Safety Compliance of Occupational Exposure to Electromagnetic Fields

Tarmo Koppel
Tallinn University of Technology
Ehitajate tee 5, 19086 Tallinn, Estonia
E-mail: Tarmio.Koppel@ttu.ee

Inese Vilcane
Tallinn University of Technology
Ehitajate tee 5, 19086 Tallinn, Estonia
E-mail: ivilca@ttu.ee

Abstract

Consequent to the 2016 legislation, European companies are expected to be in compliance with new legislation about occupational exposure to electromagnetic fields. The aim of this study is to determine the compliance of companies and the respective stakeholders with respect to the new EMF safety legislation. A questionnaire was used to determine the level of electromagnetic safety management (N=190). The stakeholders included working environment specialists, workers, occupational health doctors and labour inspectors. The study found that working environment specialists had assessed the EMF safety in companies to be better managed than did workers and labour inspectors. The key factor influencing EMF safety was training working environment specialists and workers. The shortcomings are characteristic to all companies, but are somewhat less evident in large companies. The study is contributing on how legal aspects of EMF safety are considered at different levels of stakeholders, and also show the need for reducing the exposure resultant from poorly managed safety issues.

Keywords: electromagnetic fields, occupational exposure, workplaces, legislation, European Union, directive.

1. Introduction

The safety of workers is an important factor and one of the key functions of every organisation. The working environment may encompass several risk factors of which electromagnetic fields (EMFs) are one. The relevance of having a good safety understanding of electromagnetic fields in workplaces is because, unlike many other occupational health and safety risk agents, EMFs are invisible, odourless, and cannot be detected by a human being until harm is done and adverse effects occur. An electromagnetic field (EMF) is a physical field that accompanies electricity. All electrical appliances produce this field.

The exposure to electromagnetic fields is a common term, characterising exposure either to electric, magnetic or electromagnetic fields. From the perspective of exposure, EMFs can broadly be divided into four groups, depending on their frequency: static, low frequency, intermediate frequency and radio-frequency electromagnetic fields. In the case of low frequency fields, we are mainly dealing with power frequencies (50 Hz in Europe), i.e. technically extremely low frequencies. Different frequency groups have different mechanisms that affect the human body, but all could induce biological effects. Magnetic and electric fields require differentiation and separate assessment, especially in the case of static, low and intermediate frequency fields. In the case of radio frequency fields, with far field scenarios, the electric and magnetic field are viewed as one and could be assessed as an electromagnetic field.

Occupational exposure to EMFs is a known risk factor. Recently, more attention has been paid to the long-term health effects from electromagnetic field exposure; studies have pointed out the risks related to long-term occupational exposure. (Carlberg, Koppel, Ahonen, & Hardell, 2018; Jalilian, Teshnizi, Röösli, & Neghab, 2017; Huss, Spoerri, Egger, Kromhout, & Vermeulen, 2018; Grundy et al., 2016; Turner et al., 2014). The current safety limits are based on short term health effects (Vabariigi Valitsuse määrus 01.04.2016 nr 44, 2016; The European Parliament and the Council, 2013), which rely on third party guidelines (International Commission on Non-Ionizing Radiation Protection, 1998). Since current safety limits are based on short-term health effects, only a conservative approach to organising safety in working environments and the mitigation of workers exposure could guarantee their safety.

The legislation requires reducing risks, including reducing exposure and implementing other risk mitigation measures in order to guarantee the workers' safety. The employer might not be motivated to raise the safety of workers solely on legislative demands. Productivity and the work environment are important productivity factors for the company.

EMFs are everywhere where electricity is used. Specifically, magnetic field exposure could be problematic where machinery consumes great amounts of current; such processes are native to many industrial technologies. The problem lies within the potential adverse effects on workers' well-being from the exposure to strong electromagnetic fields. The obligation of the employer is to guarantee the workers' safety, hence requiring them to reduce the EMF related risks to as low as possible. It is obvious that there is a variation in exposure to EMFs from different occupations. There are prescriptions set by legislation on how to reduce the exposure to workers.

This study aims to determine the compliance of companies and the stakeholders with respect to the new EMF safety legislation. The study investigates if the corresponding new legislative requirements are implemented in companies. The results would reveal if the new 2016 legislative requirements have had an impact on EMF safety arrangements, especially

within companies (Vabariigi Valitsuse määrus 01.04.2016 nr 44, 2016).

The research will address differences in awareness, training levels and the safety compliance of companies, depending on occupational affiliation to EMF related safety issues. The analysis is to determine if the aforementioned stakeholders consider the following factors to affect the EMF safety management:

- Workers EMF safety awareness and training,
- EMF safety management compliance of the company,
- EMF safety arrangement for strong EMF workplaces,
- EMF safety arrangement for risk groups.

The current study is relevant due to the legislative changes in organising workers safety from electromagnetic fields. In recent years the EU has issued a new directive 2013/35/EU (TheEuropean Parliament and the Council, 2013) and the consequent national decree (Vabariigi Valitsuse määrus 01.04.2016 nr 44, 2016). The legislation prescribes new obligations for companies and other stakeholders.

A questionnaire was developed to meet the task. Four target groups were approached: 1) workers, 2) working environment specialists, 3) occupational health doctors and 4) labour inspectors. Accordingly, four variations of the questionnaire were designed to locate the knowledge gaps, how much attention is paid to the issue, and generally how well prepared the stakeholders are to accept the new legislation in occupational exposure to electromagnetic fields.

The current study is relevant for occupational safety specialists, but also workers and other subgroups. The study could be used to argue for the importance of safety training and other employer contributions to safety awareness in regard to EMFs, which would include the means of identifying EMF exposure, and how to reduce exposure to safe levels etc.
The contribution of the study resides in elaborating on how legal aspects of EMF safety are considered in different levels of subgroups, and showing the possible need for reducing the exposure resulting from poorly managed safety issues. Also, the contribution has to establish the link in between the employers' contribution in educating and training specialists and workers, and the resulting safety compliance of both the strong EMF workplaces and the company in general. It may show the possible need of reducing the exposure resultant from poorly managed safety issues or the key factors regulating the EMF safety level in companies.

