Review

Scientific Basis for the Soviet and Russian Radiofrequency Standards for the General Public

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The former Soviet Union (USSR) and the USA were the first countries to introduce standards limiting exposure to radiofrequency (RF) fields. However, the exposure limits in the USSR standards were always much lower than those in the USA and other countries. The objective of this article is to provide a history of the development of the Soviet and Russian RF standards. In addition, we summarize the scientific evidence used to develop the original USSR RF and subsequent Russian public health standards, as well as the mobile telecommunications standard published in 2003, but we do not critique them. We also describe the protective approaches used by the Soviet and Russian scientists for setting their limits. A translation of the papers of the key studies used to develop their standards is available in the online version of this publication. Bioelectromagnetics © 2012 Wiley Periodicals, Inc.

Key words: radiofrequency fields; Soviet Union standards; Russian standards; public health

INTRODUCTION

Radiofrequency (RF) standards for both the public and occupational health issued by the former Soviet Union (USSR) and more recently, the Russian Federation, have always contained exposure limits that were well below those in non-Soviet Bloc countries. An early article discussing these differences was published by Sliney et al. [1983]. However, the reasons for the significantly lower limits have never been fully explained in the international literature. The World Health Organization's (WHO) International Electromagnetic Field (EMF) Project held a number of meetings in Russia to understand the results of scientific studies that formed the basis for their RF standards. It is of interest to national authorities and other standards setters to know why the Soviet and Russian RF exposure limits are much lower and what studies support these limits. Further, their approach to protection for setting their RF limits is different from that used in other standards, and particularly, the international standards published by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the Institute of Electrical and Electronics Engineers (IEEE).

Standards limiting RF exposure of workers were first introduced in 1958 in the former USSR

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and public exposure standards came much later. In the 1970s, the USSR's Ministry of Health, Council of Ministers, Military Medical Academy, and the Aerospace Institute of the Ministry of Defense (Moscow) funded research for some 15 years to investigate the effects of EMF exposure on human health [Grigoriev et al., 2003a]. The results of these studies, specifically those commissioned by the USSR Ministry of Health, formed the scientific basis for the first general public RF standard published in 1978 [USSR Ministry of Health, 1978]. Some of these studies were published in the Russian scientific literature but many were unpublished reports archived in Moscow, Leningrad (now St. Petersburg), Kharkov, and Kiev.

Professor Y. Grigoriev was a member of the original Soviet committee drafting RF standards and is currently the Chair of the Russian National Committee on Non-Ionizing Radiation Protection, which makes recommendations to the Ministry of Health on RF and extremely low frequency (ELF) field standards, as well as standards on individual devices such as mobile phones. Grigoriev et al. [2003b] have indicated that while the results of many other studies were considered, such as those on mechanisms, effects of acute and chronic exposure of animals, and effects on volunteers and workers, some of the most important studies providing the basis for the RF exposure limits were immunological studies [Dronov and Kiritseva, 1971; Vinogradov and Dumanski, 1974, 1975; Shandala and Vinogradov, 1982; Shandala et al., 1985; Varetski et al., 1985; Vinogradov et al., 1985, 1987, 1991; Vinogradov and Naumenko, 1986].

The purpose of this article is to provide a history of the development of Soviet and Russian standards. We summarize the scientific evidence used to develop the original USSR occupational RF exposure limits and subsequent Russian public health standards, as well as the more recent mobile phone standard published in 2003 [Russian Standard, 2003], but our objective is not to critique them. We also describe the philosophy of protection used by the Soviet and Russian scientists for setting their limits and make a general comparison of them with the international RF standards. Only a few studies underpinning Soviet and Russian standards have been published outside the USSR since most were not freely available at the time.

METHODS

We were provided with the original publications (in Russian) of the most important immunological studies used to develop limits in the Soviet and Russian RF standards. These were translated so the scientific results could be summarized. In addition, a number of other reviews of early Soviet and Russian studies and standards were examined for insights related to our objectives.

A meeting of co-authors of this article was held in Moscow in September 2011 to discuss the details of these Soviet-era and more recent studies with Russian colleagues involved in the research and to prepare the first draft with the help of Russian colleagues.

RESULTS

Translation

The key articles were translated by a scientific expert in the area and are summarized in Table 1. The fully translated articles are also available in the online version of this publication.

