methods, precisely specifying the concept of "harmful action threshold" as applied to exposure to radio radiations, setting a differentiated standard as a function of the frequency characteristics of a band and exposure time as well as extrapolating experimental data from animals to man.

Professor M.G. Shandala, in emphasizing the body of research to be used in ascertaining the threshold levels of a factor, noted that to establish the adequacy of methods, the understanding of the mechanisms of a factor is of great importance. Professor M.G. Shandala feels that the set of methods recommended by the conferees is suitable only for special categories of persons. However, when the issue involves the population, the regulating of radiation for persons in various age groups and of different health status, then some other criteria are needed to evaluate the harmful action of a factor. The author believes that a special resolution of the question of using the setting of communal health standards in practice for the health safety margin factors is also needed.

Candidate of the medical sciences F.A. Kolodub underscored the fact that changes in the exchange processes are the basis for the structural and functional changes which are interpreted as signs of harmful exposure to electromagnetic emissions; among these changes, a disturbance of the energy exchange is to be put in first place. F.A. Kolodub considers it important to estimate the level of macroergic [sic] compounds, and the intensity of oxidation and phosphorylation processes. As far as protein exchange is concerned, changes in it, as a rule, are evidence of far advanced stages of disturbances. Preformed ammonia can be used as an integral indicator in this case. The author of the paper cited nucleic acid content, the overall level of enzymes, testosterones as well as indicators which characterize the function of the vegetative nervous system as important biochemical indicators.

I.P. Los' turned the attention of seminar conferees to the importance of developing predictive methods of studying nonionizing radiations, which requires the gathering of rather precise information at the present stage, where this information characterizes the biological impact of electromagnetic emissions. He also noted that in research using low intensities, the duration of exposure to a factor is of great importance. The author of the paper shared the results of his own work which is directed towards finding integral parameters which characterize the biological activity of radio frequency exposures. In this regard, indicators for the rate of recuperative processes and the probability of occurrence of deviations were treated based on the data from an analysis of the variability of the individual functions which were studied.

V.D. Vatutin emphasized the necessity of standardizing not only the methods of studying biological indicators, but also the methods of irradiating animals. Working out the requirements placed on the technical hardware for experiments should be accomplished taking into account the specific features of specific radio frequency bands. Such standardization is important from the viewpoint of the possibility of comparing the results of studies by various authors.

In speaking on the report of T.V. Kalyada, V.N. Nikitina and M.V. Shepeleva, "Methods and Criteria for Evaluating the Results of Studies on Volunteers when Resolving Questions of Setting Health Safety Standards", professor B.M. Savin dealt with the issue of the site of observations of volunteers included in other studies when substantiating maximum permissible levels. He does not share the viewpoints of authors concerning the simultaneous conduct of experimental research on animals and on volunteers. Such a formulation of the question, in his opinion, is possible only in those cases where there is already a sufficient amount of data which makes it possible to estimate the degree of danger of one exposure or another. And an experiment on animals, in which obtaining data on safe levels of a factor is assured, should precede studies on volunteers. The goal of the latter should be to check the safety of the values recommended as the maximum permissible levels and to ascertain the specific features of reactions to exposure of the human organism to a factor.

Professor B.M. Savin then turned the attention of the conferees to the fact that it is impossible to put an equal sign between the realignment of a functional level in general and a cumulative effect. A realignment may even be expedient which is directed towards equalizing external effects. Whereas a cumulative effect means that the organism is not coping with the load impinging on it, that there is no recovery after periodic exposure to a factor, the accumulation of various shifts with time is observed. The transition from adaptation to a cumulative effect occurs where the realignment becomes extreme. There is doubt as to the ability to study such shifts in man. This is evidence of the fact that the question of criteria for evaluating results obtained in studies on volunteers requires serious procedural preliminary work.

The seminar participants showed great interest in the clinical questions of the problem. Candidate of the medical sciences M.N. Sadchikova in her report characterized the dynamics of clinical manifestations of exposure to a factor. She demonstrated that for persons working in the production shops of radio electronics enterprises with intensities of up to several milliwatts per square centimeter, there was no pathology in the initial years. Hypotension and bradycardiya were noted in this case on the part of the cardiovascular system. However, after 7 to 10 years, despite a fundamental improvement in working conditions, illnesses began to manifest among these persons, where the diseases are characterized predominantly by the sympathotonic direction of the vegetative reactions. The vegetative vascular changes were retained among the patients after the work was stopped, but as a rule, they were no longer accompanied by paroxysmic manifestations. The author of the paper verified the fact of the occurrence of ischemic heart disease among a number of workers and in a few individual cases, myocardial infarct. However, it was not possible to completely relate these cases to exposure to the factor. M.N. Sadchikova feels that it is correct to speak of diagnosing an illness related to exposure to radio frequency electromagnetic emissions as an independent nosological unit "radio frequency disease".

Doctor of the medical sciences A.M. Vyalov shared his opinion that in occupational pathology, it is not expedient to use the term "neurosis", which modern science understands to be of psychogenic origin and due to an unfavorable social situation or neuro-emotional stresses, and that it is better to speak of neurosis-like states. He also noted the inhomogeneity of the clinical data from a symptomatological viewpoint, and the somewhat artificial distribution of the symptomatology with respect to definite symptoms. A.M. Vyalov called for a more careful analysis of the clinical symptomatology for the purpose of defining a single syndrome characteristic of radio frequency exposures, something which will make it possible to more adequately assess the health status of workers. He defined the presence of changes in the vegetative nervous system as the most characteristic attribute of occupational pathology, where neurotic reactions are in first place in the case of situational exposure.

