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Executive Agency for Health and Consumers

EXECUTIVE AGENCY FOR HEALTH AND CONSUMERS

PROMOTING HEALTHY ENVIRONMENTS WITH A FOCUS ON THE IMPACT OF ACTIONS ON ELECTROMAGNETIC FIELDS (LOT 3)

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The Institute of Cancer Epidemiology

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1. INTRODUCTION

1.1. OBJECTIVE

This study aims to support Action 13 relating to electromagnetic fields of the EU Environment & Health Action Plan by evaluating the impact and the effectiveness of EU actions undertaken since 2004, as well as by assisting in the identification of future actions.

Specific objectives of this study include:

- Analysing the actual exposure of the general public to EMF in the EU (extremely low frequencies, intermediate frequencies, and radio frequencies as defined by the SCENIHR), and the trends in this exposure and public concern in the EU since 2004.
- Assessing the actions taken at EU level since 2004 (regulatory actions, technical standards, research funding, and scientific assessments)
- Identifying additional measures that could be taken to reduce the exposure of the general public to EMF in all frequency ranges, to assess the advantages and disadvantages, and to estimate the costs of these measures at EU level.

1.2. APPROACH

This analysis is based on existing information sources and data measurements and modelling was not performed (e.g. on EMF exposure assessment). A detailed and comprehensive review of existing literature and legislative sources was carried out.

Scientific information is analysed and validated with external experts in the field in order to derive reliable conclusions. This report is structured into three main sections:

- Analysis of EMF public exposure in the EU (chapter 2.)
- Evaluation of the current EU approach (chapter 3.)
- Additional measures to reduce the exposure (chapter 4.)

The conceptual framework of this study is presented in Figure 1.1.

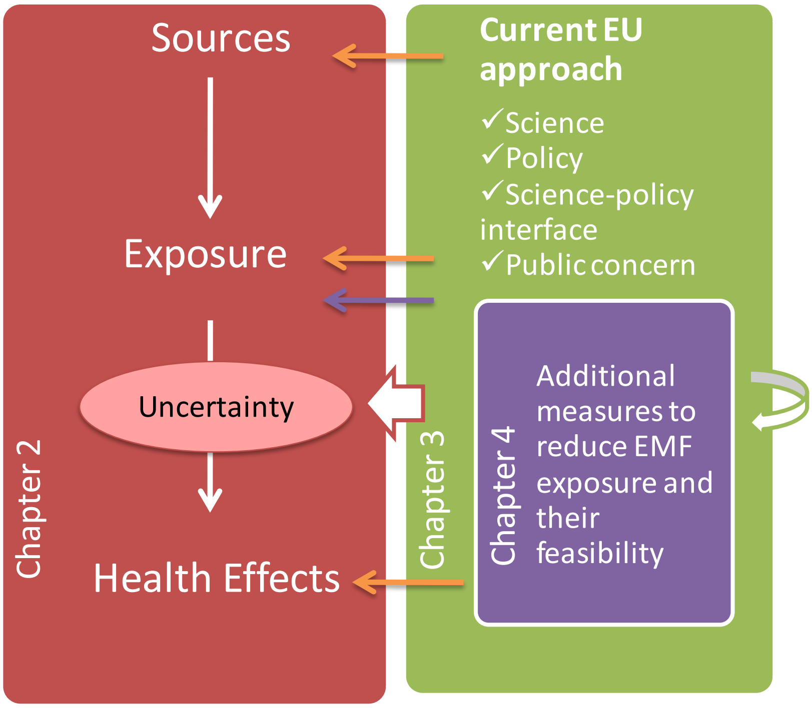

Figure 1-1: Conceptual framework for the study

2. ASSESSMENT OF EMF EXPOSURE

2.1. BACKGROUND

Electromagnetic fields (EMF) have existed on Earth since always and are not necessarily man-made. An example of EMF existing in nature is electric field produced by the local build-up of electric charges in the atmosphere associated with thunderstorms. During the twentieth century, man-made sources of EMF have steadily increased due to electricity demand, wireless technologies, telecommunications, broadcasting, and medical equipment such as soft tissue healing appliances, magnetic resonance imaging (MRI), etc.

Due to an extensive development of mobile telecommunications and a significant increase in the number of electronic appliances since the 1990s, the number and type of EMF sources have increased, resulting in increased possibilities of our daily exposure to EMF. There have been scientific and political debates regarding the potential adverse health effects of EMF, notably at long-term and high levels of exposure. However, the technologies responsible for EMF also provide social and economic benefits as they improve the quality of life. Without electricity, our society would come to a standstill, and both broadcasting and telecommunications have become an inherent and accepted fact of the modern life.