This paper consists of four chapters, including 1. Introduction, 2. Research background 3. Safety management 4. Data and method, 5. Results, 6. Discussion and conclusions.

2. Research Background

2.1. EU Directive 2013/35/EU

The European Parliament (EP) issued a new directive on occupational exposure to electromagnetic fields on 26.06.2013 (TheEuropean Parliament and the Council, 2013). The directive sets minimum requirements for safety issues in regard to occupational exposure to electromagnetic fields. A three year adoption period was given for the Member States to harmonise their national legislation with the requirements of the directive. The 1 July 2016 is the date by which the directive should be implemented at the national level.

The directive is a legal tool that enables the European Union to enforce common principles across the Member States. The commitment of the European Union (EU) to improve the work environment and to protect workers is written into the Treaty on the Functioning of the European Union (article 153 p.1, a) (European Union, 2012). It also gives the EU the authority to issue directives to that end.

Secondly, the obligation to protect workers is laid down in the article 31(1) of the Charter of the Fundamental Rights of the European Union: "every worker has the right to working conditions which respect his or her health, safety and dignity" (European Commission, 2000).

A framework directive (89/391/EEC) was laid down in 1989 to introduce general prevention principles in the field of occupational health and safety. The directive applies to all fields of activities, except the armed forces, police and civil protection services. It sets principles for the prevention of risks, the assessment of risks, the protection of safety and health, and informing, consultation, training etc. (The Council of the European Communities, 1989a).

The framework directive forms the basis for several other specific directives to be issued. The framework directive provides general principles applicable to all sectors, but where individual directives contain more stringent and specific provisions, the special provisions of specific directives apply. Since the adoption of the framework directive, a number of specific directives setting minimum requirements for the protection of workers have been issued. These directives can be classified as dealing with (The European Agency for Safety and Health at Work, 2014):

- specific tasks (e.g. manual handling of loads),
- specific hazards at work (e.g. exposure to dangerous substances or physical agents),
- specific workplaces and sectors,
- specific groups of workers (e.g. pregnant women, young workers),
- certain work related aspects (e.g. organisation of working time).

Since the framework directive, several other directives on physical hazards have been issued, including vibration – Directive 2002/44/EC(The European Parliament and the Council of the European Union, 2002), noise – Directive 2003/10/EC (The European Parliament and the Council of the European Union, 2003), and artificial optical radiation – Directive 2006/25/EC (The European Parliament and the Council of the European Union, 2006).

From the point of view of occupational health and safety, electromagnetic fields are classified as a physical risk factor. But EMFs are also covered by legislation and standards from the point of view of the operability of electronic apparatuses – electromagnetic compatibility (EMC) and electromagnetic disturbances (EMD). An electromagnetic disturbance is seen as a phenomenon which degrades the performance of the electronic device. This includes radiated emissions, immunity from EMFs, mains disturbances, conducted transients and radio frequency, and electrostatic discharge and lighting surges (Williams, 2016). EMC and EMD are covered with both international standards and European Directives (The Council of the European Communities, 1989; The European Parliament and the Council, 2004a).

Figure 1. Apparati bearing the 'CE' marking and released to general public are in compliance with directive 2004/108/EC and therefore also with the EMF safety limits set for the general public (The European Parliament and the Council, 2004a)

An "apparatus" is considered a finished appliance or a combination of appliances that have been made commercially available as a single functional unit and intended for the end user (The European Parliament and the Council, 2004a). A "CE" (fig.1.) marking is found on an apparatus if it complies with the EMC directive (The European Parliament and the Council, 2004a). Such apparati are also seen to comply with safety limits set to protect the general public from exposure to electromagnetic fields (The Council of the European Communities, 1999). Therefore, if a working environment consists only of electrical appliances also intended for use by the public consumer (e.g. offices), the workplace is automatically conforming to the general public EMF directive 1999/519/EC (The Council of the European Communities, 1999). If a work place includes any industrial electrical appliances or any other devices that are not intended for use by the general public, the compliance with 1999/519/EC is not automatically met.

The general public EMF directive is applied to areas where members of the general public spend significant time, e.g. public places, homes, schools etc. The latter is however not a directive officially, but a recommendation – it does not force the EU Member States to comply with the set rules. However, Member States do follow the same set of safety limits or even stricter ones, as set in the Council's recommendation (The Council of the European Communities, 1999).

But for work places, a specific set of rules has been developed – a directive on the minimum health and safety requirements regarding the exposure of workers to risks arising from physical agents (electromagnetic fields) (The European Parliament and the Council, 2004b, 2008) (The European Parliament and the Council, 2004b, 2008; The European Parliament and the Council, 2013). This occupational EMF directive applies to all work places. Whether the work place is also subject to the EMF directive for the general public is determined if a member of the general public is granted access to the work place in question; for example, customer service areas (i.e. hair salons, bank offices) are subject to both the general public EMF directive and the occupational EMF directive.

The directive is however not a document that enforces companies and other entities to act on its requirements. The directive is a set of rules and minimal requirements that the national legislation of the EU Member States must conform to; that is, the national requirements for safety in electromagnetic fields in working environments cannot be any less than those specified in the directive. Likewise, the directive does not prevent Member States to maintain or introduce more stringent protective measures. In fact, the occupational EMF directive 2013/35/EU states that the implementation of the directive should not serve to justify any regression in relation to the situation already prevailing in the Member States (The European Parliament and the Council, 2004b, 2008; The European Parliament and the Council, 2013). Standards, such as EN 50499, for example, could also be referred to in

organising the procedures of EMF risk assessment (CENELEC, 2008). Therefore, the safety regulations across the EU Member States can vary.

