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ORIGINAL ARTICLE

Radiofrequency electromagnetic field of base stations in Northern Cyprus: A descriptive study

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Abstract

Objective: The purpose of this study is to analyze the change in Radiofrequency Electromagnetic Field (RF-EMF) public exposure caused by base stations (BSs) between 2009-2020 in Cyprus with respect to the parameters stated in the reports, and to define potential adverse health effects by comparing the results with national and international guidelines.

Method: In this study, six measurement reports published by Information Technologies and Communication Authority (ITCA) in Cyprus between 2009-2020 were reviewed, the change in the RF-EMF public exposure caused by BSs were analyzed and adverse health effects comparing the results with national and international guidelines were defined.

Results: The total of measurement points is 18.390 in 2009, 20.000 in 2011, 28.691 in 2013, 170.725 in 2016, 486.214 in 2018, 353.819 in 2020. The number of mobile phone users is 596.000 in 2013, 804.345 in 2016, 877.990 in 2018, 818.728 in 2020. In Lefkoşa, Girne, Gazi Mağusa, Güzelyurt and Yeni İskele the measurement values varied between 5.65-0.63, 2.82–0.57, 3.26-0.58, 3.27–0.57 and 3.85–0.55 V/m in 2009 and 2020, respectively.

Conclusion: The present data along with scientific evidence lead to the conclusion that short-term RF-EMF exposure results should be defined within the precautionary principle. Measurement results were highly variable and varied considerably between years within as well as between districts. To define the explicit reason for exposure level change during the years, the measurements must be done by considering short- and long-term adverse effects in the same location in each year.

Keywords: Radiofrequency, Electromagnetic Fields, Health Effects, ICNIRP

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INTRODUCTION

Today, mobile telephones have become an unavoidable part of regular lifestyles. People are under uncontrolled exposure to electromagnetic (EM) radiation of mobile phone base stations (BSs) even if they do now no longer use mobile phones. Due to the explosive growth of the mobile phone industry, the variety of mobile phone BSs have placed at many residential areas in urban areas within a mile of each BS. The deployment of the next generation of cellular network technology, 5G, will increase BS density to a great extent and there have been health concerns related to wireless radiation from (1) portable communications equipment, (2) occupational exposures, (3) home exposures, (4) indoor wireless networks at businesses and schools, (5) automotive radars and (6) other sources of non-ionizing EMF radiation, such as "Internet of Things" and "Smart Meters".[1]

The final outcome of this increase is the growth of health and biological effects of the electromagnetic radiation produced on all living beings. There is scientific consensus on some effects, such as thermal and microwave hearing effects, while other biological and health effects are still under investigation. This is why the electromagnetic field measurement according to international recommendations is often the subject of worldwide research. It is important to expect EMF levels before establishing BS traffic, especially in the case of a next generation mobile system deployment.[2]

Exposure to EM radiation is categorized as non-ionizing and ionizing radiation. Non-ionizing radiation contents; (i) 3–3000 Hz frequencies which are referred to as Extremely Low Frequency (ELF), involving highvoltage transmission towers, electrical lines and inhouse wiring and (ii) 30 kHz to 300 GHz frequencies which are referred to as Radio Frequency (RF), involving mobile phones, BSs, 5G technologies, and smart devices. EM radiation generates electrical field, measured as volt per meter (V/m), and magnetic field, stated in Tesla or defined as magnetic flux density, measured as ampere per meter (A/m).[3]

A part of the EMF energy is turned into kinetic energy to be transformed to heat in the body (described as "warmth" at 10 MHz), which can negatively affect health. Also, if the induced electric field is strong enough and below about 10 MHz, it can perform electrical forces that are sufficient to cause change in the permeability of biological membranes (with continuous 18 GHz wave exposure), and to stimulate nerves (described as tingle feeling for about 100 kHz frequencies). EMF below 6 GHz penetrate deep into tissue. On the contrary, absorbed EMF above 6 GHz is more superficial. However, epidemiological and experimental investigations on the EMF exposure's adverse effects on the brain electrical activity, higher cognitive functions, on neurodegenerative diseases, on the neuroendocrine system, on the cardiovascular system, thermoregulation or autonomic nervous system, on the haematology or immune system, on reproduction or fertility, and on auditory, ocular, or vestibular function or pathology are still ongoing.[4]