The issues underlying EMF relate to a diversity of actors. It has thus become a hot topic not only in the political sphere but also in the domains of public health, health-related scientific research, and related industries (mobile phone companies, internet service providers, wireless communication companies, etc.). Numerous studies, including a series of large-scale epidemiological surveys, have been carried out in different countries on the possible health effects of EMF on humans, animals, plants, and cell or tissue cultures. Nonetheless, although some health effects have been observed in some studies on EMF, no concluding evidence has been established and after more than two decades of scientific research, no scientific consensus has been achieved concerning the adverse health effects from EMF exposure (namely long-term exposure). There are still significant knowledge gaps, namely in multi-exposure and regarding the effects of long-term exposure.

Conflicting outcomes from research on the potential health effects of EMF have fuelled the on-going debate on the extent by which the health effects could possibly be caused by exposure to EMF. While a number of recent studies support either sides of the debate, many frequently cited reports, such as those conducted by the World Health

Organization (WHO)[1] fail to provide conclusive scientific evidence to link EMF exposure with negative health consequences.

2.2. MAIN SOURCES OF EMF

Electric fields are created by charged particulates and magnetic fields are created by magnets or charged particulates in movement. EMF are characterised by their frequency, i.e. number of variations per second, measured in hertz (Hz) and wavelength (1/frequency), a distance measured in metres. The strength of electric fields is measured in volts per metre (V/m). Magnetic fields are measured in tesla (T).

In the wave model of electromagnetic radiation, electric and magnetic fields oscillate together and perpendicular to each other (Figure 2-1). In the corpuscular model, electromagnetic radiation is described as a flow of photons. Such flow is measured by its energetic density in Watt per square metre (W/m^2).

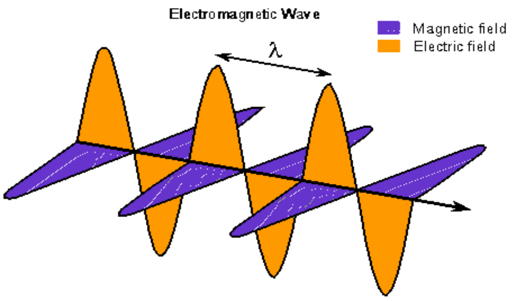

Figure 2-1: Electromagnetic waves[2]

EMF can be derived from a variety of natural and man-made sources. Natural sources of EMF are the Earth's magnetic field, the solar and lunar cycles, and thunderstorms which produce electric discharges in the atmosphere. Light itself is an electromagnetic radiation that can be visually detected. Anthropogenic sources of EMF are mainly electrical, telecommunication, and medical devices. The electromagnetic fields of anthropogenic origin are ubiquitous and in general stronger than those of natural origin[3].

EMF have a very wide range of frequencies (Figure 2-2), from non-ionising extremely low frequency (wavelengths of some hundreds of metres), to optical range (i.e. light, with a wavelength between 380 and 780 10^{-9} m) to ionising very high-frequency (wavelengths around 10^{-18} m).

[1] World Health Organization. Electromagnetic fields (EMF) – Summary of health effects: www.who.int/peh-emf/about/WhatisEMF/en/index1.html [Accessed online 12/03/2010]
[2] Electric and magnetic fields: www.astronomynotes.com/light/s2.htm [Accessed online 25/02/2010]
[3] Kato M. Electromagnetics in biology. Springer 2006.

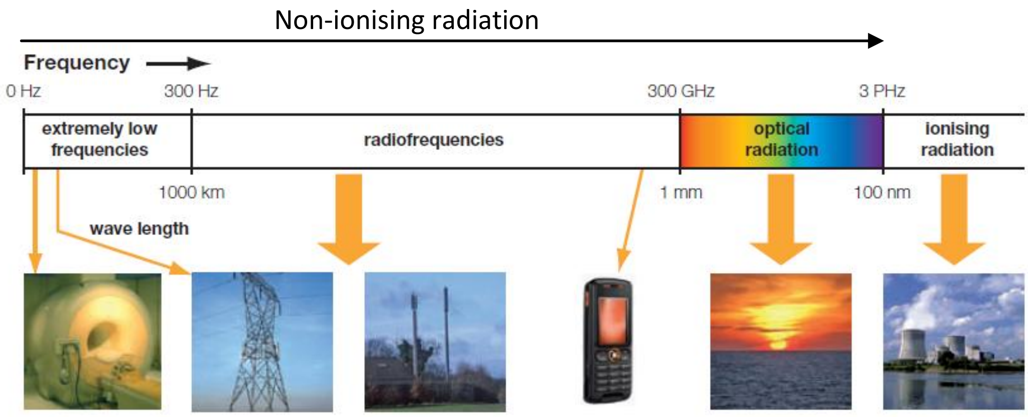

Figure 2-2 : The electromagnetic spectrum[5]

In this report, only static fields (0 Hz), electromagnetic fields (EMF) with extremely low frequencies (ELF, between 0 and 300 Hz), intermediate frequencies (IF, between 300 Hz and 100 kHz), and radio frequencies (RF, between 100 kHz and 300 GHz) are considered. They all belong to non-ionising radiation. Some confusion may exist with ionising radiations such as X-rays and gamma rays that possess much higher frequencies and documented health effects.