2.2. Precursors to the Directive

The preparation for implementing new European Union legislation on protecting workers from electromagnetic fields had been ongoing for more than ten years. A previous directive on the same matter (The European Parliament and the Council, 2004b) had been approved by the European Parliament already on 30 April 2004, and was originally intended to be implemented by the Member States by 30 April 2008. After a lobbying campaign involving patient groups and MEPs (members of the European Parliament), the deadline was subsequently postponed to 30 April 2012 (The European Parliament and the Council, 2008). Some stakeholders expressed discontent with the 2004 version of the directive, namely the Magnetic Resonance Imaging (MRI) sector. They saw that the safety limits proposed by the 2004 directive would limit the use of MRI devices, as workers close to the MRI scanner would be exposed to EMFs (namely in the range of 110 Hz to 5 kHz) above the proposed safety limits (Hill, McLeish, & Keevil, 2005).

Continuing the use of MRI for both research and clinical use was seen to be under threat. The new directive (2004/40/EC) would limit the options for medical staff to take care of patients, like children, the elderly and those anaesthetised, needing help and comfort during MRI scans. In addition, the use of MRI would be hindered in interventional and surgical procedures, and researching new techniques that allow better clinical information and avoid using ionizing radiation (European Science Foundation, 2010; Keevil et al., 2005; Keevil & Krestin, 2010). The postponement and review of the directive was called for.

The dialogue, led by the European legislator, continued amongst stakeholders in order to accustom the directive to new scientific data and the needs of the stakeholders. In addition, the industry was worried about the directive hindering the operability of manufacturing processes and other tasks demanding workers to be exposed to EMFs. A revised proposal of the directive was made public on 14 June 2011 (European Commission, 2011) "title": "Proposal for a directive of the European Parliament and the Council on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields)."

2.3. A Newly Emerging Risk Factor

The relevance of electromagnetic fields as a working environment risk factor is emphasised by the European Union by classifying it amongst the "emerging health risks" (European Commission, 2008). An advisory structure called the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) has been set up since 2004 by the European Commission to provide expert opinions on electromagnetic fields and other emerging or newly identified environmental risks (Commission, 2008). The role of SCENIHR is to provide the European legislators with comprehensive assessments of the risks to the safety of both the public and employees (Scientific Committee on Emerging and Newly Identified Health Risks SCENIHR, 2007, 2009, 2013).

A great portion of the population is interested in and worried by potential exposure to electromagnetic fields. According to the last Eurobarometer poll on electromagnetic fields

conducted across the EU Member States, 58 per cent of people do not believe that public authorities protect them from potential health risks related to EMFs. This is a criticism of the public authorities. Half of the respondents (48 per cent) feel that the EU should inform the public of these potential health risks. Only 20 per cent of the respondents said they had received some information on the potential health effects of EMFs (TNS Opinion & Social, 2010).

Both 2007 and 2010 Eurobarometer polls showed that the public is most concerned with high voltage power lines and mobile phone masts affecting their health, while sources of electromagnetic fields were placed in the bottom half of the list that contained several other environmental health risk factors (TNS Opinion & Social, 2007, 2010).

A Eurobarometer poll (April 2014) on working conditions in EU countries revealed that only 24 per cent of the respondents said their workplace have measures to address new emerging risks (TNS Political & Social, 2014).

An electromagnetic field consists of an electric and a magnetic field, which may be of independent strength (at low and intermediate frequencies). Therefore, two sets of safety limits have been produced to cover both electric and magnetic fields. Where the voltage is higher, the accompanying electric field is stronger, whereas electrical appliances that use more power tend to produce stronger magnetic fields. At radio frequencies the electromagnetic field is treated as one field.

Electrical appliances in different working regimes and utilising various technologies may generate a number of electromagnetic frequencies that the worker is exposed to.

2.4. Health Effects and Safety Levels

Health effects are frequency dependent and may occur when the strength of the EMF reaches a certain level. The directive (2013/35/EU) addresses short-term and acute health effects mainly related to thermal effects and the electrical stimulation of tissues. Such effects may include (The European Parliament and the Council, 2013):

- vertigo and other physiological effects related to the disturbance of the human balance organ,
- electric stimulation of peripheral and central nervous system tissues in the body,
- electric field effects on the central nervous system in the head, i.e. retinal phosphenes and minor transient changes in some brain functions
- localised heat stress in the head and trunk or in the limbs,
- whole body heat stress,
- auditory effects caused by exposure of the head.

The process of forming the directive has taken more than ten years. This itself describes the complex set of views related to the issue. A number of stakeholders are affected by the new legislation. Such parties may be viewed as 1) scientists, 2) legislators, 3) employers, 4) employees, 5) work inspectors and 6) occupational health doctors, plus others affected to some extent by the new legislation (Koppel & Kristjuhan, 2013).

The main point of discussion could be viewed as the safety level prescribed by the directive: whether the directive should set a high level or a moderate to low level of protection from EMFs. Some may favour a non-binding and voluntary set of rules, whereas others see obligatory legislation to be the only solution. The confrontation of interests is inevitable,

since each party has their own balance sheet of obligations and benefits. Employees are likely to favour strict safety rules and exposure limits as their interest concerns their good health and work ability. Employers on the other hand need to invest into the new safety measures by procuring new equipment, implementing new work procedures and so on. Even though the employers may also see that a healthy worker is a productive worker, payables and receivables need to be summed up. Therefore, employers are likely to favour legislation that would grant them more room to manoeuvre. One example could be brought by the way the European Engineering Industries Association regards the topic, as "irrational public concerns" and "public authorities rushing through legislation" (European Engineering Industries Association, 2014).