The Council of the European Union (EU) issued Recommendation (1999/519/EC, "EU Recommendation") on limiting the public electromagnetic fields exposure (0-300 gigahertz) in 1999. It contains basic limitations for induced electric fields and currents as well as absorbed energy in the body and reference levels for the strength of electromagnetic fields outside the body. The EU recommended limits are derived from the 1998 guideline on limiting EMF exposure of the International Commission on Non-Ionizing Radiation Protection (ICNIRP).[5] The World Health Organization (WHO) has created the International EMF Project to evaluate the scientific evidence regarding the potential health effects of EMFs between the 0-300 GHz frequency.[6] ICNIRP published an update to the ICNIRP guidelines in March 2020.[4] Also in October 2019, the Institute of Electrical and Electronics Engineers (IEEE) published an update to the standard C95.1-2019.[7] IEEE and ICNIRP limits are harmonized and energy density limits for total body exposure fields are uniform above 30 MHz.[7] In 2011, WHO's International Agency for Research on Cancer (IARC) classified RF radiation between 30 kHz and 300 GHz frequency as Group 2B as 'possible' carcinogen for human.[3]

Most countries have accepted exposure limit values of RF-EMF based on IEEE standards or ICNIRP guidelines; however, some countries like Türkiye have decided to adopt additional precautions to protect their people. International reference values are given in Table 1.[9,10,4] The lowest reference level for the public is 27.7 V/m.[4,11] National reference values correspond to 70% for the environment and 20% per device of the BS limit reference values determined by ICNIRP. In Cyprus ITCA reports, it corresponds not to exceed one quarter (1⁄4) per a single device.[9,12,13]

Using different exposure limits in various countries has increased scientific and public concern. Public institutes are encouraged by WHO to follow guidelines established by IEEE and ICNIRP scientific expert panels or restricts set by experts. Best practice for public institutes is to measure RF levels in the environment caused by mobile network technologiesis to define the exposure limits accordance to the international and national guidelines.

METHOD

Measurements and evaluation of RF-EMF levels, the RF-EMF exposure guidelines for the workers and general public are the main issues of risk communication management and assessment. RF-EMF measurements are made for various reasons. These reasons are to define regulatory documents or safety hygiene standard, to obtain data to be used for epidemiologic studies, to identify RF-EMF sources, and to observe long term exposure results. So that the methodology to define accurate exposure assessment should be chosen with special attention. Taking into account the basic physical properties of electromagnetic waves (interference, reflection, and absorption), the measurement equipments setting can effect the correctness of the results due to changing circumstances.[14]

The crucial point while settling RF-EMF field measurements is to identify measurement locations properly.[14,15] In previous measurement studies, several different measurement methods and different kinds of devices were used. This differentiation leads to difficulties to compare the measurement results among studies.[15]

National and international guidelines defining the limit values for RF-EMF exposure generated by BSs are used for RF-EMF measurement assessments. Nevertheless, to evaluate the main components of the physical measurement area and to estimate RF-EMF measurement results on the main and side lobes of the radiation pattern and to calculate the total exposure level of various antennas is difficult. Correspondingly, RF-EMF measurement methodologies (measurement points, measurement devices and related probes, measurement duration and etc.) should be detailed in order to predict the radiation level in the environment.[14,15]

Determining the main radiation direction pattern from each BS antenna at which point the RF-EMF measurement results will be the highest is one of the most important part to start the measurement. This part is done either by conducting real time field measurements or by analyzing the technical characteristics of mobile BS antennas. On the other hand, all the directional diagrams of in the horizontal and vertical planes of BS antennas are utilized while determining the main radiation direction.[14]

The hypothesis of our study is that in the measurement reports published by the ITCA between 2009-2020, the number of mobile phone users, the technical data of the BS, the number of the BS, comparability of BS RF levels in measurement areas, and what precautionary measures have been taken are to be able to reached and evaluated. Hence, this study gives information about the errors while defining the measurement points and all other steps during the measurement process.

RF-EMF exposure levels from the BSs located in Cyprus were taken from the reports published by the ITCA in Cyprus between 2009-2020. In these measurement reports, it was reported that those electromagnetic field levels in North Cyprus were measured with Narda EMR300 in 2009, 2011, 2013 and with Narda SRM3006 in 2016, 2018, 2020. RF levels are measured with specific measurement devices and their isotropic probes. Factors affecting the measurements reliability can be classified into two groups. The first category is related with measurement device concerns such as calibration, measurement units and recording duration. The second category is related with measurement conditions such as measurement time, measurement location, weather conditions and technical specifications of BSs.