2.2.1. STATIC FIELDS

Even if only few anthropogenic sources of static fields exist (Table 2-1), there is a rapid development of new technologies which produce static fields. One of the main applications producing static fields[4] are medical devices, e.g. magnetic resonance imaging (MRI) scanners (Figure 2-3) used for identifying different types of tissues in the human body (Box 2-1). Many scientific techniques also use the nuclear magnetic resonance (NMR) for studying molecular physics, crystals, and non-crystalline materials through NMR spectroscopy. Static fields are also produced in some industrial processes used in the aluminium and chlor-alkali industries, in welding processes, and in certain railway and underground transport systems[5]. The use of direct current in rail systems can also generate this type of EMF inside the train.

[4] Nuclear magnetic resonance (NMR) is a property that magnetic nuclei have in a magnetic field and applied electromagnetic (EM) pulse or pulses, which cause the nuclei to absorb energy from the EM pulse and radiate this energy back out. NMR is also routinely used in advanced medical imaging techniques, such as in magnetic resonance imaging (MRI).

[5] European Commission, DG Health and Consumers protection website: www.ec.europa.eu/health/opinions2/en/electromagnetic-fields/index.htm#1 [Accessed online 25/02/2010]

Table 2-1: Anthropogenic sources of static fields

Source	Frequency	Occupational exposure	Residential exposure	Ambient exposure	Possibility of exposure
MRI	0 Hz	Yes	No	No	Occasionally for treating patients but possibility of exposure of radiology personnel during the device use
Industrial electrolysis	0 Hz	Yes	No	No	Possibility of exposure of workers in chlor-alkali industries
Welding devices	0 Hz	Yes	No	No	Possibility of exposure of the welders during welding
Railway and under-ground train systems	0 Hz	Yes	No	Yes	Possibility of exposure during transportation/ travels

Figure 2-3: MRI scanner

Box 2-1 – Magnetic Resonance Imaging (MRI) [6]

MRI is a medical diagnostic tool used for providing three-dimensional images of body structures, e.g. brain. MRI uses the magnetic characteristics of the body's hydrogen atoms and their interaction with both external magnetic fields and radiofrequencies to produce highly detailed images of the human body. The nucleus of the hydrogen atom contains a single proton. Nuclei containing an odd number of protons and/or neutrons have a characteristic motion in EMF. MRI creates a steady magnetic field and hydrogen nuclei align themselves in the direction of the magnetic field. A RF field is then applied to the patient, changing the previous disposition of hydrogen atoms. When the RF pulse stops, the nuclei return to equilibrium, parallel to the first magnetic field. During this return to equilibrium, called relaxation, the nuclei lose energy by emitting their own measurable RF signal, called the response signal. To produce a 3D image, this signal is encoded by adding a new gradient magnetic field of low frequency. The colour intensity of a tissue on the image depends on the proton density, the higher the proton density, the stronger is the response signal. In MRI, contrasts also depend on the relaxation time for nuclei to return to equilibrium and the time to send the response signal. When MR images are acquired, the RF pulse is repeated at a predetermined rate and the response signals can be measured at various times within the interval. This interval and the time between the application of the RF pulse and the response signal can be adjusted to contrast different tissue types. Therefore, MRI devices produce three types of fields: a static EMF, a low frequency EMF and a radiofrequency EMF.

2.2.2. EXTREMELY LOW FREQUENCY EMF

Electromagnetic fields of extremely low frequency (ELF), i.e. between 0 and 300 Hz, mainly originate from anthropogenic sources such as electrical appliances and power transmission and distribution lines (Figure 2-4). Electricity is transmitted from power stations to cities, factories, and homes through overhead and underground cables. Such cable networks containing electric current generates ELF fields.

In residential areas, the major sources of ELF fields are electrical equipment (e.g. TV, computers) and domestic electric installations. In industrial facilities, electric power installations, welding, induction heaters, and electrified transport systems are important sources of ELF exposure. ELF fields are also often used in industry for the induction heating of metals and semiconductors.

ELF fields can be also used in therapeutic and diagnostic applications, such as bone growth stimulation after a fracture or in wound healing, pain treatment, or cancer detection[5].