Undoubtedly, there are also discussions and contradictory views among stakeholders as well. From within the scientific community we can find parties that would welcome legislation that covers all the biological effects, resulting in quite strict safety limits (Carpenter & Sage, 2007; Group, Sage & Carpenter, 2012). At the same time, scientists following a more conservative approach would like to see a scientific body of research that irrefutably makes a case for the new effects before changing the legislation (European Health Risk Assessment Network on Electromgnetic Fields, 2010; Scientific Committee on Emerging and Newly Identified Health Risks SCENIHR, 2009). The latter approach forms the prevailing view in legislation formulation.

2.5. Implementation

After passing the new EMF legislation, the implementation at Member State level has begun. This process involves the stakeholders presented in Figure 2.

Figure 2. Stakeholders in the implementation of the EMF legislation at national level

Source: compiled by the author

The implementation of the directive is also likely to be impeded by a lack of risk assessment and measurement service providers capable of adequately dealing with exposure scenarios

in various workplaces. One shortcoming is certainly the lack of know-how to deal with the full range of electromagnetic fields from static fields to ultra high frequencies. Such service providers should possess the expertise to measure, calculate, and assess the exposure, and the effects of the electromagnetic fields, and to suggest effective mitigation options in the situations encountered. The service providers also need to be equipped with adequate measurement devices such as electromagnetic field meters and spectrum analysers for all frequency ranges (0 Hz to 300 GHz). Specially designed measurement devices may be additionally needed to cover electromagnetic fields with special signal characteristics (e.g. ultra short pulse radars, pulsed signal communications etc.). Such peculiar signals are becoming more common in workplaces and the typical EMF meters are usually not adequate to measure these. Therefore, national regulations in regard to EMF measurement and assessment service providers are likely to be subject to revisions. In Germany, such professionals are assigned the title "EMF Expert" and are required to have a university or college education in the relevant courses, two or three years of professional experience, good knowledge of the measurement and evaluation procedure, and proof of their competence (attendance of special courses) (Institution of Chemical Engineers, 2004).

The new occupational EMF legislation prescribes activities for all stakeholders: renewing or issuing a new national legislative act; training workers in regard to the relevant safety knowledge; training work environment specialists; renewing safety measures in companies; educating occupational health doctors to diagnose EMF related health effects; educating labour inspectors to identify EMF exposure related situations etc.

The European legislators understand that overly strict regulations are not good for business, and that Europe viewed in terms of global competition needs entrepreneur-friendly legislation. In fact, the Treaty on the Functioning of the European Union, which is the legal basis for EU directives, under article 153 p. 2 (b), states that "such directives shall avoid imposing administrative, financial and legal constraints in a way that would hold back the creation and development of small and medium-sized undertakings" (European Union, 2012).

Therefore, the aforementioned prerequisite may, however, be viewed as discrepant to the point of view of the protection of workers (from environmental risk factors). The most significant improvements in the work environment are hardly available without expenditure. When it comes to EMFs, such investments tend to become costly due to the high cost of the shielding materials, acquiring new machinery, the loss of productivity while work procedures are reorganised and so on. There are several industrial processes (e.g. the car industry) and a number of professions that are accompanied by high level exposure to EMFs. Therefore, it is self-evident that the EU will not issue such legislation that would disable these industries to perform their native tasks. In order to understand the European legislation, one should also consider the task the European legislator is confronted with: finding a reasonable and balanced approach that satisfies the safety of the workforce and that companies can endure.

3. Safety Management

Recent global and financial crises in EU Member States may also be seen as one of the causes of deteriorating working conditions in companies, and this is a concern expressed by the European Trade Union Confederation (European Trade Union Confederation, 2013). The

issue was also addressed by the European Parliament by issuing a resolution on the European strategy on health and safety at work (2013/2685(RSP)), calling for rapid responses to provide a high level of health and safety at work in response to the impact of economic developments and social crises on the work environment (European Parliament, 2013).

Since electromagnetic fields as a risk factor in the work environment have not gained as much attention as many other occupational health stressors, the literature is missing studies in the field of the safety management of electromagnetic fields. The same also applies to newly emerged technologies that utilise electromagnetic fields. Therefore, in order to learn and plan activities to improve EMF safety in enterprises, one must look at the general studies conducted in the area of occupational health and safety. Next, the implications of the European study of New and Emerging Risks are introduced, as these can be reflected on electromagnetic fields' policy development.

According to the European Survey of Enterprises on New and Emerging Risks, the main occupational health and safety concerns are accidents, musculoskeletal disorders and work-stress. In larger enterprises, more attention is paid to health and safety services, such as safety experts and occupational health doctors (González, Cockburn, Irastorza, Houtman & Bakhuys Roozeboom, 2010). Smaller companies report comparatively fewer occupational health and safety management measures. However, the number of measures decrease with regard to company size at a much faster rate in companies with less than 100 employees. Independent companies reported fewer occupational health and safety management measures than those that are part of a larger entity (Stolk, Staetsky, Hassan & Kim, 2012). Companies fulfilling their legal duties and employee requests appeared to be the main drivers for addressing occupational health and safety issues. According to the study, managers report employee participation to be a key success factor for occupational health and safety management; therefore, the role of social partners remains important in implementing effective measures. Worker participation, whether formally through a works council and shop floor trade union or informally by direct involvement, is associated with better quality management of health and safety (González et al., 2010). Countries with better occupational health and safety management practices tend to have smaller differences in reporting these practices between smaller and larger organisations than countries reporting less occupational health and safety practices, in the overall sample across size ranges (Stolk et al., 2012).

Järvis et al. (2016) examined differences between formal safety and real safety in Estonian small and medium-sized enterprises. Their work revealed key issues in safety culture assessment, finding many organisations with an excellent safety culture and positive safety attitudes. However, their qualitative research approach revealed important safety weaknesses and aspects, and a gap between formal safety and actual safety (Järvis, Virovere & Tint, 2016).