Each ITCA studies done in same districts (Lefkoşa, Girne, Gazi Mağusa, Güzelyurt, Yeni İskele) in each year were examined with the common data including number of BSs, number of mobile phone users and electric field strengths (maximum value, average value and number of measurement points). There were two kinds of reports; one is quarterly published documents about sector developments including number of BSs and users, the second type documents were about the electromagnetic measurements results conducted around North Cyprus.

For the purpose of this study, the change in RF-EMF of BSs between 2009 and 2020 was analyzed and the results were compared with national and international guidelines, thus creating a discussion ground in terms of negative health effects.

The measured results for the different districts were compared with respect to years, number of BSs, electromagnetic field measurement results/number of measurement points and number of users for each year. In the specified area where RF-EMF measurement will be done the most important parameters to be selected are order to identify spatial distribution of antenna: The antenna's geometric center height, the main radiation direction (main lobe), and the required down tilting of the directional pattern on the horizontal and vertical planes.[14]

Unfortunately, the measurement conditions have different designs and the distribution of parameters across these reports are heterogeneous, so that comparability is quite limited. In order to obtain reliable conclusion, we evaluated the largest appropriate independent information from different six reports.

2.1. Regulations about Precuationary Measures

Relevant regulations of human RF radiation exposure contain: 1. Permissible limits for ambient exposure due to emissions from wireless networks and BSs, known as maximum exposure limits allowed in the countries; and 2. exposure limits for local exposure at body and head from mobile phones, home and personal devices, known as specific absorption rate (SAR) limits. The ICNIRP and IEEE standards used as the basis for many government limits have remained largely unchanged since the 1990s, and they are intended to protect against the effects of high-power exposure over short-term. These limits are not designed to protect against the effects of chronic, long-term, low-level exposure.[16]

In United States, limits for RF radiation were issued by the Federal Communications Commission (FCC) in 1996, largely based on a 1986 report by the National Council on Radiation Protection and Measurement (NCRP) and the IEEE (ANSI/IEEE) C95.1-1991 standard. US limits for environmental RF levels are similar to those in Japan, Australia, Germany and other countries have also adopted ICNIRP limits.and among the mildest in the world.[16]

However, some countries such as Switzerland, Italy, Russia and China, have imposed regulatory limits on emissions from mobile phone BS networks that are much stricter than the limits stated in ICNIRP and FCC limits which are based on thermal effects of RF radiation.

European countries have prepared their regulatory policies and limits based on the precautionary principle which is used as a decision-making key factor. This principle is based on the wise advice of Benjamin Franklin: *prevention is better than cure*.[16]

The Parliamentary Assembly of the Council of Europe (PACE) resolution strongly recommended that “as low as reasonably achievable” (ALARA) principle is performed covering both the biological effects or thermal and non-thermal effects of electromagnetic radiation or emissions in 2011.[17]

On the contrary, some countries, such as Russia and China, apply not preventive but “scientific-based” limits which are based on studies done by their own scientists. India reduced the limit to one-tenth the ICNIRP limit in 2012 in response to a report by an inter-ministerial committee that reviewed studies on impacts on wildlife, including bees and insects, pollinators, and concluded that “the majority of the published literature points to harmful effects of EMF in different species”.[16]

The ICNIRP exposure limits are frequency dependent and national frequency dependent precautionary exposure limits have been set as to limit the radiation level from one single BS and special limit values for sensitive areas such as schools, kindergartens and hospitals. The national precautionary limits of electric field strengths are four times less than the ICNIRP guidelines. General public exposure limit values defined by national and international organizations are comparatively given in Table 1.[4,12,18-20]

in 2020. The number of mobile phone users is 596.000 in 2013, 804.345 in 2016, 877.990 in 2018, 818.728 in 2020 however no data available in 2009 and in 2011. In Lefkoşa, Girne, Gazi Mağusa, Güzelyurt and Yeni İskele the measurement values varied between 5.7 - 0.6, 2.8 – 0.6, 3.3 – 0.6, 3.3 – 0.6 and 3.9 – 0.6 V/m in 2009 and 2020, respectively. The number of BSs and the electromagnetic field measurement results-number of measurement points are given in Tables 2 and 3 respectively.[13,21-25] The analysis of the reports is discussed according to the international policies on electromagnetic fields based on precautipnary principle.