[6] Simon Fraser University (SFU) computing science. Basic Principles of MRI, 1995: www.cs.sfu.ca/~stella/papers/blairthesis/main/node11.html [Accessed online 15/03/2010]

Figure 2-4 : Power transmission and distribution lines[7]

Electromagnetic fields produced by transmission lines are measured by their ground-level field strength, which varies widely depending on the current flowing through the conductors, which in turn depends on the demand for electric power, on the configuration of the transmission line, and on the distance of the measurement point from the line. Typically, a transmission line's contribution to the ambient EMF disappears at distances greater than 100 metres from the line[2].

Table 2-2 summarises various types of ELF fields and the potential human exposure.

Table 2-2: Sources of extremely low frequency fields

Source	Frequency	Occupational exposure	Residential exposure	Ambient exposure	Possibility of exposure
Power transmission and distribution lines	50 Hz	Depends on the location	Depends on the location	Yes	Possibility of exposure of people living or working near a line (within 100m)
Household appliances: electric iron, toaster, electric oven, vacuum cleaner, electric shaver, etc.	50 Hz	No	Yes	No	Exposure levels depending on the frequency of use of domestic electrical devices
Trains, trams and subway systems	16 2/3 Hz; 25 Hz or 50 Hz for high-speed lines	Yes	No	Yes	Possibility of exposure during travel/ transportation. People living in buildings located near such networks are more exposed.

[7] Texas Attorney Blog: www.texasattorneyblog.com/utility_and_transmission_line/ [Accessed online 10/03/2010]

Source	Frequency	Occupational exposure	Residential exposure	Ambient exposure	Possibility of exposure
Welding machines	50 Hz	Yes	No	No	Possibility of exposure of the workers during welding
Induction heaters	50-300 Hz	Yes	Yes	No	Exposure levels depending on the frequency of use of induction heaters
Induction furnaces	50-300 Hz	Yes	No	No	Possibility of exposure for those working next to furnaces
Medical: MRI, bone growth stimulation, wound healing, pain treatment, cancer detection	MRI: 100-1000 Hz Others medical applications: 50-100 Hz	Yes	No	No	Occasionally for treated patients. Possible exposure of medical personnel during treatments.
Natural sources, e.g. storms	From several Hz to GHz	No	No	Yes	Possibility of exposure during storms
Electric engines in cars	50-60 Hz	Yes	No	Yes	Possibility of exposure while driving
Generators used in power plants	50 Hz	Yes	No	No	Possibility of exposure of workers in power plants

2.2.3. INTERMEDIATE FREQUENCY EMF

Intermediate frequencies of EMF, ranging between 300 Hz and 100 kHz, are produced by anti-theft devices (e.g. in shop exit doors), induction hobs and hotplates, electric engines, and card readers. Other sources include computer and television screens containing cathode ray tubes, compact fluorescent lamps, radio transmitters, and high voltage feeders[8] (Table 2-3).

This category of EMF can also be generated by industrial processes such as welding, medical applications such as electrosurgery (Figure 2-5) (which uses electric current to cut or remove tissues), and MRI[9] .

[8] Electromagnetic field, health and environment - Proceedings of EHE'07. Studies in Applied Electromagnetics and Mechanics, 2008.

[9] Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR). Health Effects of Exposure to EMF. 2009

Figure 2-5 : Electrosurgery device[10]

Table 2-3: Sources of intermediate frequency fields

Source	Frequency	Occupational exposure	Residential exposure	Ambient exposure	Possibility of exposure
Anti theft devices	tens of Hz to few GHz	Yes	No	No	In shops, possibility of exposure of the sales personnel during their whole working time
Induction hobs and hotplates	20 to 50 kHz	No	Yes	No	Possibility of exposure during the working of these devices
Card readers (safety, keys, badge, etc.)	100 kHz	Yes	No	No	Possibility of exposure of people passing near these devices /workers
Welding devices	A few hundred kHz	Yes	No	No	Possibility of exposure of the workers during welding
Induction heaters	Tens of Hz to tens of kHz	Yes	Yes	No	Exposure levels depending on the frequency of use of induction heaters
Electro-surgery	Hundreds of kHz	Yes	No	No	Occasionally for treated patients. Possible exposure of medical personnel during treatments.

[10] North West dental equipment - electrosurgery: www.dental-chairs.co.uk/electrosurgery.html [Accessed online 10/03/2010]

Source	Frequency	Occupational exposure	Residential exposure	Ambient exposure	Possibility of exposure
Computer screens (CRT)	100 Hz	Yes	Yes	No	Exposure levels dependent on the frequency of use of computers
Metal detectors	Some tens of kHz to some MHz	No	No	No	Possibility of exposure in airports, etc. of personnel working near these devices and people subjected to detection
Light bulbs	30-60 kHz	Yes	Yes	No	High exposure in all sites (home, workplace, street, etc.) lighted with light bulbs
Medium – wave Radio transmitte rs	30-300 kHz	Depending of the location	Depending of the location	Depending of the location	Possibility of exposure if the house or the workplace is located within 20 km of the tower

2.2.4. RADIO FREQUENCY EMF

Sources which generate radio frequency (RF) (from 100 kHz to 300 GHz) are widespread in our society. RF fields are produced by mobile phones and their antennas and base stations (Figure 2-6). The nature of transmitted RF fields depends on several factors, including the cell size of the base station and the type of mobile phone.

