

EU Directive, ICNIRP Guidelines and Polish Legislation on Electromagnetic Fields

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This review describes the general provisions of and the philosophy behind European Directive 2004/40/EC and ICNIRP (International Commission on Non-Ionizing Radiation Protection) guidelines. As an example of national legislation on the protection of workers against excessive electromagnetic field exposure, regulations established in Poland are summarized. The problems of a practical implementation of the Directive's provisions are discussed.

electromagnetic fields occupational exposure exposure assessment regulations

1. INTRODUCTION

Electromagnetic fields (EMF) exist in the working environment as a result of the use of various electrical devices and wireless communication systems. The most common sources of exposure to EMF are electrical power distribution systems, including high voltage power lines and transformer stations, industrial devices like induction heaters and welding devices, medical devices such as those used in electrosurgery, physiotherapeutic diathermy or Magnetic Resonance Imaging (MRI) scanners, radio- and TV broadcasting transmitters and wireless telecommunication systems.

2. EUROPEAN DIRECTIVE 2004/40/EC FOR EMF OCCUPATIONAL EXPOSURE

2.1. Directive 2004/40/EC: General Justification

European legislation on the protection of workers against various harmful environmental factors in the workplace has been created on a strong legal framework. Article 137 of the European Union Treaty enables the Commission to develop proposals for directives, i.e., for binding legislation related to health and safety at work [1].

Work on compiling directives for different physical agents in the workplace—vibration, noise, EMF and optical radiation—started in 1992. The first directive,

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on vibration [2], was adopted in 2002, the second one, on noise [3], in 2003. Directive 2004/40/EC was published in May 2004 [4]. Its article 12 imposes on Member States that the provisions of the directive, considered as minimal requirements against occupational risks due to exposure to EMFs, be transposed into national legislation within 4 years, i.e., by April 2008.

2.2. Directive 2004/40/EC: Main Provisions

The EMF directive's [4] obligations of employers are more detailed than the general obligations already made compulsory by Framework Directive 89/391/EC [5]. The employers' main obligations laid down in the EMF directive concern determining workers' exposure; assessing, avoiding or reducing risk; and giving priority to collective protective measures before personal ones. Employers are also obliged to provide information and training, consultation and health surveillance for workers, making their participation possible.

The EMF directive requires that employers undertake risk/exposure assessment using detailed procedures given in harmonised European standards. The Commission's mandate M/351 [6] to develop these standards, given for the Committee for Electrotechnical Standardization (CENELEC), requires proportionality, minimal impact on small and medium enterprises (SMEs), coherence with existing EMF standards, e.g., product standards, and involvement of other European standards organisations (European Telecommunications Standards Institute [ETSI] and European Committee for Standardization [CEN]). It is intended that in most cases the employer will be able to undertake risk assessment, requiring specialist or external expertise in few situations. CENELEC's Technical Committee 106X is leading the work programme under mandate M/351 [7].

2.3. Permissible Exposure Levels: Internal and External Measures

The employer shall assess and, if necessary, measure and/or calculate the levels of EMFs to which workers are exposed. On the basis of an

assessment of the levels of EMF (Annex, Tables 1 and 2), if action values are exceeded, the employer shall assess and, if necessary, calculate whether exposure limit values have been exceeded. According to the directive's obligations workers shall not—in any event—be exposed above exposure limit values. The physical quantities used to specify EMF exposure limit values were established as a set of internal measures of maximum permissible exposure effects inside an exposed worker's body. Additionally, action values were defined for testing and assessing environmental conditions in the workplace. Action values are obtained from exposure limit values according to the rationale presented in ICNIRP (International Commission on Non-Ionizing Radiation Protection) guidelines [8] as a set of external measures of exposure levels.

When carrying out risk assessment, the employer shall give particular attention, among others, to the following: the level, frequency spectrum, duration and type of exposure; exposure limit values and action values; multiple sources of exposure; and simultaneous exposure to multiple frequency fields.