Cooklin et al. (2017) conducted a systematic review (31 studies) on occupational health systems. They concluded that effective interventions were mostly aimed at improving employee physical or mental health, whereas less consistent results were found from integrated interventions targeting occupational health and safety management, injury prevention or organisational cost savings (Cooklin, Joss, Husser & Oldenburg, 2017).

Few studies are available on EMF risk perception among workers. Fatahi et al. (2016) investigated the perception of health risks from electromagnetic fields by MRI radiographers and airport security officers. The findings revealed that MRI radiographers perceive the risk

from EMFs less than thought by the general working population, and less than the security officers. Security officers, who felt more positive about EMFs, were determined not to be significantly related to the perceived risk of EMF in general or EMF from other home sources – negative emotions were strongly related to perceived risk. The study concluded that although differences in occupations seem to be reflected in the different perceptions of EMF, the level of occupational EMF exposure does not predict the perceived health risk (Fatahi, Demenescu & Speck, 2016).

4. Data and Method

4.1. Study Design

A questionnaire was developed for four different stakeholder groups. The groups were selected based on the professions most affected by the new legislation. The questionnaire included a common set of questions, and groups also had to answer questions focusing on their role in the new legislation post-implementation (see Table 1).

Table 1. Groups targeted by the questionnaire and the main issues explored

Group	Predictive variables	Response (and predictive) variables (no of items in parentheses)
Workers (W)	age risk group affiliation company size professional tenure workplace type (office, industrial, etc.) workplace EMF level	EMF safety awareness and perception (6) Compliance of company in terms of EMF safety (7) EMF safety arrangement in strong EMF workplaces (8) EMF safety arrangement for risk groups (No. of items in parentheses) (1)
Working environment specialists (S)	age company size company type (office, industrial, etc.) OHS* professional tenure awareness of strong EMFs at workplace	Assessment of workers EMF safety training (5) Compliance of company in terms of EMF safety (10) EMF safety arrangement in strong EMF workplaces (9) EMF safety arrangement for the risk groups (6) Knowledge of EMF propagation and safety principles (3)
Occupational health doctors (D)	age OHS* professional tenure awareness of strong EMFs at workplace	Assessment of workers EMF safety training (5) Knowledge of the health effects of EMF (1) Has diagnosed/suspected EMF health effect (1)
Labour inspectors (I)	age OHS* professional tenure awareness of strong EMFs at workplaces	Assessment of workers EMF safety training (5) Knowledge of EMF propagation and safety management (4) Compliance of companies in terms of EMF safety (2) EMF safety arrangement in strong EMF companies (12)

Notes: OHS = Occupational Health and Safety.
Source: authors' data

The questionnaire provided the respondents the following number of questions:

- workers – 28,
- work environment specialists – 26,
- occupational health doctors – 21,
- labour inspectors – 22.

The questionnaire focused on the key issues addressed by the new occupational EMF directive (2013/35/EU). The occupational health and safety (OHS) experts (working environment specialists, occupational health doctors, labour inspectors) were asked an expanded set of questions to determine their knowledge about the legislation, EMF induced health effects, risk groups, the obligations of the employer and EMF mitigation options.

The questionnaire aimed to determine whether the respondent's (workers and work environment specialists) company belonged to a high EMF exposure group (i.e. where industrial machinery or installations are present that produce high EMF levels). A list of machinery in specific professions was presented to identify if the company has any of these. If the respondent answered positively, an additional set of questions was given to determine the level of EMF safety management and training. One should know that if the workplace lacks high EMF generating equipment, the company (employer) is not obligated to arrange any EMF specific training or safety management.

Similarly, the same logic was followed in regard to the risk groups. If a worker reported him or herself to be in a risk group (pregnant or wearing medical implants), an additional set of questions was presented to determine the attention paid to his or her condition in the presence of high EMFs. Similar inquiries about the safety arrangement regarding workers in risk groups were addressed to the work environment specialist.

4.2. Data Collection

The questionnaire was published in an online form (Limesurvey server software). The questionnaire was adaptive and presented to the respondents with questions based on their answers in the first sections.

The questionnaire could be filled out anonymously and the respondents were assured that the responses will not be forwarded to anyone outside the research group. An option was also given to relinquish anonymity by leaving an email to receive feedback on the study (N=87).

The questionnaire was published in Estonian, but also in English for those workers or OHS specialists that had immigrated from other countries.

The main method of delivery was by directly emailing the target groups, but other channels of delivery were also used as presented in Table 2. The questionnaire was distributed to companies which are expected to include elevated electromagnetic fields on the basis of their registered field of activity. This included mainly industrial companies, but also enterprises from transportation, communications, power generation and distribution and others. Due to the mixed methods approach, the target population is undetermined. Two rounds of questionnaires were distributed – in April and October of 2017.

Table 2. Channels for approaching the survey target groups and collecting the results

Target group	Target group contacted via
Workers (W)	Companies/institutions directly Companies' work environment specialists OHS thematic internet sites/portals
Working environment specialists (S)	Companies/institutions directly Ministry of Social Affairs OHS thematic internet sites/portals
Occupational health doctors (D)	Occupational health care service providers (clinics, hospitals etc.) The Society of Occupational Health Doctors Ministry of Social Affairs OHS thematic internet sites/portals
Labour inspectors (I)	Labour inspectorate OHS thematic internet sites/portals

Source: authors' data.

Depending on the information sought, the questions were presented either with a Likert scale (1–5) or as general questions (yes/no). The latter was applied where factual information was mostly sought about whether certain safety measures had been implemented in the company. The questions were grouped in categories and analysed by averaging the value given by the respondent. The average values were on the scale of 0–1. Hence, each category represents a variable, the combination of which was used to conduct a bivariate correlation analysis. Workers and work environment specialists were grouped together to reflect the EMF safety situation in the companies.