Figure 2-6 : Mobile phone base stations[11]

Key sources of RF fields (Table 2-4) include cordless phones, local wireless networks and radio or television transmission towers[3]. Other examples of sources of general exposure to RF fields are medical scanners, microwave ovens, civil and military radar systems, private mobile radio systems, or new technologies such as digital audio broadcasting systems, and Wi-Fi.

Some of the more recent anti-theft systems and several industrial appliances, like broadcasting stations or heating appliances, also operate in the RF range.

In addition, electromagnetic fields in the RF range are used in various therapeutic applications, like soft tissue healing appliances for analgesic applications (heating body tissue can ease pain), hyperthermia for burning and killing cancer cells, and diathermy[12]. Another common application of RF fields in medicine is magnetic resonance imaging or MRI (Box 2-1).

Table 2-4: Sources of radio frequency fields

Source	Frequency	Occupational exposure	Residential exposure	Ambient exposure	Possibility of exposure
Mobile phones	900 MHz – 2 GHz	Yes	Yes	Yes	Levels of exposure dependent on the frequency of use – also related to the frequency of use of the surrounding people
Cordless phones	1880 MHz - 1900 MHz	Yes	Yes	No	Possibility of exposure at a frequency dependent on the phone location

[11] West Seattle blog: www.westseattleblog.com/category/utilities/page/4 [Accessed online 10/03/2010]
[12] Physical therapy using high-frequency electric current, ultrasound, or microwaves to deliver heat to muscles and ligaments. Source: www.aarp.org/health/conditions/articles/harvard__arthritis-keeping-your-joints-healthy_9.html [Accessed online 20/02/2010]

Source	Frequency	Occupational exposure	Residential exposure	Ambient exposure	Possibility of exposure
Mobile phone base stations	900 MHz - 2 GHz	Yes	Yes	Yes	Frequency of exposure variable depending on location
Medical applications: MRI, healing appliances, burning cells, medical scanners	MRI: 10-100 MHz Scanner: 2.5 - 10 MHz	Yes	No	No	Occasionally for treated patients. Possible exposure of medical personnel during treatments
Heating	Until some tens of MHz	Yes	Yes	No	Possible exposure when heating is on
Radar systems	3 - 30 GHz	Yes	Yes	Yes	Possible exposure when the radar is on
Private mobile radio systems	Some hundreds MHz	No	Yes	No	Exposure levels dependent on the frequency of use
TV antennas	800 MHz	Depends on the location	Yes	Yes	Possibility of exposure when home/workplace are located close to an antenna
Radio stations	Some hundreds MHz	Depends on the location	Depends on the location	Yes	Possibility of exposure when home/workplace are located close to a radio station
Microwave ovens	2.45 GHz	No	Yes	No	Exposure dependent on the frequency of use
Anti-theft devices	Hundreds of Hz to few MHz	Yes	Yes	No	Possible exposure if the device is activated when someone is in the protected building
Wireless computer networks	2 - 5 GHz	Yes	Yes	No	Potential continuous exposure if these systems are installed in the residential and working environment

2.3. CURRENT LEVELS OF EXPOSURE OF EU POPULATION

2.3.1. EXPOSURE OF INDIVIDUALS IN THE EU POPULATION

Numerous surveys have been conducted by regulatory authorities in different Member States, in compliance with EMF protection guidelines such as Council Recommendation 1999/519/EC. The focus of such surveys is on particular EMF sources, often under worst case scenarios. All surveys show that non-compliance with the protection guidelines suggested by the International Commission on Non-Ionising Radiation Protection (ICNIRP) is generally not an issue; the situation however is different for regions that have adopted lower protection levels as a precautionary measure, such as Switzerland, where compliance with guidelines sometimes has an impact on the location of a mobile phone base station. The data collected from these surveys do not provide good insight into the exposure levels of individuals, who are often exposed to multiple sources at the same time and who move from one place to another. Therefore, data on the EMF exposure of individuals can only be obtained by explicit measurements, using for example dosimetric devices. Alternatively, the exposure only in residential areas can be measured when it can be assumed that it is the dominating exposure. A number of surveys have also been carried out on individuals, but they do not follow a standard protocol, hence the results are difficult to compare.