Table 1. General public exposure limits defined by the ICNIRP and national authority at mobile communication frequencies.

Frequency (MHz)	900			1800			2100			2700		
Institute	ICNIRP	ITCA Türkiye	ITCA Cyprus	ICNIRP	ITCA Türkiye	ITCA Cyprus	ICNIRP	ITCA Türkiye	ITCA Cyprus	ICNIRP	ITCA Türkiye	ITCA Cyprus
Electric field for total environment (V/m)	41.3	28.8	N/A	58.3	40.7	N/A	61	42.9	N/A	61	42.9	N/A
Electric field for single antenna (V/m)	N/A	8.3	10.3	N/A	11.7	14.6	N/A	12.3	15.4	N/A	12.3	15.4

N/A: Not applicable

RESULTS

In the present study, six measurement reports published by ITCA in 2009, 2011, 2013, 2016, 2018, 2020 were analyzed with respect to the parameters stated in the reports; number of users, measurements, BSs, measurement points, and measurement levels defined by V/m. In Figure 1, change in the number of BSs over the years, in Figure 2 change in the number of measurement points over the years and in Figure 3 average measurement levels in five different districts were analyzed. Although the measurements in each year were done in different districts, we have chosen Lefkoşa, Girne, Gazi Mağusa, Güzelyurt, Yeni İskele since they were common in all reports. The total of measurement points is 18.390 in 2009, 20.000 in 2011, 28.691 in 2013, 170.725 in 2016, 486.214 in 2018, 353.819

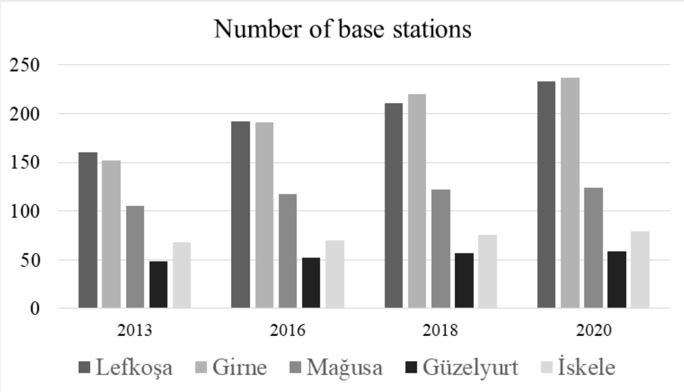

Figure 1. Number of base stations in five different districts.

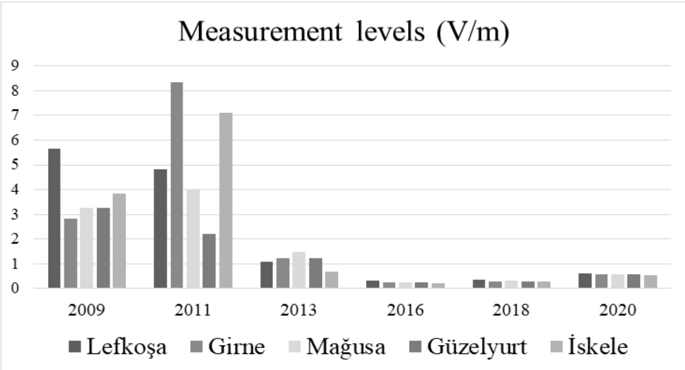

Figure 2. Number of measurement points in five different districts.

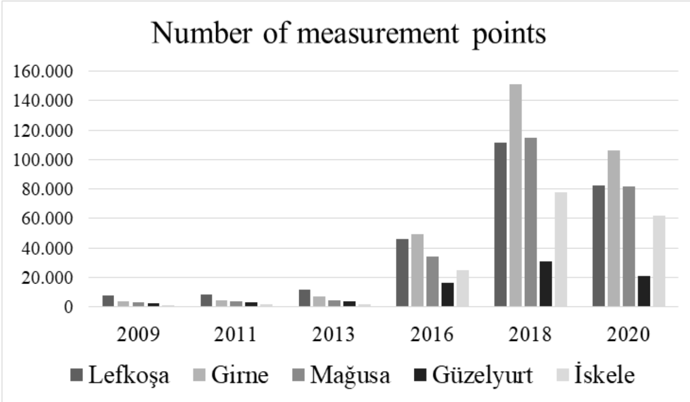

Figure 3. Average measurement levels in five different districts.

Table 2. Number of base stations change according to time in five different districts.