4.3. Statistical Analysis

The data was assessed using the structured questionnaire approach, and sent to an online depository. Scores as averages for question groups were calculated based on the structure as presented in Table 1. The description of the sample is presented in Table 1. A Pearson product-moment correlation coefficient was conducted to evaluate the relationship between the EMF safety variables using SPSS 21.0. To test the differences of the subgroup means, an independent samples t-test was performed. In addition, the assumption of homogeneity of variances were tested using Levene's F test, where $p<0.05$ was considered statistically significant.

4.4. Sample

This questionnaire survey was conducted in Estonia. A total of 190 responses were collected from stakeholders. Table 3 presents basic descriptive statistics on the target groups.

Table 3. Descriptive statistics classified per respondent group

	Stakeholder group				All groups (average)
	Workers (W)	Work environment specialists (S)	Occupational health doctors (D)	Labour inspectors (I)	
Number of respondents	113	39	21	17	190
Age average/min/max age (y)	43/18/78	41/27/70	56/38/77	48/24/69	45/15/78
Professional tenure average/ min/max (y)	15/1/45	8/1/28	14/2/45	11/1/25	18/1/45
Gender male/female/unknown	41/46/26	15/24/0	5/16/0	6/11/0	67/97/26

Source: authors' calculations

5. Results

EMF safety component scores are presented in Table 4. Safety training for workers was assessed by all stakeholders, whereas workers themselves also assessed their EMF safety awareness and perception.

Table 4. Assessed score (0–1) of EMF safety management components as assessed by the stakeholder subgroups (mean values of subgroups)

code	Variable	Stakeholder group			
		Workers (W)	Work environment specialists (S)	Occupational health doctors (D)	Labour inspectors (I)
A	Workers EMF safety awareness and training	0.42	0.45	0.50	0.38
B	Compliance of companies in terms of EMF safety	0.09	0.33	NA	0.20
C	EMF safety arrangement of strong EMF workplaces	0.19	0.45	NA	0.21
E	Knowledge of EMF propagation and safety principles (health effects)	NA	0.44	0.63	0.57
D	EMF safety arrangement for risk groups	0.50	0.65	NA	NA

Notes: NA – not asked; Source: authors' calculations.

The assessment of (A) Workers EMF safety awareness and training by all subgroups, including the workers themselves, showed no statistical significance between the workers with respect to work environment specialists $t(104) = -.72$, $p = .472$, occupational health doctors $t(88) = -1.78$, $p = .079$ and labour inspectors $t(83) = -.98$, $p = .328$.

A large discrepancy can be seen between workers and work environment specialists assessing (B) Compliance of the companies in terms of EMF safety. The independent samples t-test was associated with a statistically significant effect, $t(44) = -3.20$, $p = .003$. This could indicate that workers do not perceive the EMF safety as the work environment specialists claim or intend. However, the mean scores for EMF safety compliance of the companies was not statistically significantly different between the working environment specialists and the labour inspectors, $t(42) = 1.75$, $p = .088$.

(C) Workplaces with high exposure to EMFs were addressed with a dedicated set of questions. The same discrepancy is also detected here, where work environment specialists report the safety arrangement to be more than twice as good as that perceived by the workers. The independent samples t-test was associated with a statistically significant effect, $t(49) = 2.44$, $p = .018$. The score given by labour inspectors supports the workers point of view by being statistically significantly different from the work environment specialists' mean score, $t(24) = 2.38$, $p = .026$.

(E) Knowledge of EMF propagation and safety principles was explored among the work environment specialists and labour inspectors, while a similar question about EMF health effects was asked of the occupational health doctors. The mean scores for the work inspectors and occupational health doctors were relatively high – this can be explained as both groups had EMF safety training organised by the government. As these subgroups were measured using a different set of questions corresponding to their specialist field, the statistical significance is not tested here.

(D) Meeting the needs of the risk groups was reported by the work environment specialists as being higher than the workers. However, the mean scores of these two subgroups are not statistically significantly different, $t(41) = 1.14$, $p = .261$.

Only 8 per cent of the workers reported themselves as belonging to one (or several) risk groups. Five per cent of the workers belonged both to a risk group and those who reported having high EMF workplaces at their company. Only a third of these workers reported having had attention paid to their condition in regard to the high EMFs present at the company. In addition, workers belonging to the risk groups did not exhibit any better knowledge in regard to EMF knowledge (score 0.30 out of 1) (Workers EMF safety awareness and training) than the rest of the sample. Although the size (N=9) of the subsample (workers affiliated with risk groups) is small, this may indicate that little attention is paid to training members of this group about electromagnetic fields and safe work practices at such workplaces.

A correlation analysis is presented in Table 5, to describe EMF safety management in companies, based on the workers and work environment specialists subgroup.

Table 5. Correlations between EMF safety variables: subgroup, workers and work environment specialists (N=152).

	AG	PT	CS	AW	A	B	C	D	E
AG	1								
PT	.671**	1							
CS	-.072	-.258**	1						
AW	.049	-.025	-.043	1					
A	.036	-.009	.054	.692**	1				
B	-.021	-.210	.220	.661**	.493**	1			
C	.057	-.142	.341*	.142	.381**	.824**	1		
D	.023	-.229	.007	.084	.270	.479**	.541**	1	
E	-.142	-.233	.023	.646**	.869**	.702**	.472	.409	1

Notes: * Correlation is significant at the 0.05 level; ** Correlation is significant at the 0.01 level;
Source: authors' calculations.
AG – age; PT – professional tenure; CS – company size; AW – awareness of strong EMFs at the company's workplace; A – workers EMF safety training; B – company's EMF safety compliance: C – EMF safety arrangement of strong EMF workplaces; D – EMF safety arrangement for the risk groups; E – Knowledge of EMF propagation and safety principles.

The analysis reveals the key factors influencing EMF safety management in companies. First, the awareness of work environment specialists (AW) about whether their company has strong EMF producing equipment is strongly positively correlated with (B) Compliance of the company in terms of EMF safety, and (E) Knowledge of EMF propagation and safety principles. Hence, the training of work environment specialists; that is, in terms of (E) Knowledge of EMF propagation and safety principles, also correlates strongly with (B) Compliance of the company in terms of EMF safety.