Doctor of medical sciences A.Ye. Vermel' feels that the term "neurosis-like state" proposed by A.M. Vyalov is not a successful one, since such a diagnosis should be based only on knowledge that the patient worked under conditions of exposure to electromagnetic radiations in a particular band, and since the symptomatology related to exposure to the factor completely conforms to the clinical picture of neuroses. The author of the report devoted to problems of clinical studies in setting health safety standards for radio frequency electromagnetic emissions does not agree either with proposal of singling out an illness related to electromagnetic radiation exposure as an independent nosological form - "radio frequency disease" - since the issue involves known illnesses of a polymorphous etiology, where the factor we are considering can also be guilty in the occurrence of the disease along with others. He states that an illness cannot be called an independent disease which does not have an independent pathogenesis as well an independent clinical picture and specific marker criteria.

In the opinion of candidate of the medical sciences K.V. Nikonova, the investigation of the fate of hypertensive states in the clinical picture of radio exposures is problem No. 1, on the solution of which the fate of our health safety standards depends to a considerable extent. She turned the attention of seminar participants to the fact that at high exposure levels for a factor, only hypotension occurred. The the hypotensive reaction is also a characteristic feature seen in the data of experimental studies, since hypertension has been noted in experiments predominantly either with thermal electromagnetic radiation intensities or as a short term transient phase. The observation that special studies do not ascertain any definite dependence of frequency and extent of hypertension cases among workers using microwave sources on the intensity of the exposure. Considering the nonspecific nature and wide dissemination of the changes under discussion, the clarification of the question of their relationship to working conditions for various categories of specialists is an important clinical problem.

Professor Ye.V. Gembitskiy noted the importance of solving procedural questions of setting health safety standards for radio emissions. Attributing great importance to studies on volunteers, he supported the opinion put forward by B.M. Savin concerning the procedure for the developmental work: first the experimentation on animals to establish the harmful exposure thresholds and only thereafter, the studies on man. Analyzing the situation which has arisen with the recognition of the pathology related to exposure to the factor, in the USSR and related to its denial abroad, Ye.V. Bembitskiy noted the existence of significant procedural difficulties when studying the impact of electromagnetic emissions on an organism. Is there radio wave disease or not? This question is proving agonizingly difficult to solve for two reasons: 1. There is no specific symptomatology; 2. The pathological symptoms are not clearly drawn. This question requires careful preparation and treatment in a special symposium. The author of the paper does not support the term "radio frequency illness" and the singling out of all cases of illnesses as independent nosological unit; he is a supporter of syndromological diagnosis. Ye.V. Gembitskiy emphasized that despite the arguable nature of the terminology, the question of the possibility of the occurrence in workers using microwave sources of disturbances of the functions of the nervous, cardiovascular and other systems of the organism is beyond doubt. He feels that in the report of V.G. Artamonova and A.Ye. Vermel', the following three directions for clinical studies are justified as the major ones: ascertaining early premorbid forms; studying remote consequences; ascertaining the impact of a factor on the course of other illnesses (hypertension, ischemic disease, stomach ulcers). He thinks that the scheme proposed in the paper for the conduct of investigations can be taken as the basis. Ye.V Gembitskiy also turned attention in his address to the fact that the use of the concept "radio sensitivity" and "radio vulnerability", carried over from the radiobiology of ionizing radiations does not have adequate bases in the case of nonionizing factors.

A number of foreign colleagues, cooperating with Soviet specialists in the field of standardizing approaches to the environmental physiological evaluation of nonionizing radiations via CEMA channels likewise became familiar with the seminar materials. The GDR representative, national coordinator for the indicated efforts, doctor Ju. Kupfer familiarized us with their opinion. He noted that the materials of the seminar were accepted with approval. He underscored the importance and timeliness of holding the seminar in connection with the existence of fundamentally different approaches to the estimation of the danger of the factor in various nations. Doctor Ju. Kupfer pointed out that characterizing radio frequency exposures only in terms of the parameter of intensity is inadequate and it is necessary to take into account the time and conditions of the exposure as well. He noted that in setting standards for numerous physical and chemical factors, a dosage approach has proved itself well and that at the present time, there are all the reasons for discussing the possibility of utilizing it in setting standards both for microwaves and for other lower frequency electromagnetic fields. Doctor Ju. Kupfer warmly supported the idea of coming up with procedural recommendations for the performance of studies having the goal of substantiating maximum permissible levels. He feels that the recommendations should include the requirements placed on the conduct of both experimental and epidemiological investigations; they should set the regulations for the conditions under which experiments are conducted and the approaches to extrapolating experimental data to man as applied to various frequency bands, as well as contain a program for processing biomedical data by means of modern computer hardware. In conclusion, doctor Ju. Kupfer expressed confidence that the seminar and the decisions it worked out will promote an increase in the mutual understanding and a coming together of the points of view of scientists of various nations concerning the question of estimating the danger of both radio frequency and other bands of nonionizing radiations.

The material presented in this paper attests to the fact that a number of extremely important issues was raised at the seminar concerning the methodology for setting health safety standards for radio frequency electromagnetic emissions. Differing points of view exist at the present time concerning a number of them. It appears that the exchange of views at the seminar will promote greater closeness in the viewpoints of specialists working in the problem area and the development of unified approaches to setting standards for the factor.