Responsibility for Setting Standards

In 1958, the USSR Ministry of Health approved the first RF standard and subsequently issued more than 30 separate standards on 50 Hz, EMF in general, RF fields, and EMF-emitting devices such as airport and meteorological radars, video display terminals (VDTs), and others. After the breakup of the Soviet Union, responsibility for issuing standards for the Russian Federation was assigned to the Federal Service for the Control of Compliance of Consumer Rights and Human Welfare (Rospotrebnadzor) and its Chief Health Physician. However, in July 2011, a Russian federal law was passed that transferred responsibility for issuing "sanitary-epidemiological regulations and norms" (SanPiN) to the Ministry of Health and Social Development (Minzdravsotsrazvitia). This was enacted to fulfill requirements for accession of the Russian Federation to the World Trade Organization (WTO) and to harmonize Russian standards with international standards. The objective of the Working Group formed by the Ministry of Health and Social Development under this law is to develop health standards that are in accordance with international standards, recommendations, and other documents of international organizations.

The Russian National Committee on Non-Ionizing Radiation Protection (RNCNIRP) was created in 1997 by the Russian Academy of Medical Sciences (RAMS) within the framework of the Russian Scientific Commission on Radiation Protection (RSCRP); RSCRP acts as the chair of RNCNIRP. The

TABLE 1. Summary of USSR and Russian Immunological Studies

Refs.	Animals	Exposure conditions	Results
Dronov and Kiritseva [1971]	Rabbits	UHF 4 h/day, 4 months, 15 rabbits exp. to 50 μW/cm^2, 5–10 μW/cm^2	Decreased IgG antibody formation from 50 μW/cm^2 but not from 10 μW/cm^2 exposure
Vinogradov and Dumanski [1974]	Guinea pigs, white rats	UHF 5 h/day to 50 μW/cm^2 for 14 days	50 μW/cm^2 exposure changes brain tissue antigen composition so they become immunologically foreign
Vinogradov and Dumanski [1975]	Guinea pigs, white rats, rabbits	UHF 6 h/day to 50 μW/cm^2 for 1 month	Sera from 50 μW/cm^2 exp. animals suppresses phagocytosis capacity of neutrophilic leucocytes of live animals
Shandala and Vinogradov [1982]	White rats	UHF 7 h/day to 500 μW/cm^2, 20 days (whole of pregnancy)	500 μW/cm^2 exp. induces circulating antibodies in mother against fetal tissue
Shandala et al. [1983]	Mature CBA mice and white rats	2375 MHz. Rats for 7 h/day to 1 or 5 μW/cm^2 for 3 months or 10, 50 or 500 μW/cm^2 for 1 month. Mice to 1 h/day for 1 month to 0.1 or 10 μW/cm^2	500 μW/cm^2 exp. permanently reduced PHA stimulation of rat lymphocytes; 50 μW/cm^2, a temporary reduction; and 10 μW/cm^2, a smaller temporary reduction. Low intensities (1.5 μW/cm^2 over 3 months) had no such effects. Mice exp. to 0.1 or 10 μW/cm^2 showed minor immune system effects
Shandala et al. [1985]	Pregnant white rats	UHF 500, 50 or 10 μW/cm^2, 7 h/day for 30 days	Injection of sera from 500 μW/cm^2 exposed rats into pregnant rats causes anti-brain antibodies and post-implantation loss of offspring. 50 μW/cm^2 exposure causes no effect on offspring
Vinogradov and Naumenko [1986]	Wistar rats	2375 MHz, 500 μW/cm^2, 7 h/day for 15 days	Exposure causes anti-brain antibodies, and altered brain tissue rendering them immunogenic. Also, increased reticulo-endothelial and plasma cells in bone marrow and spleen and decreased small lymphocytes in bone marrow
Vinogradov et al. [1991]	Female Fisher rats	2375 MHz, 500 μW/cm^2, 7 h/day for 15 days	Exposure reduced mitogen-induced (PHA, Con-A) proliferation and induced autoantibodies to brain tissue antigens. Cells injected from exposed animals ''led to analogous conditions'' in normal recipient rats

RNCNIRP includes 40 specialists, 38 of whom are qualified scientists, and 2 are representatives from the Ministry of Health. This is an independent scientific committee that has no financial support except by the committee member's own institution. The Ministry of Health considers the recommendations of the RNCNIRP when setting standards.

Basis for Public Health Standards

While the USSR and Russian standards were based on many areas of research, the immunology studies were viewed by the standards committees as providing the most consistent results and so were important for setting exposure limits. More details of key studies used to develop RF exposure limits are given in Grigoriev et al. [2003c]. We summarize the most important of these studies and their results in Table 1.