The directive's obligations refer to the following physical quantities of action values, which can be used to describe EMF exposure (external measures): electric field strength (E), magnetic field strength (H), magnetic flux density (B) and power density (S). The results for an exposed body, which were taken as exposure limit values (internal measures), refer to current density (J) and specific absorption rate (SAR). Additionally the provisions of the EMF directive refer to contact current (I_C) and limb induced current (I_L).

Magnetic flux density, contact current, electric and magnetic field strength, and power density can be measured directly in the working environment. Other quantities related to exposure limitation in the workplace can only be calculated by using an analytical or numerical model of a specific exposure situation. Because of the electrical heterogeneity of the body, current densities should be calculated as averaged over a cross-section of 1 cm^2 perpendicular to the direction of current flow. Besides the whole-body averaged SAR , local SAR values are necessary to evaluate and limit excessive energy deposition in small parts

of the body resulting from special exposure conditions (e.g., a grounded individual exposed to radiofrequency fields in the low megahertz range or individuals exposed in the near field of an antenna). Localised *SAR* averaging mass is any 10 g of contiguous tissue with nearly homogeneous electrical properties. The maximum *SAR* so obtained should be the value used for estimating the exposure level.

Assessment of a worker's exposure should be performed on the basis of the results of measurements of the rms value of unperturbed (existing in the workplace during the absence of workers) electric and magnetic field strength averaged over the worker's body position and averaged for a particular time, which depends on the frequency of the assessed fields. For example, in the case of the EMF of the frequency of 100 kHz–10 GHz, *E* and *H* should be averaged within any 6 min of a worker's exposure, and E^2 and H^2 should be averaged over the worker's body position.

3. ICNIRP GUIDELINES FOR EMF EXPOSURE LIMITATION

3.1. ICNIRP's Role

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) is an independent group of scientists established to evaluate research data on the effects of non-ionizing radiation (NIR) on human health and well-being, and to provide scientifically based guidelines on limiting exposure. ICNIRP is a formally recognised non-governmental organisation in NIR protection for the World Health Organization (WHO), the International Labour Organization (ILO) and the European Union [9].

ICNIRP monitors continuously and carries out periodically critical reviews of the scientific literature on the sources and possible biological and adverse health effects of NIR. In general, ICNIRP limits its surveillance to published original scientific reports. To assist in the review process, ICNIRP has four standing committees, whose membership also includes non-ICNIRP

experts. In addition, the Commission invites relevant experts as consulting members.

3.2. EMF Health Risk Assessment: Scientific Approach

EMF exposure may cause different biological effects, with a variety of consequences for a human being [9, 10]. For instance, annoyance or discomfort may not be pathological, but can affect the physical and mental well-being of a person and the resultant effect may be considered as a health hazard or occupational risk. Reliable risk assessment requires consistent information from multiple studies published in peer-reviewed scientific literature. Therefore, ICNIRP monitors the accumulation of new evidence which may lead to updating health risk assessments. It is important to recognise that ICNIRP advice is based on current knowledge, and as such will be subjected to revision in the light of new evidence.

The exposure limitations developed by ICNIRP are intended to protect against diseases and other adverse health effects. Because adverse consequences of EMF exposure can vary from trivial to life threatening, a balanced judgement is required before deciding on exposure limitation. Biological effects without any identified adverse health consequences do not form a basis for exposure restrictions.

Because risk assessment is focused on human health, ideally data should be derived from human studies. The relationship between exposure and certain short-term biological effects can sometimes be evaluated from human laboratory studies, whereas data on long-term human effects can only be derived from epidemiological studies. However, epidemiological studies do not provide sufficient evidence of causal relationships without biological data from experimental studies.

A decision must be first made whether available evidence allows an identification of an exposure hazard, i.e., an adverse health effect that is caused by EMF exposure. By this identification, the effect becomes established. For complete risk assessment, selected studies should provide additional, mostly quantitative, data on

- a definition of a biologically effective quantity, which may vary with organs;
- an exposure–effect relationship, and an identification of a threshold;
- exposure distribution and identification of sub-populations with high exposure;
- differences in a population’s susceptibility.