METHODS OF STUDY AND EVALUATION CRITERIA FOR THE BIOLOGICAL EFFECT OF ELECTRICAL FIELDS AT THE INDUSTRIAL POWER FREQUENCY

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The problem of the biological effect of industrial power frequency electrical fields (EP p/ch) is taking on increasingly greater importance.

The rapid development of electrical power engineering and bringing larger ultra-high voltage (SVN) power systems on line with lengths of tens of thousands of kilometers provide the basis for treating the electrical fields they produce as a factor which takes on ecological significance.

The existing data attest to the fact that industrial power frequency electrical field can exert an unfavorable influence on the human organism and the environment. This governs the necessity of setting regulations for the exposure to the factor. The inadequate degree of study of the biological impact of industrial power frequency electrical fields and the lack of rigorously substantiated health safety standards sharply increase the difficulty of planning ultrahigh voltage lines and substations. The lack of scientifically substantiated design standards in turn can lead to the creation of electrical power transmission lines (LEP's) which are ecologically dangerous or to an unjustified increase in their cost.

Assuring human and environmental safety from the unfavorable impact of industrial power frequency electrical fields becomes an especially acute problem because of the planned placing in service of the 1,150 KV and higher power lines. The resolution of the question of the ecological safety of the power engineering facilities of the immediate future depends to a significant extent on the results of medical and biological research.

The problem of the biological impact of industrial power frequency electrical fields has a number of independent areas which provide for the study of the influence of the factor on the human organism as well as flora, fauna and ecosystems.

Methods of studying and evaluation criteria for the biological impact of industrial power frequency electrical fields are treated in this paper, where these methods and criteria are employed in substantiating the maximum permissible levels (PDU) for the action of a factor on the human organism.

In accordance with data from the literature, the intensity of industrial power frequency electrical fields to which a human can be exposed is already reaching 30 KV/m at the present time. A further rise in the capacities of power systems and the increasing working voltages may lead to an even greater increase in the exposure levels, which if special protective measures are not implemented, may reach 40 KV/m and more.

The resolution of issues related to the study of the impact of industrial power frequency electrical fields on man was started as early as the 1960's in USSR because of the mastery of 500 KV electrical power transmission. During these years, Soviet authors performed a number of investigations, the result of which was the establishing of the first health safety standards in world practice which set regulations for the exposure level to industrial power frequency electrical field for workers [1-2].

TABLE 1.
Health Safety Standards in Force in the USSR

Electrical Field Intensity, KV/m	Permissible Exposure Time of Personnel During a 24-Hour Day, in Minutes
Less than 5	Unlimited
From 5 to 10	No more than 180
From 10 to 15	No more than 90
From 15 to 20	No more than 10
From 20 to 25	No more than 5

The maximum permissible levels for electrical fields which are in force in the USSR, for fields generated by industrial power frequency currents at voltages of 400 KV and higher, are given in Table 1.

For the remainder of a working day, the electrical field intensity should not exceed 5 KV/m. At field intensities above 25 KV/m, a provision is made for the use of special protective gear.

The research materials taken as the basis for the existing health safety standards have been repeatedly reported at international forums and have caused great interest among foreign researchers [3]. Along with this, a number of critical remarks have been put forward. In line with the tasks of this paper, the indicated materials which have been supplemented with work in later years will be analyzed in comparing the data of foreign authors for the purpose of ascertaining the reasons for the contradiction in the opinions on the question of the unfavorable impact of industrial power frequency electrical fields.

It is completely obvious that the studies performed in the 1960's cannot pretend to a final and exhaustive resolution of the question, since their conclusions were based on the use of a comparatively limited number of methods. They were basically devoted to an evaluation of the health status and the status of individual physical functions of the personnel servicing high voltage power installations and subjected essentially to an aggregate of production factors.

In studies on people, the health status evaluation was made using the data of a questionnaire and a medical clinic examination of workers using a number of clinical and laboratory methods.

As a result of examining the health status of more than 300 persons, Soviet authors determined that persons servicing ultrahigh voltage substations and open wire lines (VL) complained about headaches, irritability, increased fatigue, sleepiness, disturbance of the memory and attention, pain in the region of the heart, a reduction in sexual potency, etc. [4-5].

Various kinds of changes in the regulation of vascular tonus and heart activity have been described [6]. A change in the content of hemoglobin, reticulocytes, neutrophyls or tendency towards leucopenia with pathological graininess of the neutrophyls, monocytosis, moderate thrombocytopenia as well as retardation of the erythrocyte sedimentation rate have been noted in studies of the peripheral blood [2, 5, 6]. According to the data of V.D. Dyshlovoy and V.S. Kachura [4], a reduction in the production of male sex hormones of both testicular and adrenal origin was found in persons with a changed sex function.

Based on the results of a medical clinic examination of a portion of those persons involved in servicing ultrahigh voltage electrical facilities, changes in the functional status of the central nervous and cardiovascular systems were diagnosed, where these changes are manifest in the form of vegetative vascular dystonias and more rarely as a neurasthenic syndrome. It was noted that for the personnel of 500 KV substations, the indicated disturbances were encountered more often than among workers at 330 KV substations.

It has been noted in a number of papers that the ascertained changes are pronounced to a moderate extent and are of a reversible functional nature [6].