	Lefkoşa	Girne	Gazi Mağusa	Güzelyurt	Yeni İskele	Total
2009	NA	NA	NA	NA	NA	NA
2011	NA	NA	NA	NA	NA	NA
2013	160	152	105	48	68	533
2016	192	191	117	52	70	622
2018	211	220	122	57	75	685
2020	233	237	124	59	79	732

NA: No data available

Table 3. Electromagnetic field measurement results/number of measurement points change according to time in five different districts.

		2009	2011	2013	2016	2018	2020
Lefkoşa	Average E-field (V/m)	5.7	4.8	1.1	0.3	0.4	0.6
	Number of measurements	7.500	8.100	11.871	46.183	111.514	82.633
Girne	Average E-field (V/m)	2.8	8.3	1.2	0.2	0.3	0.6
	Number of measurements	3.900	4.100	6.971	49.077	151.263	106.509
Gazi Mağusa	Average E-field (V/m)	3.3	4.0	1.5	0.2	0.3	0.6
	Number of measurements	3.100	3.500	4.118	34.168	115.077	81.848
Güzelyurt	Average E-field (V/m)	3.3	2.2	1.2	0.2	0.3	0.6
	Number of measurements	2.500	2.800	3.893	16.114	30.713	21.138
Yeni İskele	Average E-field (V/m)	3.9	7.1	0.7	0.2	0.3	0.6
	Number of measurements	1.390	1.500	1.838	25.183	77.647	61.691

DISCUSSION

This paper analyzed the result of measurements conducted by ITCA between 2009-2020 and utilized the health effects of RF-EMF exposure caused by BSs. In contrast to our hypothesis, any clarification indicating the reason for BS exposure levels would be increased due to the increased number of mobile phone users and number of BSs could not find in the measurement reports. Measurement results were extremely variable and varied considerably between years within as well as between districts. For example, in Lefkoşa the measurement values varied between 5.7 V/m (in 2009) and 0.6 V/m (in 2020). Also between districts meaningful differences were observed for each report. To define the explicit reason for exposure level change during the years, the measurements must be done in long durations and in the same location in each year.

All RF-EMF measurement results given in the reports were below both ICNIRP and national reference levels. Until now, no health effects can be mentioned under this level. However, there is some uncertainty about long-term health effects at low exposure levels and reducing exposure to RF-EMF has been suggested with previous studies and thus numerous countries have introduced precautionary measures.[16,26-28] The results of the precautionary exposure limits are difficult to predict because more necessary regulations effect the BS network configuration. It is conceivable that elevated exposure values can be reduced by precautionary limits but mean value may even be increased due to the higher network density with more microcells installed closed to where the population spends its time. The measurement reports used in our study however did not show any indications to support this situation. In Figure 3 it is seen that average measurement levels are decreasing during years while number of BSs is increasing. Within this study the reason for sharp decrease in the electric field levels caused by BSs cannot be defined since in all reports technical specifications of BSs i.e. frequency, antenna directions, etc. were not given in the reports. Hardly, to increase general public's awareness it is important to give the technical specifications must be given with measured exposure levels.

It can be argued that the RF-EMF exposure level is not important as long as the reference levels are not exceeded. However, there is some uncertainty regarding long-term health effects, and reducing exposure can minimize this uncertainty. The measurements were only own street level. We cannot ignore that more exposure levels can occur at such sites in the districts with higher regulatory limits. If there is concern about such high exposure, the exposure level can be reduced by limiting the output of BS.[29] This problem can be explained with the results of spot RF measurements that they are not capable of fully representing the spatial distribution of the RF field. The reasons for this are: a) the measurement pattern may be too small and does not take into account high exposure areas b) measurement points do not overlap with the RF hotspots that usually occur around the BS antennas. Also, the field distribution is uneven as RF hotspots depend on the surrounding environment and the radiation pattern of the antenna. Only computer simulations or detailed measurements can identify RF hotspots around the antenna.[30]

Current scientific data lead us to the conclusion that short-term mobile phone RF-EMF exposure is not associated with health levels or physical symptoms in individuals with EMF hypersensitivity. Also, thesee individuals fail to detect the presence of RF-EMF and present with a range of severe symptoms and often have a very poor life quality.[26,31]

In recent years, there are studies in the dentistry literature investigating the adverse effects of RF-EMF on oro-facial structures.[32-34]