Dronov and Kiritseva [1971] conducted one of the earliest studies contributing to the exposure limits in the RF standards. They exposed 15 rabbits to 50 μW/cm^2 and 5 rabbits to 10 μW/cm^2 ultra high frequency (UHF) fields (no frequency given) for 4 h/day for 4 months. The 15 animals exposed to 50 μW/cm^2 were divided into 3 groups of 5 animals each: the 1st group was sensitized (injected with an antigen) during exposure, the 2nd group was sensitized before exposure, and the 3rd group was sensitized after exposure. The 10 μW/cm^2 group was sensitized during exposure. Immunological changes were assessed using the agglutination reaction, reaction to indirect hemagglutination, and differential determination of macro- and micro-globulin antibodies with a sedimentation constant of 19S (immunoglobulin M; IgM) and 7S (immunoglobulin G; IgG), respectively. The authors reported that 50 μW/cm^2 caused a decreased antibody response only when exposure occurred prior to or during sensitization, and no effect was produced from the 10 μW/cm^2 exposure.

Vinogradov and Dumanski [1974] exposed Guinea pigs and white rats (no strain mentioned but probably Wistar rats since they were used in subsequent studies) to UHF fields (no frequency given) at 50 μW/cm^2 for 5 h/day for 14 days and reported alterations to the structure and/or expression of tissue antigens using the method of anaphylaxis with desensitization. Animals injected with normal brain tissue antigens were not completely desensitized by tissue antigens from exposed animals and vice versa. The authors concluded that RF exposure could induce the expression of antigens not normally expressed in brain tissues and/or alter the antigen structure of normally expressed antigens. In a follow-up study, Vinogradov and Dumanski [1975] reported exposure to UHF (50 μW/cm^2) induced autoantibodies reacting with brain tissue antigens in Guinea pigs, white Wistar rats, and rabbits. Autoimmune reactions were determined using the complement binding reaction and plaque-forming cell techniques, which revealed the presence of antigen-specific antibodies and antigen-specific antibody-producing cells, respectively. Moreover, leukocytes from UHF-exposed Guinea pigs showed a reduced serum-mediated phagocytic activity.

Shandala and Vinogradov [1982] exposed 11 pregnant white Wistar rats to UHF fields (500 μW/cm^2, 7 h/day for 30 days) and reported an increased response to fetal liver antigens in terms of both frequency of antibody-producing lymphocytes in blood and autoantibodies in serum, compared to 11 unexposed controls. Lymphocytes from exposed pregnant rats also showed a reduced mitogen-stimulated cell proliferation compared to controls. When sera were injected into pregnant rats (10 exposed and 10 controls) "to evaluate the pathological meaning of the autoantibodies," sera from exposed rats increased embryo lethality during pregnancy and higher offspring mortality at around 1 month of age.

Shandala et al. [1983] exposed CBA mice and Wistar rats to 2375 MHz (7 h/day). When mice were exposed to 0.1 or 10 μW/cm^2, spontaneous and mitogen-stimulated (PHA) cell proliferation increased, which persisted for 30 days after the last exposure. When rats were exposed for 3 months to 1 or 5 μW/cm^2, or for 1 month to 10, 50, and 500 μW/cm^2, there was a decrease in the proliferative response to PHA, which was still evident 3 months post-exposure. No effects were observed in rats exposed to 10 and 50 μW/cm^2. The authors concluded that RF exposure induced important changes in T-cell immunity.

Vinogradov et al. [1985] exposed white Wistar rats for 30 days to 10, 50, and 500 μW/cm^2 (no frequency given, probably UHF, 2375 MHz) and a sham-exposed group was used as controls. Induction of autoantibodies toward brain tissue antigens (brain extracts) was evaluated with the complement binding/fixation assay and pathological effects were assessed by injecting autoantibody-containing sera into pregnant animals. Electrophoresis patterns of sera immunoglobulin were also evaluated. Exposure to 50 and 500 μW/cm^2 induced autoantibodies to brain tissue antigens as revealed by indirect degranulation of basophiles and complement fixation assays. No effects were induced from exposure to 10 μW/cm^2. Exposure to 50 and 500 μW/cm^2 also decreased cell proliferation (blast formation). Sera from exposed (or sham-exposed) rats were injected into pregnant rats to verify whether the presence of the autoantibodies was pathological. Sera from rats exposed to 500 μW/cm^2 increased post-implantation loss and decreased the number, body mass and length of the newborns. Analyses of soft tissues from the fetuses revealed the presence of hemorrhages in the subcutaneous tissue, peritoneal cavity, liver, and brain. The authors also reported that exposure to 500 μW/cm^2 (but not 10 μW/cm^2 or 50 μW/cm^2) led to alterations in immunoglobulin electrophoresis, with the appearance of a new peak similar to that of class A antibodies, and concluded that it caused strong changes in physico-chemical and immunological properties of serum humoral factors. The authors concluded that such changes might render proteins naturally produced in the body as immunologically "foreign" and stimulate autoimmune responses.