A weak positive correlation was found with (CS) Company size and (C) EMF safety arrangement of strong EMF workplaces, possibly indicating that larger companies manage EMF safety issues better.

No significant correlation was found between (PT) professional tenure and the relevant EMF safety variables. The same applied to respondent's age. This could indicate that neither age nor professional tenure play a role in managing EMF safety in companies. In the example of work environment specialists, neither professional tenure or age determine (E) Knowledge of EMF propagation and safety principles. In addition, neither age or professional tenure was a predictor for being aware of strong EMF workplaces in the company (AW).

The respondent companies (responses from workers and work environment specialists) were gathered from different size companies, based on the European Commission's classification of micro, small, medium and large companies (Centre for Strategy & Evaluation Services, 2012; European Commission, 2009). The size of the company/institution and respondents affiliation:

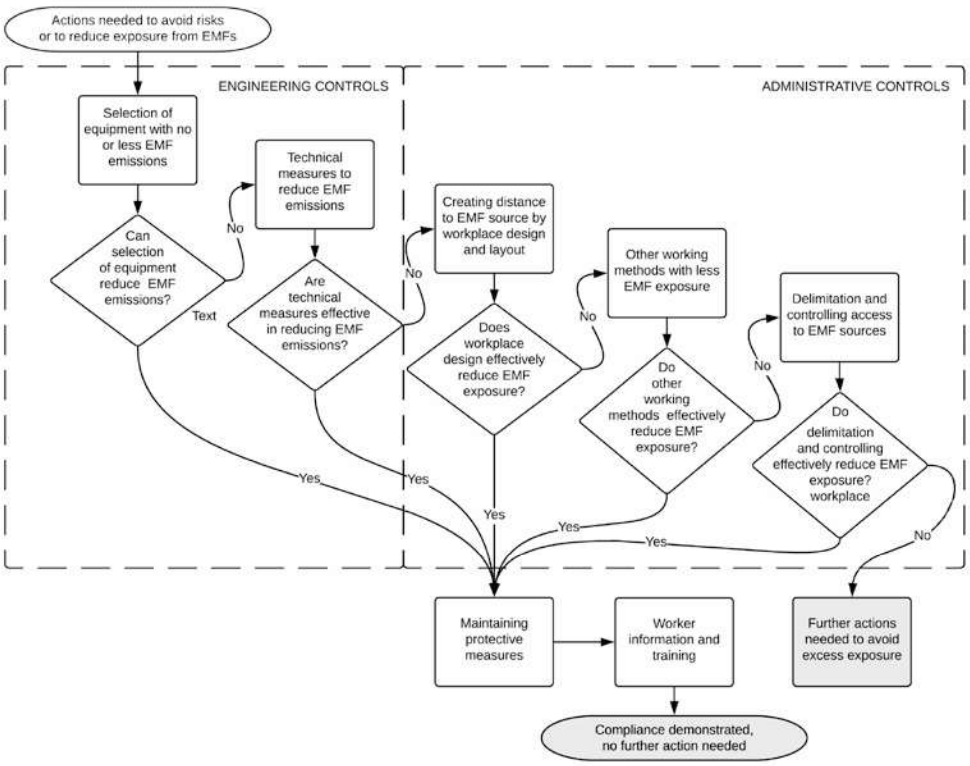
- micro (up to 9 employees) 14%,
- small (10–49 employees) 27%,
- medium (50–249 employees) 32%,
- large (over 249 employees) 27%.

In conclusion, the results of the analysis presented above showed that little attention is paid to EMF safety arrangements, and the awareness of safe practices in work concerning EMFs varies among stakeholder groups.

Following the EMF risk management guidelines set in the directive (The European Parliament and the Council, 2013) and the consequent national legislation (Vabariigi Valitsuse määrus 01.04.2016 nr 44, 2016), the author proposes an operational model of measures to reduce EMFs (figure 3). The model depicts hierarchically the activities presented in order of preferred implementation. The philosophy of the model follows general occupational safety principles, collective protection, where measures that benefit most of the workers should be preferred, such as established in the EU occupational health and safety framework directive, by which collective protective measures should be given priority over individual protective measures (Article 6, p.1) (The Council of the European Communities, 1989a). This prescribes trying first to eliminate the risk at the source. General measures should be preferred to localized measures. The aim of the process is to achieve a proper level of safety and to demonstrate compliance with the legislative requirements and good practice.

The model prescribes first selecting equipment that radiates less EMFs. Alternative technologies and equipment that produce less EMFs could solve this issue. However, changing equipment may not always be practicable. Sometimes this requires replacing the entire process and results in significant investments in new technical machinery.

Figure 3. Operational model of measures to reduce EMFs



In cases where emissions from the equipment are a necessary part of the work process, other technical measures should be implemented that reduce EMF emissions at the source. Shielding is most often used to control emissions from the equipment. A shield could be included by the manufacturer of the equipment or devised later by the employer. Shielding requires a frequency dependent approach and may not always achieve acceptable results, especially at low frequencies. Technical measures could include guarding. This could include interlocks and other automated technical means to cut the power from radiating equipment which otherwise would expose the worker to high levels of EMF in close proximity. Other technical measures could include human presence detection systems, such as light curtains, pressure mats etc. Two hand control devices and emergency stop buttons could be implemented where applicable. Technical measures should be preferred to administrative measures, as these could potentially remove the high exposure risk and in general provide a higher level of safety to all workers. The employer should employ specialists, as technical measures require an in-depth understanding of EMF propagation principles.