A clinical geneological examination performed on 200 families of 330 KV to 750 KV substation and line service workers did not reveal any changes which could be related to the effect of the industrial power frequency electrical fields based on such indicators as the ratio of sexes in the progeny, spontaneous abortions, stillbirths, or inherited diseases [4].

The physiological investigations performed by a number of authors in the course of a working day using a set of methods which allow for the evaluation of the functional status of the central nervous and cardiovascular systems, visual analyzer, thermoregulation, etc., found changes among personnel of ultrahigh voltage substations in the indicators which characterize memory and attention, an increase in the sensomotor reaction time, an elevation of the olfactory sensitivity thresholds, a decrease in the frequency of heart contractions, a retardation of intracardial conductivity and a change in vascular tonus [7-9].

Similar data attesting to the presence of functional disturbances among workers exposed to industrial power frequency electrical fields were subsequently obtained by Spanish author F. Fole [10], who noted among workers shifted over to servicing a new 500 KV substation complaints of headaches, dizziness, fatigability and nausea. A reduction in the frequency of heart contractions, physical endurance and an increase in arterial pressure was found during an objective investigation. However, the small population of the observed group (8 to 9 people) raises justified doubts as to the representative nature of the material obtained.

Along with this, a whole series of authors from the U.S. and Western Europe in studies on persons exposed to industrial power frequency electrical fields both under industrial conditions and in everyday life did not obtain any data which attest to the unfavorable effect of the factor.

W.B. Kouwenhoven, et al. [11] published the results of examining the health status of 11 linemen (a power line voltage of 345 KV) exposed to "high intensity" electrical fields. Of the 11 workers who were under observation for 42 months, 4 worked without protective gloves. The examination did not reveal any changes in indicators characterizing the status of the emotional sphere, cardiovascular or motor systems, or the visual analyzer. Only among 2 men were deviations detected in the sperm characteristics. The lack of pathological changes in the given contingent of persons was confirmed in later years by M.L. Singewald, et al. [12].

E. Malboysson [13] made an examination of the health status of 84 workers of 138 KV - 400 KV transformer substations and 76 linemen. Besides the physician's examination, the examination included a questionnaire, clinical and laboratory studies (chest X-ray, electrocardiography, blood and urine analysis, the determination of sugar content in the blood, as well as cholesterol, triglycerides, urea and uric acid), and analysis of the morbidity with the time lost as unfit for work. As a result of a comparison with the data of a control group (94 linemen on low voltage open wire power lines), a higher frequency of deviations from the norm was found among the substation workers as regards the digestive, motor and nervous systems. In the opinion of the author, the differences in the frequency of the changes in the motor sphere and digestion were related to differences in age and diet. The question of the relationship of high frequency of complaints of headache to working conditions requires further clarification. Including that there is a lack of pathological changes among the persons examined, the author emphasizes that the time the examined personnel worked close to the 400 KV equipment was quite short (on the order of 15 minutes per work day).

K. Busby, et al. [14] using a questionnaire did not find any unfavorable influence of 765 KV open wire lines on people or large cattle on 18 nearby farms.

M.V. Strumza [15], in comparing two groups of the population (525 persons in all), one of which lived at a distance of 25 m from 200 to 400 KV power lines, while the other lived at a distance of more than 125 m, did not find any significant differences between the groups in the frequency of seeking medical assistance or using medications.

An analysis of the papers cited here is evidence of the existence of the well known contradictory nature of the data obtained by specialists in different countries in evaluating the health status of persons exposed to industrial power frequency electrical fields. However, it is difficult to compare the results of these studies by virtue of the substantial differences in the exposure levels as well as in the health status study methods and evaluation criteria. The ultrahigh voltage substations in the USSR differ structurally from similar substations in the U.S., Canada and a number of other countries. The use of comparatively low supports holding high voltage equipment is responsible for the higher electrical field intensities in the working zones. In terms of the work conditions, servicing personnel are constantly on site at substations. The changes in the health status noted in the papers of Soviet authors concern primarily 500 KV substation personnel, where the electrical field intensity at individual points in the working zone can reach 25 to 29 KV/m.

As far as the data of W.B. Kouwenhoven, et al., are concerned, they apply to personnel servicing 345 KV power lines and using protective suits in this case. The data of E. Malboysson were obtained on persons subjected to short term exposure to the fields of electrical installations at voltages of 138 to 400 KV.

In dealing with the research methods, it must be noted that the possibility of using the frequency of seeking medical assistance and consumption of medications as the main indicators characterizing health status is extremely disputable. The data of a questionnaire are an insufficiently objective indicator also. Differences in the results of investigations can also be related to the use of differing criteria for health status evaluation of the persons examined. Thus, Soviet authors fix their attention on functional changes, while the authors of other countries focus on pathological ones.

A definite drawback to work of a clinical and physiological nature is the lack of satisfactory data on the environmental physiological characteristics of the conditions of exposure to a factor, without which it is impossible to correctly evaluate the material obtained. Usually, data only on the power facility voltage or on the maximum possible field intensity in the work zone is cited in the papers, which cannot be characteristics of the actual exposure to which a person is subjected. In this case, the possibility of the influence of spark discharges and capacitive currents, besides the electrical fields themselves, is not analyzed. Even less attention is devoted to other factors in the environment (the microclimate, noise, toxic substances, atmosperic ionization, specific features of the production process), although the biological activity of some of them can be higher than that of the industrial power frequency electrical fields. The significance of some research is reduced because of the lack of data on the health status of the contingent of persons being examined when they arrive for work and on the dynamics of the ascertained changes, as well as because of a lack of similar data for corresponding control groups.