Shandala et al. [1985] exposed female Wistar rats to UHF fields (probably 2375 MHz since this was reported in a previous study) at 50 and 500 μW/cm^2 for 7 h/day for 30 days. They investigated the induction of autoantibodies and found that these exposures induced the formation of autoantibodies to brain tissue extracts using the basophil degranulation technique. The authors then investigated the immunogenicity of brain extracts from exposed animals by injecting these extracts into normal animals. Their hypothesis was that normal tissue should not induce antibodies to brain tissue since recipient animals should recognize them as their own tissues. If exposure to UHF fields induced alterations in antigen expression and/or structure, the tissue extract should become immunogenic and therefore able to raise an antibody response. The authors reported that brain tissue extracts from animals exposed to 50 and 500 $\mu W/cm^2$ induced antibodies in injected animals but basophil degranulation was seen only in animals injected with extracts from animals exposed to 500 $\mu W/cm^2$. To assess the pathological significance of the autoantibodies, they injected sera from animals exposed to 500 $\mu W/cm^2$ into pregnant rats, and the post-implantation loss increased. No effects were induced by the injection of sera from animals exposed to 50 $\mu W/cm^2$. The authors concluded that only exposure to 500 $\mu W/cm^2$ was capable of inducing anti-brain antibodies, leading to an adverse effect.

To repeat the results of Shandala et al. [1985], Vinogradov and Naumenko [1986] exposed Wistar rats to 2375 MHz fields at 50 or 500 $\mu W/cm^2$ for 7 h/day for 30 days. They confirmed that exposure to 500 $\mu W/cm^2$ increased plaque-forming cells and induced anti-brain antibodies using complement binding and basophil degranulation assays, suggesting that RF exposure altered brain tissues and rendered them immunogenic. When rats were injected with extracts from animals exposed to 500 $\mu W/cm^2$ the authors also reported an increased number of reticulo-endothelial and plasma cells in bone marrow and spleen, and a decreased number of small lymphocytes in bone marrow.

Vinogradov et al. [1987] reviewed the results of these immunological studies and concluded that exposure to UHF fields at a power density of 500 $\mu W/cm^2$ irreversibly damages organisms; 50 $\mu W/cm^2$ induces some effects, often non-pathogenic; and 10 $\mu W/cm^2$ does not affect any immunological parameters.

Vinogradov et al. [1991] exposed female Fisher rats to 2375 MHz fields (500 $\mu W/cm^2$, 7 h/day for 15 days). The effects of exposure were assessed by injecting lymph node cells from exposed or sham-exposed animals into normal recipient rats. This was to determine if it was possible to transfer the "conditions of autoimmunity caused by the exposure" into recipient animals. Analyses were then performed on both donor and recipient rats, and, consistent with previous reports, the authors found that exposure reduced mitogen-stimulated cell proliferation (PHA and Con A) and induced autoantibodies toward brain tissue antigens as shown by basophil degranulation and plaque-forming cell assays. Moreover, cells injected from exposed animals (but not from sham-exposed rats) "led to analogous conditions" in normal recipient rats.

When the public health standards committees analyzed all studies, they agreed with the conclusions of Vinogradov et al. [1987] and summarized them as follows: chronic daily exposure to 100–500 $\mu W/cm^2$ can induce persistent pathological reactions (based on the immunology studies above), the most striking effect being offspring death after injection of foreign serum; $\sim$50 $\mu W/cm^2$ is the threshold exposure for the unfavorable biological effects found in the immunology studies but these effects were not pathological since the organism could compensate for the exposure, and continual compensation could lead to long-term adverse effects and thus should be protected against; and chronic exposure to $\leq$10–20 $\mu W/cm^2$ does not induce any noticeable biological changes in small laboratory animals.