Following the philosophy described here, basic restriction (internal measure) and reference level (external measure) limit values are intended mainly for the protection of workers against harmful EMF exposure results occurring inside exposed bodies during exposure. Long-term effects of chronic exposure have been excluded from the scope of the guidelines because it was considered that currently there was not sufficient consistent scientific evidence to fix the thresholds for such possible effects. The provisions of the present European directive [4] are based on a similar philosophy and rationale.

3.3. Exposure Characteristics

ICNIRP’s general strategy is to define internal measures of exposure (basic restrictions) in terms of a biologically effective quantity, and then to

relate them to external measures (reference levels) expressed in terms of a directly measurable quantity of external exposure (e.g., power density or field strength) [10]. The use of reference levels ensures compliance with basic restrictions on exposure, since the relationships between them have been developed for situations of maximum coupling conditions between fields and exposed people. If the reference level is exceeded, basic restrictions are not necessarily exceeded. This has to be ascertained through a more detailed investigation, e.g., by numerical calculations.

Hence, basic restrictions are closely related to biological mechanisms, while reference levels are easier to evaluate. They also make it possible to avoid the use of complicated dosimetric relationships in practical occupational hygiene management.

Reference levels are, therefore, provided strictly as an aid for practical exposure assessment, to determine whether basic restrictions are likely to be exceeded. ICNIRP recommends the use of reference levels as a general guidance for limits for workers and the general public [8] (Figure 1).

The basic restriction/reference level strategy depends on an understanding of the interaction

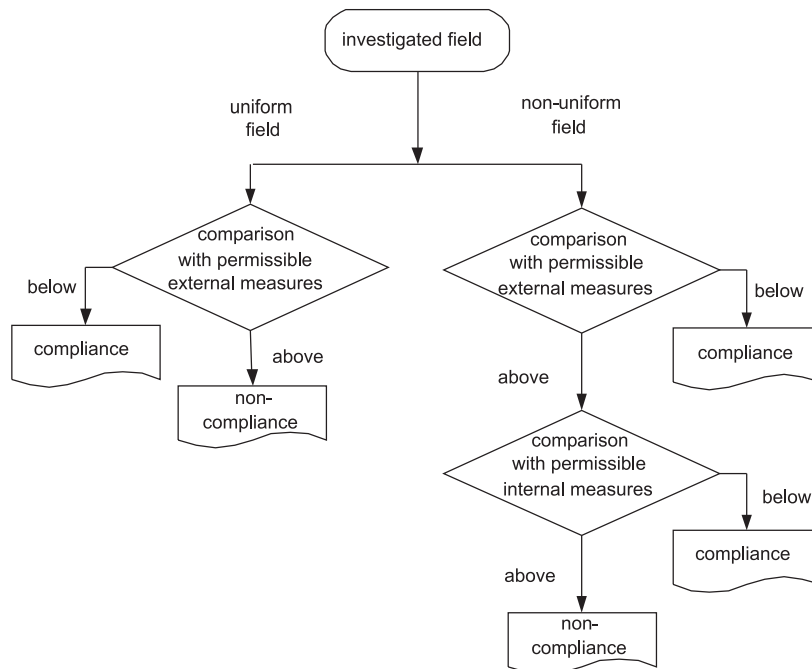


Figure 1. A scheme of EMF exposure assessment rules established by ICNIRP guidelines [8] and Directive 2004/40/EC [4]: external measures (ICNIRP reference levels or action values of the directive) and internal measures (ICNIRP basic restrictions or exposure limit values of the directive). Notes. EMF—electromagnetic fields, ICNIRP—International Commission on Non-Ionizing Radiation Protection.

mechanism, and an appropriate development of dosimetric relationships. In some circumstances, an adverse effect may be identified, but exposure limitation can only be described in terms of external exposure. In such cases, reference levels are used to control exposure directly.

Many forms of EMF are used in medical practice. In the case of patients receiving EMF exposure as part of their medical treatment, ICNIRP considers such exposure to lie outside the scope of its exposure guidelines because patients are under active medical management.