What has been attests to the necessity of the further development of clinical and physiological studies, refining their organization and improving the methodological level. An important role in evaluating the biological impact of industrial power frequency electrical fields belongs to research of this kind, since it can provide information on the direct human long term chronic exposure to a factor at levels encountered in practice. However, to perform this task, their conclusions should be based on the study data for a sufficiently large contingent of persons with a rigorous metering of the electrical field exposure levels and the possible influence of other environmental factors.

The obtained data should be compared with examination data for corresponding control groups and evaluated in the plan for determining the clinical significance of the ascertained changes.

In working out the problem of the biological impact of industrial power frequency electrical fields, experimental studies should occupy an important place. This is governed by the possibility of studying the isolated influence of industrial power frequency electrical fields under experimental conditions for specified exposure parameters. It turns out that when studying a factor, the clinical manifestations of which are so disputed at the present time, the experimental approach to the solution of the problem is of especially great importance.

Widescale experimental studies on the biological impact of industrial power frequency electrical fields are just now expanding in the USSR. In this regard, we shall consider the results of work which has been done up to the present time.

T.Ye. Sazonova studied the influence of industrial frequency electrical fields on the process of the formation of a complex motor stereotype and the performance of automated work using 23 volunteers [16]. The results of the study showed that the exposure level characterized by an intensity of 16 KV/m and a duration of 2 hours causes threshold changes in the precision of work performance. At exposure intensities of 32 and 64 KV/m (a 20 minute exposure), along with a reduction in the precision of work performance, a degradation of the overall sense of well being of the test subjects, a change in the pulse rate, as well as in the arterial pressure and peripheral blood were noted. The ascertained shifts were of a functional nature. Rapid and total normalization of the indicated functions began following the termination of the electrical field exposure.

Yu.D. Dumanskiy, V.M. Popovich and I.P. Kozyarin made physiological studies of 34 volunteers under natural conditions with 330 KV and 750 KV open wire power lines. The following were studied in this case: the functional status of the central nervous system (operational memory volume, capability of concentrating the attention, electroencephalography), thermoregulation, work capability, electrocardiograms, certain indicators characterizing the status of exchange processes (blood glucose content, as well as urine and residual nitrogen) and nonspecific immunity (lysozyme and complement titer, and bactericidal power of the blood). As a result of the studies which were done, no statistically significant changes were found in the functions which were studied with exposure to electrical fields with an intensity of 5 KV/m (2 hours each over a period of 6 days) and 12 KV/m (for 30 minutes each 3 times a day for a period of 6 days). In the case of exposure to electrical fields with intensities of 15 to 16 KV/m (for a period of 6 days, 30 minutes each 3 times per day), complaints of the test subjects of headaches, fatigue and irritability were noted. Deviations were also recorded in the individual indicators being studied, which did not go outside the range of physiological fluctuations and which allow the authors to speak only of tendencies towards changes. In this case, the possible influence of other environmental factors cannot be excluded.

The staff of the Kiev Institute of General and Public Hygiene imeni Marzeyev also conducted a set of experimental studies on animals. The biological impact of industrial power frequency electrical fields at intensities of 5, 3, 1, 0.5 and 0.1 KV/m with around-the-clock irradiation and 15, 7, 4, 2, and 1 KV/m in the case of daily exposures of 2 hours per day was studied using rats and rabbits for a period of 4 to 4.5 months. A large set of experimental methods was used in this case (weight dynamics, electrocardiography, electroencephalography, cholinesterase and sulfhydryl groups in the blood, the dynamics of the absorption and secretion of I_{131} by the thyroid, the thyroxine binding power of blood serum, the residual nitrogen and urine in the blood, the 17-ketosteroids, catecholamines, Na^+ and K^+ content in the urine, the phagocyte activity of leucocytes, the lisocyme and complement titer and the bactericidal power of the blood, the morphological picture of the organs and tissues, etc.).

For animals subjected to around-the-clock exposure to electrical fields with intensities of 1, 2, and 5 KV/m, changes in the functional status of the central nervous system were noted, which the authors concluded based on the dynamics of a number of indirect indicators (a reduction in cholinesterase activity and sulfhydryl group content in the blood) and the bioelectric activity of the brain [18], as well as shifts in indicators characterizing the activity of certain endocrine glands - the thyroid and adrenals [19].

After 4.5 months of around-the-clock exposure to an electrical field with an intensity of 5 KV/m, disturbances of the reproductive power of rats were observed, which were manifest in a change in the estral cycle among the females and the sperm characteristics of the males, as well as poor fertility of the progeny, and an increase in the number of weak individuals and those having developmental anomalies among the progeny [20].

In the case of a 2-hour exposure to electrical fields, changes in the functional status of the central nervous and endocrine systems, as well as in the indicators characterizing exchange processes occurred at field intensities of 7 and 15 KV/m [21].

It should be noted that the data cited here, obtained under conditions of long term chronic trials, deserves the most serious attention, although additional improvements are needed. In particular, the procedure for the group radiation of the animals (without the isolation of separate individuals) does not allow for a precise evaluation of the actual electrical field levels to which each animal was exposed. An analysis of the data obtained for individual groups of animals attests to the necessity of further studies, taking into account spontaneous fluctuations in the indicators being investigated, as well as the evaluation of the ascertained changes from the viewpoint of their significance, etc.