Mobile Phone Standards Assessment

It is important to know how the Russian standards for the protection of public health were developed for mobile phones as they are one of the most prevalent sources of RF exposure in the population. Because mobile phones have become an essential part of most people's lives, the RNCNIRP decided that they needed a special standard, especially since their use involves daily, repeated, and potentially life-long RF exposure to the brain, a critical organ. The committee felt there was a lack of data on long-term low-level (non-thermal) exposure to the brain. Further, mobile phone use by children was seen as a special situation since they may be more susceptible to RF exposure than adults [Grigoriev, 2005; Kheifets et al., 2005]. Finally mobile phone exposure was seen as an uncontrolled source of potentially health-threatening RF exposure; no such source of exposure to the population existed before mobile phones.

The RNCNIRP considered both national and international studies on RF, especially those involving low-level, short-term RF exposure on the nervous system. The following nervous system studies were considered important for developing the exposure limits for mobile phones since many of the studies summarized below were applicable to possible effects on the brain.

Rynskov et al. [1995]: Rabbits exposed to 6 GHz pulse-modulated fields for 50 min at a power density of 15 $\mu W/cm^2$ showed an increase in pre-seizure conditions. The authors concluded that increasing RF exposure would be expected to enhance this effect.

Sudakov [1998]: Sudakov observed epileptic brain activity following low-level exposure to 30 MHz modulated RF fields (modulation 2–50 Hz, 30–120 V/m).

Grigoriev et al. [1995]: Motor activity of rabbits was altered following a 30-day exposure to 1.5 GHz pulsed fields (pulse width 16 ms, repetition rate 0.12 Hz) at an average power density of 300 μW/cm^2. According to the researchers, the basis for these changes was an increase in the arousal processes in the central nervous system since the rabbits developed restlessness after 14 days.

Grigoriev and Stepanov [1998, 2000]: When chicken embryos were exposed to 10 GHz (continuous wave or pulse modulated) fields during different stages of development, it was found that a single exposure of 1 mW/cm^2 for 30 min retarded the memory (imprinting) process in 50% of chicks. A dose-dependent effect of low-level exposure on brain function was reported.

Shtemberg et al. [2000, 2001]: When rats and mice of different ages were exposed to 970 MHz fields as low as 15 μW/cm^2 for up to 120 min there was a tendency toward a decrease in exploratory behavior, a suppression of the righting reflex, and a slowdown in adaption to experimental conditions. In addition, a fourfold decrease in noradrenaline levels was observed in exposed animals compared to the control group.

Afrikanova and Grigoriev [1996]: When an isolated frog heart was exposed to 9.3 GHz modulated fields (1–100 Hz) at an average power density of 16 μW/cm^2 for 5 min, effects on various modes of heart activity were observed compared to unmodulated fields.

When determining the limit values for mobile telecommunications technology, the RNCNIRP decided to leave the limit value of 10 μW/cm^2 for the general public unchanged, as it was set in 1984 and this value was well justified by previous research so there was no need for change. Thus, base stations should not expose the public to more than 10 μW/cm^2. To set the limit value for mobile phone users, an assessment of domestic and foreign studies was made by the RNCNIRP, and limits were set based on the results of an animal study performed earlier in the Research Institute of Occupational Medicine in Moscow, Russia by Rubtsova and Paltsev, but only published in 2006, (110 rats, Global System for Mobile Communications (GSM) 900 and 1800 MHz at 0.5 and 2 mW/cm^2 for 1 h/day for 40 days) [Rubtsova and Paltsev, 2006]. They reported changes in the immune status of animals exposed to 500 μW/cm^2. The results of this study were in general agreement with earlier studies indicating that exposure to 500 μW/cm^2 produced immune system changes considered pathogenic to the organism. A safety factor of 5 was applied to this power density, leading to a limit value of 100 μW/cm^2 recommended for mobile phone users [Russian Standard, 2003]. This Russian standard regulates mobile phones and their base stations and was approved by Russia's Chief Health Physician under federal law ("On the sanitary and epidemiological welfare of the population", 30 March 1999, No. 52-FZ). However, as indicated to the RNCNIRP by Repacholi [2006], there are dosimetric concerns about compliance with these standards for mobile phones when a power density limit for mobile phone handsets is used for near-field exposures.