4. LEGISLATIVE IMPLEMENTATION OF EMF DIRECTIVE AND ICNIRP GUIDELINES

ICNIRP guidelines [8] define occupational and public exposure in general terms. When applying those guidelines to specific situations, it is ICNIRP's opinion that authorities in each country should decide on whether occupational or general public guideline levels are to be applied, according to existing national rules or policies. A parallel approach was introduced into the provisions of Directive 2004/40/EC [4]. This Directive lays down minimum requirements, thus giving Member States the option of maintaining or adopting more favourable provisions for the protection of workers, in particular the fixing of lower values for EMF exposure limitation. The implementation of this directive should not serve to justify any regression in relation to the situation which already prevails in each Member State.

The following section presents national legislation developed in Poland [11, 12].

5. EMF HAZARD PREVENTION STRATEGY POLAND

5.1. The Structure of Occupational Legislation System of EMF Exposure Assessment

Regulations on occupational exposure to EMF have been mandatory in Poland since 1972.

Initially, those regulations began from the microwave range of frequency. The current regulation on exposure limitation for EMF of the 0 Hz – 300 GHz frequency range was worked out in 1999 [13]. Separate occupational safety regulations have also established: the obligation to carry out periodic testing of EMF in the working environment, and employers' obligations to apply various protective measures against EMF in the workplace. All regulations concerning employees' detailed obligations are justified by the provisions of general legislation, i.e., the Labour Code. Among others, the Labour Code implements the provisions of Framework Directive 89/391/EC [2]. Regulations are periodically revised and, if necessary, updated under the umbrella of the Interdepartmental Commission for Maximum Admissible Concentrations and Intensities for Agents Harmful to Health in the Working Environment, which is the scientific advisory body established by Poland's Prime Minister.

Polish standards determine the requirements referring to the measuring devices used for examining the working environment and the protocols how to conduct EMF measurements and exposure assessment [14]. Polish standards are published by Polish Committee for Standardization (PKN) following national work or as an implementation of international standards, e.g., CENELEC's or the International Electrotechnical Commission's (IEC).

5.2. EMF Exposure Level- and Duration-Dependent Approach to Workers' Exposure Assessment

According to the general provisions of Polish regulations concerning exposure limitation for all environmental ambient factors [13, 18], special attention to the consequences of multi-year exposure is mandatory. Workers' protection has to cover not only the immediate consequences of exposure, but also any possible long-term adverse health effects, which can occur during their whole working life as well as their children's life. As a consequence of such a general rule, the use of precautionary measures for workers' protection against harmful health consequences of exposure is mandatory for, among others, EMF

exposure limitation. Poland's limitation of long exposure during one shift is more restrictive than the European Commission (EC) directive's [4] and ICNIRP guidelines' [8]. That is so because the results of some bio-medical investigations still provoke questions if limitations based only on short-term effects adopted by ICNIRP are not too liberal in the case of chronic of up to 40 years of working life, frequently of high-level (which possibly occurring many times a day) occupational exposure and if workers affected by such exposure are sufficiently protected against adverse health consequences during the long years of their working activities.

The main basis for working out thresholds of permissible exposure to EMF, established by regulations in Poland [13, 18], was taken from the thresholds of thermal and nerve excitation effects, similar to ICNIRP's approach (which were also taken as a basis for the EC Directive) [15]. As periodic assessment of EMF exposure level in the workplace is mandatory in Poland, the regulations directly refer to external measures only (E, H). Internal measures (J, SAR) have not been directly introduced into regulations since it is not possible to measure them in real conditions. However, permissible internal measures of exposure effects defined by ICNIRP guidelines [8], already published when current regulations were drafted,

and internationally well-known standards of the Institute of Electrical and Electronics Engineers (IEEE) were very deeply considered for theoretical modelling, experimental investigations and consensus negotiations [15] concerning thresholds for prohibited exposure to EMFs of various frequencies (Figure 2).