A work which was a targeted study to ascertain the nature of changes in human cells exposed to industrial power frequency electrical fields is generating a great deal of interest [4]. In experiments using cultured human embryo fibroblast-like cells and peripheral blood lymphocytes, the nature of the growth in the cultures, the state of the chromatin of the interphase nuclei, the nucleus and cytoplasm ultrastructure, the mitotic activity of the cultures, and the rate of DNA, RNA and protein synthesis were studied. The existence of changes in a number of the studied indicators was established at electrical field intensities of 50 to 200 KV/m.

In experiments on mice, the authors noted a depression of behavioral reactions when the animals were located in a field with an intensity of 50 KV/m and higher, as well as a drop in the fertilization rate and a decrease in the birth rate. The characteristics of the progeny born from individuals exposed to an electrical field with an intensity of 50 KV/m attested to the disruption of embryogenesis processes, which was manifest in a change in the ratio of the sexes, an increase in the frequency of stillbirth cases and developmental monstrosities.

At the present time, the data cited here can be treated as preliminary. When continuing the research, it is necessary to observe stricter requirements on the conditions for the performance of the experiments. The basis for such a conclusion is the small number of observations, something which is especially important when the tests employed by the authors are characterized by a pronounced variability in the indicators. There can also be errors in evaluating the field intensity levels when performing the work, which is related both to the group method of irradiating animals and to difficulties in monitoring the field when working with cell structures.

In recent years, the number of publications on questions of the biological effect of industrial frequency electrical fields has increased in the U.S. and Western Europe. In analyzing this literature, attention is drawn to the well known contradiction in results obtained by different authors. In individual cases, a contradictory nature of the conclusions follows from studies by the same authors. Table 2 lists the literature in which no biological effect of industrial frequency electrical fields was found. The literature where the authors observed changes in some of the particular human or animal functions being studied is shown in Table 3. A comparative analysis of the indicated materials, taking into account both the number of papers and the volume of investigations reflected in each of the tables makes it possible to state with a sufficient basis that industrial frequency electrical fields cause biological effects for certain exposure parameters. Thus, the fact itself that there is a biological effect of industrial power frequency electrical fields is beyond doubt and follows from the work of both Soviet and foreign authors.

TABLE 2.

Literature in which No Influence of Industrial Power Frequency Electrical Fields on the Indicators (or Functions) Being Studied Was Found

Author	Subject of the Study. Experimental Conditions	Indicators (or Functions) Being Evaluated	Results
Kepnen, 1964	People, 50 Hz, 7.5, 12.5 and 27 KV/m; 15-30 min.	EKG	No influence found
Johanson, et al., 1973	People, 60 Hz, 100 KV/m (the actually effective field)*	Subjective perceptions	The same*
Veyyesteynas, Viola, et al., 1975	Rabbits**, 50 Hz, 80 KV/m, from several min. up to 500 hours	Cardiac overshoot, frequency of heart contractions, arterial pressure	The same
Shefer, Sil'ni, 1977	Rats, cats, 50 Hz, 80 KV/m	EEG, muscle tonus	No pronounced changes detected***
Kantone, Kinwald, et al., 1975	Rats, 50 Hz, 100 KV/m, 30 min. and 8 hours each over a period of 48 days	Spermatogenesis, embryogenesis	No influence detected
Kruger, Giarola, 1972	Chicks, 60 Hz, 3.6 KV/m	Weight dynamics	The same
Wittke, et al., 1977	Chicken eggs, industrial frequency, 1.5 and 5 KV/m	Embryogenesis	The same
River, 1976	Bacteria, fungi; 50 Hz; 10, 50 and 200 KV/m	Culture growth and number of mutations	The same

Notes: *The 100 KV/m intensity was given taking into account the field distortion introduced by the biological subject. Individual test subjects noted unpleasant perceptions which the author related to weather conditions.

**The studies were performed on anesthetized rabbits.

***The detection of EEG changes were related to vibration of the fur cover; in the muscle tonus - to being in confining teflon chambers.

TABLE 3.

Literature in which Industrial Power Frequency Electrical Fields Were Found to Influence the Indicators (or Functions) Being Studied

Author	Subject of the Study; Experimental Conditions	Indicators (or Functions) Being Evaluated	Results
1	2	3	4
Hauf R., 1976; Hauf G., 1974	People; 50 Hz; 1-20 KV/m, up to 3 hours	Reaction time; blood, EEG, EKG, frequency of heart contractions, arterial pressure, Quick's test.	Reduction in reaction time; increase in num- of leucocytes, reticulocytes; slight changes in EEG activity*
Weibel, 1975	People; 50 Hz; 6 KV/m for three min., 2 times	EKG, EEG	Reduction of alpha rhythm frequency; increase in the number of beta waves
Kantz, 1951	People; 50 Hz; 100 KV/m	Thresholds of taste, smell, hearing and touch	Changes in the thresholds of the analyzers studied
Tsereteli, Malaguti, 1976	Dog, rabbits, rats; 50 Hz; 100, 80 and 25 KV/m, from several min. up to 500 hours	Cardiac overshoot, frequency of heart contractions, arterial pressure, blood morphology and biochemistry, reproductive function.	Dogs: increase in frequency of heart contractions when the electric field was turned on and off; decrease in hemoglobin and erythrocyte content; tendency to neutrophylysis; Rabbits**: tendency to elevate arterial pressure; Rats: tendency to neutrophylysis; reduction in sexual activity of females during short term exposure.
Sil'ni, 1976	Cats, rats; 50 Hz; 60-80 KV/m for 6-16 hours	EEG, EKG, respiration, skin and rectal temperature	Increase in frequency of heart contractions, reduction in amplitude and frequency of EEG waves; change in thermal regulation*
LeBar, Andre, 1976	Rabbits, rats; 50 Hz; 50 KV/m 24 hours; 70 hours for 5 days; 8 hours each for a period of 30-100 days.	Food consumption, growth, blood morphology and biochemistry, reproductive power	Rabbits: leucocytosis with relative lymphopenia (100-day exposure); increase in urine content in

TABLE 3, cont.