APPROACH TO SETTING LIMITS

The general approach to public health protection and setting exposure limits by previous Soviet and current Russian committees is that people should not have to compensate for any effects produced by RF exposure, even though they are not shown to be adverse to health (pathological). In other words, these committees assume there could be long-term health consequences if people have to compensate for RF exposures that produce biological but not pathological effects. Exposure limits are then set that do not cause any possible biological consequence among the population (regardless of age or gender) that could be detected by modern methods during the RF exposure period or long after it has finished. Their approach to protection is that limits of RF exposure should not cause even a temporary initiation of the protective or adaptive-compensatory mechanisms over the near or long term. Thus, the final exposure limits are set as a fraction of the minimum RF exposure that is capable of provoking some adaptation-compensatory reactions in people.

This is an important difference from the approach used by the International Commission on Non-Ionizing Radiation Protection (ICNIRP), which bases its limits on the lowest RF exposure that causes any established adverse health effect (RF_{Lowest}). Limit values in their guidelines are then set by assuming that there is maximum absorption of the RF field by people and then reducing the RF_{Lowest} by large safety factors to produce the final limits, normally by a factor of 50 lower than the RF_{Lowest} for the general public [ICNIRP, 1998].

Children

Children are not small adults since they are developing organisms with special sensitivities and might be expected to be more sensitive to EMF than adults [Grigoriev, 2005; Kheifets et al., 2005]. Thus, results of studies conducted on adults might not be validly extrapolated to children; therefore, the RNCNIRP considered that children need special consideration when developing exposure limits. According to the RNCNIRP, the following health hazards are likely to be faced in the near future by children who use mobile phones: disruption of memory, decline in attention, diminished learning and cognitive abilities, increased irritability, sleep problems, increase in sensitivity to stress, and increased epileptic readiness. For these reasons, special recommendations on child safety from mobile phones have been incorporated into the current Russian mobile phone standard [Russian Standard, 2003].

STANDARDS

The Ministry of Health was responsible for approving and promulgating public health standards in the USSR, and the scientific justification for the limits in the standards was given to the Marzeev Institute in Kiev, under its director, Shandala. The first general public RF standard was introduced in 1978 [USSR Ministry of Health, 1978] and limited exposure in the 300 MHz–300 GHz range to 5 $\mu W/cm^2$ in inhabited areas during any 24 h period.

One of the best reviews of the early RF standards developed in the former Soviet Union (USSR) was by the World Health Organization (WHO), who convened a Task Group to finalize its Environmental Health Criteria (EHC) on RF and microwaves in Geneva, Switzerland in 1981 [WHO, 1981]. The Task Group had representatives from the former USSR who were familiar with how the Soviet standards were developed and gave a detailed overview of them. The original USSR occupational RF standard for the frequency range of 300 MHz–300 GHz was published in 1959 by the Ministry of Health and reaffirmed in 1976. It was based on clinical and research evidence provided by Letavet and Gordon at the Research Institute of Occupational Medicine [Savin, 1979; Savin et al., 1983]. It limited RF exposure in working areas to 10 $\mu W/cm^2$ (0.1 W/m^2) during the entire working day, 100 $\mu W/cm^2$ (1 W/m^2) for exposures not more than 2 h per working day, and 1000 $\mu W/cm^2$ (10 W/m^2) for exposures not more than 15–20 min per working day, provided that protective goggles were used and RF exposure did not exceed 10 $\mu W/cm^2$ (0.1 W/m^2) for the rest of the working day. This early standard then influenced the development of standards for the general public.

An important stage in standardization of RF exposure limits for the general population came in 1984, after methodological recommendations for the assessment of biological effects from low intensity microwave radiation for hygienic standards in the environment were issued by the Ukrainian Ministry of Health [1981]. The first practical result of the program was the drafting of standards that related to the time of exposure and rules for protecting the population from radio engineering devices. This document was based on EMF studies conducted in the USSR, and also took into account discussions of the joint Soviet-American Intergovernmental Commission on health standards for EMF. A working group specially created under the direction of Shandala, consisting of scientists and hygienists from several institutes, reviewed the results of local and foreign studies and developed the temporary sanitary norms and regulations for the protection of the public from EMF emitted by radio technology [USSR Ministry of Health, 1984]. Table 2 gives a brief summary of the key limit values in the USSR and Russian RF public health and occupational standards, as well as a summary of the mobile phone standard issued in 2003. These are compared with the limits recommended by the ICNIRP [1998] and IEEE [2006].