Following the aforementioned regulation [10] and Polish Standard [11], exposure level expressed by the strength of electric and magnetic fields (E, H) affecting a worker's body, the frequency of these fields (f) and exposure factor (W) calculated from workers' exposure level and duration (t), should be taken into consideration during occupational EMF exposure assessment and occupational risk assessment. The level of permissible exposure depends on the group of workers taken into consideration (Annex, Tables 3 and 4):

- Prohibited exposure: exposure of high level prohibited for workers without protective clothes. Workers should not be allowed to access an area of EMF exceeding the threshold of prohibited exposure.
- Occupational exposure: the range of exposure of medium level permissible for informed workers only, when EMF exposure assessment can depend on exposure duration (below the

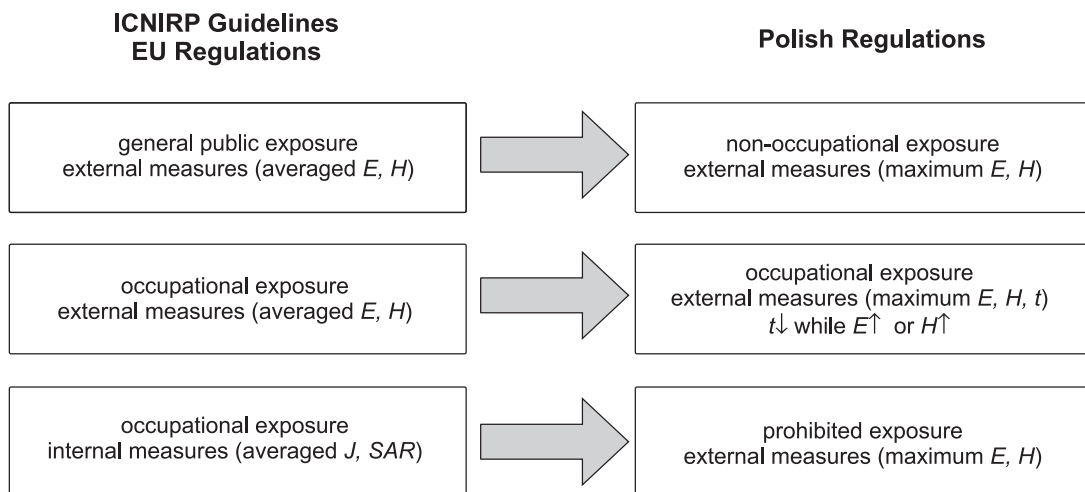


Figure 2. A comparison of the philosophy of EMF exposure assessment in European Union (EU) regulations [4, 16] based on ICNIRP guidelines [8] and Polish regulations [13, 18]. Notes. EMF—electromagnetic fields, ICNIRP—International Commission on Non-Ionizing Radiation Protection; E —electric field strength, H —magnetic field strength, J —current density, SAR —specific absorption rate, t —duration.

threshold of prohibited exposure and above a level 2- to 10-fold lower than the prohibited one). Permissible duration of exposure to such fields can be shorter than 8 hrs and can be defined by the so-called permissible exposure factor W . If both electric and magnetic fields are relatively high, the exposure factor is calculated taking into account both components, E and H , of the frequency up to 3 GHz. So, in real situations the threshold of prohibited exposure to a far field of radiofrequency is twofold lower than that taken directly from, Tables 3, 4, as a consequence of exceeding the permissible value of the exposure factor W . For higher frequencies, or in the case of exposure to low- or high-impedance fields, the exposure factor is calculated on the basis of one component (E or H) only.

- Non-occupational exposure: common low environmental exposure without restrictions of access for the general public and workers, with the threshold two- to threefold lower than permissible 8-hr occupational exposure.

The area of EMF of prohibited and occupational exposure level should be marked as so-called a protective zone. A similar approach is advised by CENELEC's draft generic standard [17]. Additionally, permissible localised exposure of the limbs to magnetic fields of a frequency up to 800 kHz is higher than that of the whole body. Permissible occupational exposure concerning a peak value of EMF is defined only for EMF of a frequency higher than 100 MHz.