Most measurement studies focus on either the ELF or RF range. The electric field component is rarely investigated for the ELF studies. In contrast, RF studies exclusively measure the electrical component and report power density in Watt/m^2 rather than field strength in Volt/m. Measurement devices measure limited and device-dependent frequency ranges. Added to this, exposures below the detection limits of the measurement devices are quite common (in the RF range it is common to have less than 10% of measurements above the detection limit) and the way non-detects are taken into account for measuring total exposure differs from one study to another, further hampering a direct comparison of results. In a recent measurement study in Austria[13] both ELF and RF median exposure in residential area were measured for 226 individuals. The magnetic and the electrical field components of the night-time ELF exposure close to the bed were 0.02 µT (magnetic) and 26.2 V/m (electric), and 25% of the measured values were above 0.07 µT and 50.4 V/m respectively. For same locations, total RF exposure was measured with a median value of 40.34 µW/m^2 and 25% of measured values exceeding 141.87 µW/m^2.

An overview of common sources of the exposure of individuals to EMF is given in the 2009 report of the SCENIHR. The highest exposures in the ELF range occur during the use of electrical appliances that are held close to the body (several hundreds of µT related to the use of electric razors or hair dryers) or in occupational settings (compare

[13] Tomitsch J, Dechant E, Frank W. Survey of electromagnetic field exposure in bedrooms of residences in lower Austria. Bioelectromagnetics. 2009 Sep 24;31(3):200-208

with job-exposure-matrix[14]). While appliance-related exposure is usually intermittent and very short-term, thus hardly contributing to cumulative exposure over the day, in some workplaces exposure is higher than usual levels over the whole working time, and workers in those occupations experience the highest levels of exposure. That is why many studies investigating risks related to EMF exposure target occupational exposure[15]. Long-term environmental exposures occur in people living close to installations of power transmission and distribution lines, mainly overhead high-voltage power lines[16]. While normal 'background' ELF magnetic field levels averaged over 24 hours are between 0.01 and 0.05 µT in residential areas, often up to 0.1 µT in apartment buildings due to higher numbers of power consumers, several µT exceptionally occur in residences situated very close to power lines.

Some data on individual levels of exposure are available from epidemiological studies. Large-scale studies in the UK and in Germany have shown that average magnetic fields (median) above 0.2 µT seldom occur (< 2% of houses). In the residences with magnetic fields above 0.2 µT, one-third of these fields were due to close vicinity to high-voltage power lines (110-420 kV), one-third to low voltage (380 V) installations, and the remaining one-third to indoor wiring[17,18]. Indoor-transformers in houses have also been identified as possible elevated field sources[19,20]. While it is likely that elevated magnetic field levels are measured in residences close to power lines, the actual magnetic field level depends on the power load of the lines, which is variable by individual power line and time, and therefore the distance to a power line is not a perfect indicator of magnetic field exposure[21].

Several European railway systems use alternating current (often 16 2/3 Hz) and therefore contribute to exposure, mainly to train drivers[22], intermittently to travellers

[14] Bowman JD, Touchstone JA, Yost MG. A population-based job exposure matrix for power-frequency magnetic fields. J Occup Environ Hyg. 2007 Sep;4(9):715-28

[15] Kheifets L, Bowman JD, Checkoway H, Feychting M, Harrington JM, Kavet R, Marsh G, Mezei G, Renew DC, van Wijngaarden E. Future needs of occupational epidemiology of extremely low frequency electric and magnetic fields: review and recommendations. Occup Environ Med. 2009 Feb;66(2):72-80

[16] Brix J, Wettemann H, Scheel O, Feiner F, Matthes R. Measurement of the individual exposure to 50 and 16 2/3 Hz magnetic fields within the Bavarian population. Bioelectromagnetics. 2001 Jul;22(5):323-32

[17] Schüz J, Grigat JP, Störmer B, Rippin G, Brinkmann K, Michaelis J. Extremely low frequency magnetic fields in residences in Germany. Distribution of measurements, comparison of two methods for assessing exposure, and predictors for the occurrence of magnetic fields above background level. Radiat Environ Biophys. 2000 Dec;39(4):233-40

[18] Maslanyj MP, Mee TJ, Renew DC, Simpson J, Ansell P, Allen SG, Roman E. Investigation of the sources of residential power frequency magnetic field exposure in the UK Childhood Cancer Study. J Radiol Prot. 2007 Mar;27(1):41-58

[19] Thuróczy G, Jánossy G, Nagy N, Bakos J, Szabó J, Mezei G. Exposure to 50 Hz magnetic field in apartment buildings with built-in transformer stations in Hungary. Radiat Prot Dosimetry. 2008;131(4):469-73

[20] Ilonen K, Markkanen A, Mezei G, Juutilainen J. Indoor transformer stations as predictors of residential ELF magnetic field exposure. Bioelectromagnetics. 2008 Apr;29(3):213-8