If the aforementioned engineering controls are inefficient or not applicable, the employer should turn to administrative control measures. To control employee exposure, first, creating distance in between the worker and the radiating equipment should be tried. The exposure levels decrease drastically when moving away from the source. If distancing does not produce satisfactory results or is not applicable, other working measures should be implemented. This could mean reducing the time the worker spends next to the radiating equipment, hence lowering

the high exposure time. Rearrangement of work procedures, repositioning equipment, redesigning the work environment could all be done to remove the worker from highly exposed areas. The last administrative measure is to limit worker access to the highly exposed work areas. The employer could also close access to rooms and areas where high exposure conditions occur. The risk assessment should critically evaluate the workers' access to EMF high exposure areas – is there an immediate need for human presence in the area during the operation of the equipment. All unnecessary personnel should be removed from access and hence grant them protection.

The employer should pay attention to documenting administrative measures and providing proper supervision over the implementation of the measures. The workers should be trained on the implemented measures, including both the intermediate staff at the site, but also other workers and groups that could enter the high exposure areas. These groups could involve firefighting personnel, premises maintenance crews, security personnel etc.

EMF reduction measures are more easily implemented in designing the workstation and work areas. The cost could be significantly higher in subsequent stages of business operations. The elimination of EMF high exposure should be the employer's goal. The EMF safety management system should encompass EMF reduction principles that involve more than one measure, covering technology, work procedures and human factors.

6. Discussion and Conclusions

A questionnaire-based study was conducted that indicated the perception of EMF safety, depending on the position of various stakeholders. The results show that contributing to safety education for both workers and work environment specialists has a positive effect on safety compliance and other related safety issues within the company; thereby, helping the organisation to demonstrate fulfilment of legislative requirements.

Despite some exceptions, the overall results indicate that compared to legislative expectations, little attention is still paid to training workers about electromagnetic fields as a work environment risk factor in terms of: how these fields are created; how to identify overexposure to EMFs; what are the safe practices when working near high EMFs, and so on. Work environment specialists exhibited better knowledge of EMF safety arrangements compared to workers, but the overall result is still too poor to bring the legislation into practice.

The shortcomings are characteristic of all companies, but are somewhat less evident in large companies. Considering the requirements of the new EMF legislation, in order for companies to achieve and demonstrate their compliance, we suggest that appropriate training programmes for work environment specialists and workers be implemented.

A discrepancy could be found in several issues according to responses from workers or work environment specialists. For example, work environment specialists reported better management of risks (than did workers) at high EMF workplaces and also in reckoning the needs of workers in risk groups. This inconsistency could be explained by a failure in the safety management procedures and training programmes; in other words, what is written on paper does not necessarily exist in practice.

According to a recent database search, there seems to be no similar research regarding EMFs, and therefore the results cannot be compared to previous relevant literature. Although there were no specific EMF safety studies that could be compared to the results of the current

study, such findings might be in line with other occupational health and safety studies, where an association between worker representation and good practice is made. The European study of worker representation and consultation on health and safety found that worker representation in developing safe working methods was more present in larger organisations, the public sector, organisations with older workers, and in workplaces where health and safety and the views of workers are seen as a priority (Stolk et al., 2012). The primary finding of the mentioned study was that the involvement of workers indeed plays a significant role in ensuring that new occupational health and safety policies and action plans are successfully implemented in practice. The same study from a period two years earlier had similar findings (González et al., 2010).

The crucial factor in implementing new occupational health and safety rules is the use of worker representatives. Additional occupational health and safety tasks, next to their regular work, require them to work extra hours. The European Trade Union Confederation sees the issue as a priority, so that the worker representatives get the needed support not only from the employers, but also other workers and trade unions (European Agency for Safety and Health at Work, 2012).

The findings of this study are in line with Järvis et al. (2016), who examined the differences between formal safety and real safety. Like Järvis et al., who determined shortcomings in real safety compared to formal safety, the current study has also indicated a discrepancy in the EMF safety score between responses from the work environment specialists and workers (Järvis et al., 2016).

The implication in light of the current study may be expressed formally that safety is organised and safety management systems include the risks from EMFs; however, as pointed out by Cooklin et al. (2017), effective work interventions are mostly those aimed at improving employee physical or mental health, whereas integrated interventions targeting occupational health and safety management with injury prevention or organisational cost savings are less effective (Cooklin et al., 2017).

An important factor in assessing worker exposure to EMFs is the availability of relevant exposure data, corresponding to the workplace and the job. Stam (2014) investigated the exposure levels at different workplaces with respect to the new EU directive (2013/35/EU). She found measures set by the directive could be complicated, as there is a scarcity of different workplace scenarios with EMF exposure and guidance on good practices (Stam, 2014).

One limitation of this study could be in regard to whether the sample is representative according to occupational exposure. Typically, there is considerable variation in exposure between companies, but also from workplace to workplace within the same company. Similar large-scale studies in the future should combine in-situ measurements with the same questionnaire design, shedding more light on the mechanisms of EMF safety management in strong EMF workplaces, and also companies in general.

Due to subgroup-specific means of delivering the invitations to participate in the study and anonymous participation, the authors could not send reminders to the subgroups or ask for additional information if needed. Due to the selected method of distributing the questionnaire, the response rate could not be determined in a valid manner. There was no list of people affiliated with subgroups (i.e. workers, work environment specialists); therefore, the overall number of these subgroups could not have been determined and the response rate assessed. The subgroups had to be reached by different means; the information on how

representative the subgroups turned out to be is not available. However, it is less likely that the results are biased according to non-representative groups because there is a clear difference between the scores of different subgroups.

The findings of this study highlight relevant EMF safety components in the process of adapting to the new EMF safety requirements. Similarly, new EMF guidelines could be better implemented in construction, mining, health and social work industries, as occupational health and safety arrangements are already best in these domains compared to others, according to the European Survey of Enterprises on New and Emerging Risks (Stolk et al., 2012). In implementing the new requirements, the EMF safety system should be integrated into the general safety management system of each company. By doing so the companies would be able to benefit from a fully functioning EMF safety system, within the meaning of the new EMF legislation.

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