The thresholds of permissible occupational exposure for pregnant woman and young workers (under 18) have been established as non-occupational exposure only. Similar values have been established as a threshold of general public exposure (Annex, Tables 3 and 4) [18].

Risk assessment of occupational exposure implemented on the basis of the aforementioned regulations (taking into account the strength of electric and magnetic fields in the workplace and the duration of workers' exposure) and procedures suggested by Polish Standard PN-N-18002:2000 [19] can be carried out as follows:

- high occupational risk: excessively long or prohibited-level occupational exposure to EMF ($W > 1$), i.e., in the case of no compliance with the regulations' provisions;
- medium occupational risk: occupational-level exposure to EMF of acceptable duration ($W < 1$), i.e., in the case of occupational exposure level and compliance with the regulations' provisions;
- low occupational risk: non-occupational-level exposure to EMF.

Workers' exposure assessment should be performed on the results of spot measurements of the rms value of unperturbed (existing in the workplace during the absence of workers) electric and magnetic field strength (maximum result of measurements over the worker's body posture). For modulated fields of intermediate frequency (non-sinusoidal), exposure assessment is based on the maximum value instead of the rms value.

Periodic external calibration (metrological testing) of measurement devices has been obligatory since 1995, but recently it was rejected because of the harmonisation of national legislation with the European system in which there is no such regulation yet. As a result, the obligation of periodic calibration of devices comes from the accreditation standard PN-EN 17025:2005 [20] only, and the details have not been established yet.

5.3. Long-Term Use of EMF Legislation: Main Advantages

Following are the consequences of a practical implementation of the presented system of EMF regulations:

- protective measures introduced by employers apply to both high- and medium-level EMF;
- workplaces exposed to EMF are under occupational safety and health (OSH) periodic inspections;
- sources of occupational-level exposure have been identified and marked;
- workers who are exposed to a high or medium level of EMF are informed and trained (on exposure levels, sources and methods of avoiding exposure), what leads to modification of work procedures and the positive psychological

effect of decreased concern about exposure, and results in a reduction in risk;

- workplaces are reorganised to minimise the level and duration of workers' exposure in identified cases of high exposure;
- shielding and other technical measures are introduced.

Practical implementation of EMF regulations is not easy because of the numerous sources of EMF, many of which are located in SMEs. Poland's National Labour Inspectorate's experience of inspections in enterprises with workers exposed to EMF has shown the most frequent irregularities in OSH systems and the most problematic areas in a practical implementation of EMF occupational regulations in real life [21]:

- the lack of sufficient assessment of occupational risk related to EMF exposure,
- the lack of sufficient measurements of EMF in the workplace,
- inadequate consideration of occupational exposure to EMF in workers' preventive health examination,
- inadequate information of workers about EMF-related risk and the requirements of safe work procedure,
- the lack of sufficient instructions on safe operation of sources of high EMF,
- the lack of appropriately safety marking of devices producing EMF,
- the use of devices with replaced or damaged EMF shields.

Almost 25 years of regulations for general public EMF exposure limits have resulted in consistent control of EMF emitted from such sources as broadcasting centres, high-voltage power lines and all mobile phone base stations. The general public is very rarely overexposed (compared to environmental exposure thresholds listed in the Annex, Tables 3 and 4).

6. CONCLUSIONS

Directive 2004/40/EC [4] has to be transposed into national legislation by all EU member states by April 2008. This process requires extensive work. Because legal systems and national history vary,

an exchange of experience in strategies is bound to be very useful.

The discussed main principles of the protection of workers against excessive EMF exposure show reasonable protection can be obtained with various legislative measures. However, employers always face the same significant difficulty: measuring or calculating workers' exposure to EMF. In real working conditions not only the location of EMF sources and workers can change significantly, but also the geometry of the source, the frequency of the field and the level of EMF in the vicinity of the source (e.g., EMF from industrial induction metal heaters). Assessing real exposure when the configuration and settings of the source of EMF frequently change is an example of how serious a challenge establishing a protocol of practical EMF exposure assessment is.