In their study, Berto and Al-Hijazi showed that there can be retardation in development of teeth and palate in the embryos of mice at the 16th day of intrauterine life when its mothers were exposed to mobile phone radiation for 120 minutes duration daily. They also reported that, tooth germ recorded to be missed and oral ectodermic thickness was hardly detected.[32]

A study by Alchalabi et al. on rats stated that, intrauterine mobile phone radiation exposure can change the intensity of bone turnover processes of certain parts of the skeleton majorly in head and the processes of bone mineralization, and thus impact embryonic skeleton development and formation directly.[33]

In another study to evaluate the effect of RF-EMF on oro-facial tissues, Yan and colleagues found that if rats continue to be exposed to mobile phone radiation, there can be potentially permanent damage over the years, most likely in the buccal and mandibular branches of the facial nerve.[34] In summary, the majority of studies with electromagnetic radiation exposures show biological responses. As a result, the findings of current studies on dentistry reveal the need for more studies on this subject.

With these results, many researchers strongly recommend that experimental and epidemiologic studies are urgently needed to better identify the health effects caused by new emerging Technologies i.e. 5G Technologies for different populations due to increasing electromagnetic field exposure density.[35]

One of the main problems in defining the RF radiation exposure assessment is to do with field level variation since the radiated power of modern mobile communication systems varies over time with unstable data traffic. To solve this problem, in the latest generation of cellular systems, the peak power extrapolation technique has been proposed and applied successfully. Basically, these techniques allow to estimate the maximum level of electromagnetic field that the BS can emit at the optimal location from measurement points in a relatively short time and represents a fundamental tool for assessing exposure to RF electromagnetic fields.[36]

While most countries follow the limits set by ICNIRP (10 W/m2) for mobile information in the frequency range (2 - 300 GHz), few countries, like Türkiye, impose much more restrictive limits on the power density of electromagnetic field values in the same frequency range. The most restrictive value for flat wave equivalent power density, 0.1 W/m2, is implemented in countries such as Lithuania, Poland, Italy and Bulgaria, which may raise concerns about the future development of 5G infrastructure for frequencies above 2 GHz.[37]

Without exception, for a highly accurate assessment of people's exposure to various mobile services, the measured electric field strength values need to be estimated according to the maximum load of the mobile network.[37]

The limitation of the current study is that data obtained from the reports having gaps about the measurement standarts during RF-EMF measurement. Therefore, it is difficult to identify adverse health effects over the years. Further limitation of our investigation, the points such as measurement duration and time, weather conditions, far field / near field issues, criteria how the BS was excepted, technical specification of BSs that should be taken into consideration while performing the RF measurements should be clearly expressed in the reports. So that there is no gap the public information about health effects.

Under uncontrolled states such as a complex environment, quite dissimilar results can be obtained with different measurements due to variable conditions. The accuracy of the measured values of RF EMF can also be affected by the settings of the measuring equipment. The another limitation of present study was failing to access information about other sources of electromagnetic waves, such as television waves, radio-frequency waves, and satellite waves; [38] evaluation of the physical environment (such as aparment buildings) restricting RF EMF propagation, the height of the geometric center of the antenna, the main radiation's direction, the incidence of individual symptoms, the distance between the inhabited area and the BS, and the RF exposure level at the vicinity of the BSs.

CONCLUSION

Electromagnetic radiation should be regarded as "environmental pollution" typically occurring in the everyday environment. There is a need to assess the potential health effects and the environmental effects of electromagnetic radiation, as well as the economic burden on the health system of the increase in health effects including hypersensitivity. The present data along with scientific evidence let to the conclusion that short-term RF-EMF exposure is not related to levels of well-being or physical symptoms in individuals. However, the results of this study indicate that long-term low-level EMF exposures, which typically occur in the daily environment, may be hazardous and preventive measures should be taken. Therefore, measurements should be made taking into account long-term and short-term negative effects. We are raising a warning flag for to define exposed subjects as potentially vulnerable, the invoke the precautionary principle and to revise existing limits.

The curiosity about whether the environmental pollution caused by the emissions of the developing 5G technology has adverse effects on individual health is increasing day by day. It is important in terms of public health science to use the possible health interruptions that may be caused by the BSs, whose sections will increase significantly with the new technology.

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collection and entry: FA, BA, Analysis and interpretation: FA, BA, KN, Literature search: FA, BA, KN, Writing: FA, BA, KN, Critical review: FA, BA, KN.

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