1	2	3	4
			blood (24 hour exposure); elevated Ca content and reduced sugar content in the blood (70 hour exposure); Rats: increased urine content in the blood (100 day exposure)
Meda, 1974	Rats, mice, guinea pigs; 50 Hz; 100 KV/m, 18 hours per day	Blood, EEG, EKG	Neutrophylysis, lymphopenia, lengthening of the P-R interval and the QRS complex
Strumzha, 1970	Rats; 50 Hz; 17 KV/m	Embryogenesis	Reduction in weight of progeny
Shpitka, 1969	Rats; 50 Hz; 50-70 KV/m	Behavioral reaction time	Change in the reaction time
Fisher, Weibel, Richter, 1976	Rats; 50 Hz; 0.05 and 5.3 KV/m; 15 min.; 2, 10, 21 and 50 days	Frequency of heart contractions	Reduction in frequency of heart contractions
Knickerboker, 1967	Mice; 60 Hz; 160 KV/m; 1,500 hours	Embryogenesis	Reduction in weight of progeny

Notes: *Attention is drawn to the fact that the detected changes do not go beyond the limits of physiological variations.

**The study was performed on anesthetized rabbits.

The next conclusion which can be drawn based on an analysis of the material cited concerns the biological activity of the factor. A majority of the data contained in the tables is evidence of the fact that at intensities of practical interest, an industrial power frequency electrical field has a weak biological effect. This follows from the slight dependence of the biological effects on the exposure intensity, as well as the lack of effects among a number of studied subjects, even at high field intensities. In this regard, the question of evaluating the significance of the observed effects takes on special importance. It seems that the differences in the conditions under which the experiments are performed and the differences in the treatment of the observation results are the major reasons comprising the basis for the existing contradiction in the opinions on the question of the unfavorable impact of the factor.

The question of the necessity of a more rigorous scientific substantiation of health safety standards has been brought up at the present time in the USSR, just as in a number of other nations in the world. Because of this, it is proposed that extremely serious attention be devoted to procedural questions related to the conduct of studies in subsequent experimental work. In particular, when irradiating experimental animals in the electrical field of a capacitor, it seems necessary to take into account such factors as electrical field inhomogeneity in the edge region of the capacitor and mutual shielding of objects which are close together.

Measurements of the current flowing through a biological object which were made with an experimental test stand in the Scientific Research Institute for Occupational Diseases and Labor Hygiene of the USSR Academy of Medical Sciences at exposure levels of up to 300 KV/m and spacings between the capacitor electrodes of up to 80 cm, showed that a substantial amplification of the effective electrical field acting on an object can occur in those cases where the spacing between the capacitor plates proves to be comparable to the vertical dimensions of the object being irradiated. Thus, with a ratio of the indicated quantities of 1.5, the current flowing through an animal increases by approximately 50 percent as compared to conditions where the ratio of the spacing between the capacitor plates to the vertical dimension of the animal is greater than 3. A further reduction in this ratio (less than 1.5) leads to a rapid exponential rise in the current through the object where the value of the undistorted field between the plates is kept constant. As far as the mutual shielding effect is concerned, it has a substantial impact at spacings between animals on the order of 1 to 1.5 of their effective diameter. In this case, there is a reduction in the current through the object by 20 to 40 percent. Where direct contact between the animals is possible, as in the case where they are placed in a common container, the mutual shielding effect can prove to be even greater. The next factor which must be taken into account is the orientation of the biological object relative to the E field vector. The possibility of placing animals both parallel and perpendicular to the E vector while maintaining a horizontal position of the body which is natural to them can be assured by using capacitors, the electrodes of which are set up both horizontally and vertically.

Exceptionally important in the substantiation of health safety standards is the question of interpreting the results of experimental studies. There are two extreme points of view at the present time, with which it is impossible to agree. Some authors do not at all differentiate the effects which attest to the physiological changes and which characterize the unfavorable effect of the factor. In this case, any change is equated to an unfavorable one. Others exhibit extreme caution and are inclined to judge the biological effect of industrial power frequency electrical fields only on the basis of the presence or absence of pronounced pathological changes.

It seems expedient to approach the evaluation of the biological effects related to exposure to industrial frequency electric fields from the viewpoints adopted at the present time in environmental physiology science and approved for the study of other unfavorable environmental factors, including electromagnetic radiations in other frequency bands.

Studies have been carried out in recent years in the USSR on the development of the theoretical principles of making the environment a healthy one, including setting health safety standards. One of the basic principles of the theory of of maximum permissible levels (PDU) for exposure to various environmental factors is the concept of the threshold nature of an effect given the appropriate criteria for harmfulness. In this case, indicators of any organism reactions to the particular exposure cannot be employed as the latter. Such an approach would place unsubstantiated requirements on protective measures, which are difficult to carry out from an economic viewpoint and would complicate technical progress.