Calculations aimed at verifying compliance with the directive require high-resolution models of a worker's body and a satisfactory representation of the working environment. Calculations of exposure limit values for specific exposure situations require high professional skills and specialised software. Moreover, they are frequently time-consuming. Because of that, the ability to conducting such calculations by individual employers, especially from SMEs, is very limited, in contrast to the relatively effective use of such techniques in companies that manufacture long series of common electrical devices, like mobile phone handsets.

The aforementioned examples illustrate the practical problems that should be solved by CENELEC standards for uniform practice and comparable exposure assessment results. This is very complicated. European standards are expected, but there is no guarantee that they will be ready before the deadline for the implementation of the directive.

The OSH irregularities which inspections carried out in Poland have revealed [21] indicate targets for particular attention when organising work in an area exposed to EMF. It is most important to provide, during OSH training courses, sufficient information for workers and supervisors on possible risk related to working in the direct vicinity of EMF sources and on safe

work practices. The first step is to identify highly exposed areas and workers, and sources of EMF fields. As payment for measuring every source of EMF is hardly viable, it is extremely important to disseminate well-documented data concerning the types of devices and work activities that should be focused on. It is also very important to start with EMF exposure assessment of workers who might be highly exposed and not to spend time and money on unnecessary assessment of less exposed workers. Such advice is in line with CENELEC's draft generic standard [17].

Regular, full, preventive health examinations of workers—relevant to the actual risk—are possible when employers inform occupational medicine physicians about risk related to exposure to EMF. As lack of such information is relatively common, occupational medicine physicians should be considered an important target group for information on EMF sources and highly exposed professions.

Realistic assessment of the actual exposure of workers who work off company premises constitutes another problem. Self-employed workers (e.g., technical staff who repair medical devices) and staff of laboratories providing EMF measurement services who might be very highly exposed face the same problem. They have practically no OSH protection and the directive [4] does not discuss them. However, according to ICNIRP's definition of occupational exposure, to be able to deal with EMF sources, self-employed workers should be informed, trained and have their exposure assessed. They could be protected by insurance companies, but such protection has so far been very rare, perhaps because of the difficulties in establishing a direct link between occupational exposure to EMF and specific negative health consequences.

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Annex

Limitation of the level of exposure to electromagnetic fields (EMF) in various legislation and guidelines

Directive 2004/40/EC of the European Parliament and of the Council of 29 April 2004 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) (eighteenth individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC). Official Journal of the European Union L 184, May 24, 2004. p. 1–9.

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TABLE 1. Exposure Limitation Referring to Internal Measures of Exposure Effects (Exposure Limit Values [4]/Basic Restrictions [8])

Frequency	Current Density	Whole Body	Localised SAR		Power
	for Head and Trunk J (rms) (mA/m^2)		Average SAR (W/kg)	(Head and Trunk) (W/kg)	
<1 Hz	40	—	—	—	—
1–4 Hz	40/ f	—	—	—	—
4–1000 Hz	10	—	—	—	—
1000 Hz–100 kHz	$f/100$	—	—	—	—
100 kHz–10 MHz	$f/100$	0.4	10	20	—
10 MHz–10 GHz	—	0.4	10	20	—
10–300 GHz	—	—	—	—	50

Notes. f —frequency (Hz), SAR—specific absorption rate.

TABLE 2. Exposure Limitation Referring to External Measures of Exposure Levels (Unperturbed rms Values) (Action Values [4]/Reference Values [8]); Contact Current and Limb Induced Current