[21] Maslanyj M, Simpson J, Roman E, Schüz J. Power frequency magnetic fields and risk of childhood leukaemia: misclassification of exposure from the use of the 'distance from power line' exposure surrogate. Bioelectromagnetics. 2009 Apr;30(3):183-8

[22] Röösli M, Lörtscher M, Egger M, Pfluger D, Schreier N, Lörtscher E, Locher P, Spoerri A, Minder C. Mortality from neurodegenerative disease and exposure to extremely low-frequency magnetic fields: 31 years of observations on Swiss railway employees. Neuroepidemiology. 2007;28(4):197-206

and to people living in residences close to railroads[23]. At intermediate frequencies, security or anti-theft devices, e.g. at shop exits, are common exposure sources, occasionally in nature for customers but significantly if shop assistant's work places are close to the installations. Although reference levels for exposure of the general public might be exceeded in the immediate vicinity, workplaces are usually located some meters away and typical exposures are well below protection limits[24]; however, large-scale systematic measurement surveys are missing and there is little monitoring of compliance with protection guidelines once the devices are installed.

Most other EMF exposures are occupational. Visual display units containing cathode ray tubes are still common sources of exposure and emit in both the ELF and the IF range, in the order of 0.001 to 0.05 µT. Radio transmitters operated in the long-wave range (30 kHz to 300 kHz) can cause exposure in the IF range with levels above the ICNIRP limits, and therefore safety measures are implemented for both the general public and workers.

In the RF range, the use of mobile phones is associated with exposure to the head concentrated in small zones, especially temporal lobes of the brain[25]. High exposures, i.e. field levels exceeding the protection limits for the general public, are experienced in occupational settings, e.g. among RF welders, RF heat sealers and broadcast tower maintenance personnel; however, the number of exposed persons is small as only few people are working in such conditions[26].

Other sources are broadcast towers for TV and radio, and mobile phone base stations. In the past, amplitude-modulated radio broadcasting was a major source of exposure, due to very powerful antennas operating to serve relatively large areas, so exposures above 1 V/m were measured several km away from the towers. Exposures from TV and frequency-modulated radio were lower and the change to the digital networks leads to further decrease in exposure levels[27]. Fields above 1 V/m were also measured in the vicinity of mobile phone base stations, in residences in the main beam of the antenna with free view to the base station[28].

Another major source of exposure is cordless phones. While the emission from handsets is much lower than that from mobile phones, the duration of use can be

[23] Schüz J, Grigat JP, Brinkmann K, Michaelis J. Childhood acute leukaemia and residential 16.7 Hz magnetic fields in Germany. Br J Cancer. 2001 Mar 2;84(5):697-9

[24] Bernhardt JH, McKinlay AF, Matthes R (editors). Possible health risks to the general public from the use of security and similar devices. Report of the Concerted Action QLK4-1999-01214 (European Commission), ICNIRP 12/2002

[25] Cardis E, Deltour I, Mann S, Moissonnier M, Taki M, Varsier N, Wake K, Wiart J. Distribution of RF energy emitted by mobile phones in anatomical structures of the brain. Phys Med Biol. 2008 Jun 7;53(11):2771-83

[26] Breckenkamp J, Berg-Beckhoff G, Münster E, Schüz J, Schlehofer B, Wahrendorf J, Blettner M. Feasibility of a cohort study on health risks caused by occupational exposure to radiofrequency electromagnetic fields. Environ Health. 2009 May 29;8:23

[27] Schubert M, Bornkessel C, Wuschek M, Schmidt P. Exposure of the general public to digital broadcast transmitters compared to analogue ones. Radiat Prot Dosimetry. 2007;124(1):53-7

[28] Schüz J, Mann S. A discussion of potential exposure metrics for use in epidemiological studies on human exposure to radiowaves from mobile phone base stations. J Expo Anal Environ Epidemiol. 2000 Nov-Dec;10(6 Pt 1):600-5

substantially longer, leading to a higher cumulative exposure. Although the RF fields emitted by cordless phone base stations are low and decrease rapidly[29], they become negligible beyond 50 cm. Individuals who keep the base station in the bedroom might experience higher exposure than from outdoor mobile phone base stations, as their fields are shielded by walls.

WHO summarised measurement studies conducted until 2007 in the ELF range[30]. Magnetic fields have been repeatedly assessed in European studies with measurement periods ranging from 1 to 7 days, either in the bedroom/domestic setting or with personal dosimeters. In all studies, the majority of studied persons were exposed to magnetic field levels below 0.1 µT (73.6- 89.9 %), but few (0.5-4.5%) had exposure levels above 0.3 µT (based on arithmetic means[31]). Geometric means[32] were only available for a small number of studies, but more than 90% had < 0.1 µT and 0.4-1.2 % had > 0.4 µT. The electric field component was more difficult to assess as it is more susceptible to shielding and perturbation by conduction bodies.