DISCUSSION

The overall objective of the Soviet-era immunology studies was to evaluate the effect of exposure to UHF RF fields on autoimmunity. The brain was considered an immunologically confined organ, meaning that under normal physiological conditions, cells could not enter the brain and produce immune responses. The induction of antibodies able to react with brain antigens was therefore a sign of auto-reactivity (‘‘auto-allergy’’ or ‘‘auto-sensitization’’). Researchers considered that the simple presence of antibodies reacting to autoantigens does not necessarily lead to autoimmune pathologies, and this is still considered valid. To verify whether the autoantibodies were pathogenic, they injected autoantibody-containing sera from exposed animals into pregnant rats to determine if this would induce detrimental effects in embryos and offspring. The Soviet-era and later Russian studies suggest that this was the case.

However, when assessing these studies it should be borne in mind that they were conducted some 20–40 years ago, when many details about the immune system were unknown, modern laboratory techniques were not available, and standards for

TABLE 2. RF Limits in USSR and Russian Standards, Compared to the ICNIRP Guidelines and IEEE C95.1 Standard for the General Public

Type of standard, approving authority	Characteristics	Refs.
Occupational, proposed in 1958, published in 1959 and confirmed in 1976	300 MHz–30 GHz (in 1958) 300 MHz–300 GHz (in 1976) 10 $\mu W/cm^2$ for working day 100 $\mu W/cm^2$ for up to 2 h/day 1000 $\mu W/cm^2$ for up to 20 min/day	USSR Standard [1976]
1978 Public USSR Ministry of Health	300 MHz–300 GHz 5 $\mu W/cm^2$ from radio, TV, radar equipment for whole day in inhabited areas	Temporary sanitary norms and regulations for the protection of the public from EMF emitted by radio-technology equipment, No. 1823-78 [USSR Ministry of Health, 1978]
1984 Public USSR Ministry of Health	300 MHz–300 GHz 10 $\mu W/cm^2$ from any RF equipment for whole day	Temporary sanitary norms and regulations for the protection of the public from EMF emitted by radio technology equipment, No. 2963-84 [USSR Ministry of Health, 1984]
1994 Public and mobile phone users. Russian State Sanitary and Epidemiological Surveillance Committee	10 $\mu W/cm^2$ from telecom base stations for whole day, $\leq$100 $\mu W/cm^2$ from mobile phones for public and $\leq$1000 $\mu W/cm^2$ for workers	Hygienic Norm HN 2.1.8./2.2.4.019-94. Temporary permissible levels of exposure to electromagnetic fields emitted by mobile radio communication systems [Russian Standard, 1994]
1996 Public. Russian State Sanitary and Epidemiological Surveillance Committee	300 MHz–300 GHz, 200 ($\mu W/cm^2$)/h, with an upper limit of 25 $\mu W/cm^2$ for an 8 h day, from RF equipment	SanPiN 2.2.4/2.1.8.055-96. Physical environmental factors. Electromagnetic factors of the radiofrequency range [Russian Standard, 1996]
1996 Public and mobile phone users (Moscow)	2 $\mu W/cm^2$ from telecom base stations for whole day; $\leq$100 $\mu W/cm^2$ from public use of mobile phones	SanPiN for the protection of the Moscow general public from electromagnetic fields emitted by radio technology equipment [Moscow Standard, 1996]
2003 Public and occupational mobile phone users and base stations	Basic limits for public and workers from telecom equipment (300 MHz–2.4 GHz) 10 $\mu W/cm^2$ for public from base stations, 25 $\mu W/cm^2$ for workers on base stations for $\geq$8 h shifts, or 1000 $\mu W/cm^2$ for $\leq$0.2 h/day Mobile phone head exposure $\leq$100 $\mu W/cm^2$ determined by phone emitting $\leq$3 $\mu W/cm^2$ at 37 cm from phone Recommends limiting mobile phone call time as much as possible and limiting possibility of use by children age <18 years, pregnant women and pacemaker wearers	SanPiN 2.1.8./2.2.4.1190-03. Hygienic requirements for the siting and operation of land-based mobile radio communications equipment [Russian Standard, 2003]
ICNIRP Guidelines on limits for occupational and public EMF exposure, 1998	*Basic restrictions* for 300 MHz–300 GHz. For whole body 0.08 W/kg, for head and trunk 2 W/kg *Reference levels* (300 MHz–300 GHz): Public: 10–400 MHz is 2 W/m^2 400–2000 MHz is f/200 (f = frequency in MHz) 2–300 GHz is 10 W/m^2	For complete set of limits, see ICNIRP [1998]. These limits were reaffirmed by the ICNIRP in 2009 [ICNIRP, 2009]. Available online at: http://www.icnirp.de/PubEMF.htm (Last accessed 24 March 2012)
IEEE C95.1 safety levels with respect to human exposure to radiofrequency electromagnetic fields, 3 kHz to 300 GHz, 2006	*Basic restrictions* for100 kHz–3 GHz. For whole body 0.08 W/kg. For head (except pinnae) and trunk 2 W/kg *Action levels* for 400 MHz–2000 MHz: f/200 W/m^2, where f = frequency in MHz 2–100 GHz is 10 W/m^2	IEEE [2006]