Frequency	Electric Field	Magnetic Field	Magnetic Flux Density,	Equivalent Plane Wave	Contact Current,	Limb Induced Current,
	Strength, E (V/m)	Strength, H (A/m)	B (μT)	Power Density, S_{eq} (W/m^2)	I_c^* (mA)	I_l^* (mA)
0–1 Hz	—	1.63×10^5	2×10^5	—	1.0	—
1–8 Hz	20000	$1.63 \times 10^5/f^2$	$2 \times 10^5/f^2$	—	1.0	—
8–25 Hz	20000	$2 \times 10^4/f$	$2.5 \times 10^4/f$	—	1.0	—
0.025–0.82 kHz	500/ f	20/ f	25/ f	—	1.0	—
0.82–2.5 kHz	610	24.4	30.7	—	1.0	—
2.5–65 kHz	610	24.4	30.7	—	0.4 f	—
65–100 kHz	610	1600/ f	2000/ f	—	0.4 f	—
0.1–1 MHz	610	1.6/ f	2/ f	—	40	—
1–10 MHz	610/ f	1.6/ f	2/ f	—	40	—
10–110 MHz	61	0.16	0.2	10	40	100
110–400 MHz	61	0.16	0.2	10	—	—
400–2000 MHz	$3f^{1/2}$	$0.008f^{1/2}$	$0.01f^{1/2}$	$f/40$	—	—
2–300 GHz	137	0.36	0.45	50	—	—

Notes. f —frequency (in the unit indicated in the frequency range column); *—not included in the internal measures of the exposure effects in Directive 2004/40/EC [4].

Regulation of the Minister of Labour and Social Policy of 29 November 2002 on the maximum admissible concentrations and intensities for agents harmful to health in the working environment. Dz. U. 2002;217(item 1833):13614–60. In Polish.

Regulation of the Minister of Environment of 30 October 2003 on maximum admissible levels of electromagnetic fields in the environment and methods of checking compliance to these levels. Dz. U. 2003;192(item 1883):13006–12. In Polish.

TABLE 3. Electric Field Strength: Exposure Limitation in Poland (External Measures) [13, 18]

Frequency	Electric Field Strength (V/m)			
	Threshold of Prohibited Exposure, E_2	Threshold of Occupational 8-hr Exposure, E_1	Threshold of Permissible Non-Occupational Exposure, E_0	Threshold of Permissible Environmental Exposure, E_{ENV}
0 Hz	40000	20000	10000	10000
0 Hz < $f \leq 0.5$ Hz	40000	20000	10000	—
0.5 Hz < $f \leq 50$ Hz	20000	10000	5000	10000
50 Hz < $f \leq 0.3$ kHz	20000	10000	5000	—
0.3 kHz < $f \leq 1$ kHz	1000/ f	100/ f	100/3 f	—
1 kHz < $f \leq 3$ MHz	1000	100	33.3	20
3 MHz < $f \leq 15$ MHz	3000/ f	300/ f	100/ f	7
15 MHz < $f \leq 150$ MHz	200	20	6.67	7
0.15 GHz < $f \leq 3$ GHz	200 (100*)	20	6.67	7
3 GHz < $f \leq 300$ GHz	1.6 f + 195	0.16 f + 19.5	0.053 f + 6.5	7

Notes. Range of occupational exposure: E_0 – E_2 ; f —frequency; *—following the rules of exposure assessment based on E and H during far-field exposure conditions.

TABLE 4. Magnetic Field Strength: Exposure Limitation in Poland (External Measures) [13, 18]

Frequency	Magnetic Field Strength (A/m)			
	Threshold of Prohibited Exposure, H_2	Threshold of Occupational 8-hr Exposure, H_1	Threshold of Permissible Non-Occupational Exposure, H_0	Threshold of Permissible Environmental Exposure, H_{ENV}
0 Hz < $f \leq 0.5$ Hz	80000	8000	2666	2500
0.5 Hz < $f \leq 50$ Hz	20000	200	66.6	60
0.05 kHz < $f \leq 1$ kHz	100/ f	10/ f	10/3 f	3/ f
1 kHz < $f \leq 800$ kHz	100	10	3.33	3
0.8 MHz < $f \leq 3$ MHz	80/ f	8/ f	8/3 f	3
3 MHz < $f \leq 150$ MHz	80/ f	8/ f	8/3 f	—
0.15 GHz < $f \leq 1$ GHz	0.53	0.053	0.017	—

Notes. Range of occupational exposure: H_0 – H_2 ; f —frequency.