In standing on the principles of environmental physiology science in the field of setting standards for various unfavorable factors in the environment, it must be remembered that at the present time, the harmful effect threshold of a factor should be taken as the criterion of injury. The harmful effect threshold is to be understood as that exposure level at which significant changes in the physiological functions of various organs and systems occur in the organism, where these changes have the danger of becoming pathological ones.

A more detailed interpretation of the harmful effect threshold is given in the paper of B.M. Savin [22].

In the experimental substatiation of health safety standards, questions of extrapolating data obtained in experiments on animals to man are of great importance. Differences in the reactions of animal and human organisms to exposure to industrial power frequency electrical fields can be due to both differences in the dimensions and shape of the body as well as the specific features of the organization and functioning of organs and systems. The resolution of the question of the comparative sensitivity and vulnerability of animals and humans requires special research. A necessary condition for the correct extrapolation of data from animals to man is knowledge of the mechanisms of the interaction of industrial power frequency electrical fields with biological objects. It must be said, however, that this question has still been studied insufficiently.

In the literature, the effect of electrical fields on an organism is related on one hand to displacement currents induced in a body by the external electrical field, and on the other hand, to the action of local field intensities on cutaneous tissues. Depending on the significance of each of the indicated mechanisms, the approaches to extrapolation can differ substantially. It the decisive factor in the development of biological effects of industrial frequency electrical fields is the current, then the extrapolation of data should be made taking into account differences in the density of the current flowing in the bodies of animals and man. The specific features of the body shape of man and animals are responsible for the fact that with the same unperturbed field intensity, a large current will be induced in a human body (a more elongated shape) than in the bodies of many species of animals. Because of this, the use of higher exposure levels in experimental studies on small animals than those which may be of practical interest is altogether justified. It is apparent that the approach which takes into account differences in the spatial distribution of the current in human and animal bodies is more precise and universal. However, practical realization of such an approach is difficult at the present time because of the lack of the appropriate methods. If the biological effects though are related to local field intensities, the extent to which they are pronounced will depend substantially on the degree of difference in the hair coat and the specific features of the development and functioning of the receptor apparatus of the skin.

Species differences in the vital activity of the human and animal organisms also have to be taken into account when extrapolating experimental data. When choosing experimental models, attention must be devoted to the ecological features, as well as the specific features of development, regulation and functioning of individual systems which are inherent in a particular species of animal. The medical and biological indicators being studied in an experiment can be determined from the principle of selecting either the most important organism function or the systems which are the most sensitive to exposure to the factor. Such systems can include the central nervous system, cardiovascular system and the blood. There are also reasons for a more detailed study of the immunobiological indicators and genetic effects. As far as the set of research methods employed in an experiment, it is apparently not expedient to limit it to any specific recommendations. It must be pointed out that while any of the most sensitive methods can be used in the study of the effective mechanisms of a factor, the methods used in substantiating the maximum permissible levels should provide for obtaining information on the health safety significance of the exposure. In this case, changes in such important vital activity indicators of an organism as the lifespan, developmental and growth dynamics, normal volume of compensator capabilities of an organism with respect to exposure to unfavorable environmental factors as well as the normal volume of work capability and psychological functions should be numbered among the manifestations of a harmful effect.

Along with questions of extrapolating experimental data in making the transition from harmful effect thresholds to maximum permissible levels, an exceptionally important question is the issue of the value of the health safety margin factors, the purpose of the introduction of which is to assure reliability of the health safety standards.

Since an industrial power frequency electrical field has a low level of biological activity, when stardards are set for it for professional groups, values of the health safety margin factors on the order of 2 to 3 will be adequate.

The question of the necessity of also introducing additional coefficients for other categories of persons (not occupationally exposed to industrial frequency electrical fields as well as the population) can be resolved based on the results of studies of the nature and extent to which biological effects are pronounced for various intensities and durations of exposure to factor. In this case, it must be kept in mind that persons of the most diverse age groups and diverse health status can be exposed. We will note that there are data in the literature which attest to the differing sensitivity of healthy and sick organisms to exposure to industrial power frequency electrical fields [23].

Research was done in the following major areas by USSR scientific institutions during 1978-1980 for purposes of working out the maximum permissible levels of exposure to industrial frequency electrical fields for various categories of persons:

- --Health safety evaluation of conditions of exposure to 50 Hz electrical fields and power facilities for various contingents of persons;
- --Studying the health status of workers when exposed to industrial frequency electrical fields;
- --Working out the principles for simulating electrical field exposure under experimental conditions;
- --The experimental study of the biological effect of industrial frequency electrical fields for the purpose of obtaining data on the characteristics of biological effects at the level of various organs and systems; establishing the dependence of biological effects on the geometric dimensions and species specific features of an organism; substantiating the principles for extrapolating data from animals to man; determining the harmful effect thresholds for various exposure durations and substantiating the health safety margin factors as applied to various contingents of persons and conditions of exposure to a factor;
- --Studying the primary mechanisms for the interaction of industrial frequency electrical fields with biological objects.

It can be stated that as a result of conducting the indicated studies, new data will be obtained on the biological impact of industrial power frequency electrical fields, which will allow for making a definite contribution to the resolution of questions of setting health safety standards for a factor and protecting the environment.

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