conducting high-quality studies were not well established. An obvious concern about these early studies is the fact that inbred animal strains were not used, few animals were used in each study, animals were of differing sexes, ages, and sizes, diets were variable, animals could be housed in rooms with natural lighting so that rodent physiology could vary significantly with the seasons, and there was a lack of raw data and analyses from which to make objective judgments of the conclusions. While study results were interpreted using the best judgments of the scientists at the time, there was little or no peer review of the early USSR studies, and few details of the study methodology were provided in the final publications. Studies of this quality would not be useful in the development of current standards. Finally, in the period during which these studies were conducted, very little exchange of scientific information occurred between the USSR and other non-Soviet Union countries.

Replication of the most important Soviet immunology studies was recommended in the WHO's EMF Project research agenda [WHO, 2006]. Experiments with a protocol similar to the early Soviet-era studies, but using more modern methodology, were subsequently conducted in Bordeaux [Poulletier de Gannes et al., 2009] and Moscow [Grigoriev et al., 2010]. While the French study was uniformly negative, the Moscow study found some positive trends in their results. Despite efforts to standardize experimental conditions in both countries, the Russian scientists considered that there were sufficient differences in the conduct of the two separate studies to contribute to differences in the final results. The Russian scientists interpreted their findings as showing a compensatory response in rats exposed to chronic, low intensity RF but that these changes were not pathological. The Oversight Committee, with access to the raw data from both studies, concluded that the results were not convincingly confirmed [Repacholi et al., 2011].

The various USSR and Russian standards committees considered that chronic exposure to non-thermal levels of RF fields was potentially hazardous to human health. Further, the key philosophy used to set limit values in the Russian standards was that RF exposure should not produce any effect that had to be compensated for by people because it was believed that this would lead to pathologic effects over the long term [Grigoriev et al., 2003b,c]. As noted above, this was not the philosophy for setting limit values adopted by other national standards committees or by either the ICNIRP or the IEEE. Furthermore, the USSR and Russian committees did not consider dosimetry in their standard setting. It was not recognized that for the same power density, the absorption in mice and rats can be orders of magnitude higher than in humans.

There are concerns about the assessment of compliance with the limits for mobile handsets in the mobile phone and base station standard [Russian Standard, 2003] because it is not valid to just have power density limits for near-field exposures. Compliance with the head exposure limit of 100 $\mu W/cm^2$ is assessed by ensuring that the power density is not more than 3 $\mu W/cm^2$ at a distance of 37 cm from the phone. This is not a measurement in the near field where exposures to the head occur. Because compliance is assessed in the far field, higher specific absorption rate (SAR) phones measured in the near field can give a lower power density at 37 cm than lower SAR phones [Repacholi, 2006].

The philosophy of protection of the public—that RF exposure of individuals should not cause any compensatory response—is not used in standards outside of Russia. National authorities in most countries want to know what health effects they are protecting against and not make assumptions about what effects may occur. This is the philosophy of the ICNIRP and IEEE committees.

CONCLUSIONS

The objective of this article is to provide the scientific basis for the Soviet and Russian RF standards, and not to provide a detailed critique of them. Copies of the complete articles translated from the original Russian into English are provided in the online version of this article.

Special internal studies within various agencies of the former USSR were carried out for many years using the recommendations, accepted at that time, from the Ukrainian Ministry of Health [1981] for assessing biological effects from low-level microwave exposure and how the results should be applied for developing standards. Therefore, the results of the Soviet studies should be seen in this context. Following the break-up of the Soviet Union, the development of Russian standards continued to use similar methodologies and approaches to protect the public from RF exposure. It should be recognized that the Soviet-era studies were conducted before much improved laboratory methods, requirements for quality research, and a better understanding of the immune system were available, and the significantly stricter requirements of modern-day peer-reviewed scientific journals for details of descriptions of experiments, results, and analyses.

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