The average European RF exposure level is more difficult to assess, as exposure levels have been reported in different ways in different countries and a large proportion of measurements in most studies were below the detection limits of the existing measurement equipment. Furthermore, many studies were conducted in suspected high exposure environments such as urban areas and near antennas or other sources of *a priori* interest for the given study, and only a limited number of countries conducted measurements of representative exposure levels of individuals. The existing measurements were conducted for various reasons and no uniform or comparable measurement protocol was applied. Since the focus of the conducted studies was often to compare existing health risks and not to describe exposure as such, the data that were reported were not always sufficient to assess the average or median exposure levels. Given these limitations, some indications of the exposure levels are provided from the studies that have used the various personal measurement devices that have become available in recent years[33].

In the Swiss QUALIFEX study 166 subjects carried meters for 7 days around Basel during 2007-2008[34]. The median exposure was 0.09 mW/m^2 (ranging from 0.014-

[29] RF fields decrease with square of the distance in theory, but that rarely applies, as an apartment is usually not free space but full of all kind of items that could shield, reflect etc.

[30] www.who.int/peh-emf/publications/elf_ehc/en/index.html [Accessed online 09/03/10]

[31] The arithmetic mean of a set of values, commonly called the mean or the average, is the sum of all the values divided by the number of items in the list. The arithmetic mean is not a robust statistic because it is influenced by outliers. Thus it does not match with the notion of “middle” of the distribution of the values.

[32] The geometric mean indicates the central tendency of a set of numbers. In the geometric mean, the numbers are multiplied and then the nth root (where n is the count of numbers in the set) is applied to the result. The geometric mean takes into account the proportion of the values in the distribution.

[33] Radon K, Spegel H, Meyer N, Klein J, Brix J, Wiedenhofer A, Eder H, Praml G, Schulze A, Ehrenstein V, von Kries R, Nowak D. Personal dosimetry of exposure to mobile telephone base stations? An epidemiologic feasibility study comparing the Maschek dosimeter prototype and the Antennessa SP-090 system. Bioelectromagnetics. 2006 Jan;27(1):77-81

[34] Frei P, Mohler E, Neubauer G, Theis G, Bürgi A, Fröhlich J, Braun-Fahrländer C, Bolte J, Egger M, Röösli M. Temporal and spatial variability of personal exposure to radio frequency electromagnetic fields. Environ Res. 2009 Aug;109(6):779-85

0.881 mW/m^2) and the median night-time exposure was about one third of the daytime exposure (0.028 mW/m^2), with the main contributors being mobile phones, mobile phone base stations, and DECT cordless phones. Living close to mobile phone base stations, broadcast transmitters, or owning a mobile phone, cordless phones, or WLAN equipment, all increase mean exposure. A French study with 24-hour personal measurements of a random population sample of 377 subjects reported a total mean field of 0.201 V/m[35,36]. As in the Swiss study DECT, UMTS and WLAN frequencies were major contributors but also FM radio was high. Exposure in more rural locations was lower than in urban centres (0.156 V/m vs. 0.231 V/m) but no difference between day and night was seen for total exposure. In both the Swiss and French studies more than half of the total RF field measurements were below the detection level of the measurement devices. In a Bavarian study of children (n=1477) and adolescents (n=1508) who carried dosimeters for 24 hours, median exposure was reported as 0.17% of the ICNIRP protection guidelines (range 0.13-0.92 %), with the exposure being higher in the more urban areas[37].

Several further studies using stationary measurements have been carried out. A large German cross-sectional study included 1326 participants[38]. In 65.8% of the households a mean total field value below the detection limit of the dosimeters of 0.05 V/m was measured for the mobile phone base station frequencies. The 90% percentile was 0.1 V/m (0.027 mW/m^2) and this was lower in the rural area than in the suburban and urban areas. The maximum value was 1.141 V/m (3.452 mW/m^2).

More recently a study on RF performed measurements in homes, offices, public transports, and outdoor in five European countries (Belgium, Switzerland, Slovenia, Hungary, and the Netherlands)[39]. The aim was to compare mean exposure levels and contributions of different sources of RF in different environments. This study showed that the exposure levels measured are in the same order of magnitude in all countries. The highest RF exposure occurs in transportation vehicles (cars, buses, trains), mainly due to radiation from mobile phone handsets, followed by outdoor urban exposure, offices, and urban homes. The Netherlands are the exception because the highest exposure levels were measured in offices. However, all the exposure levels were below the international exposure limits. The study concludes that mobile telecommunication can be considered as the main contribution to RF exposure in all countries studied.

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[35] Viel JF, Cardis E, Moissonnier M, de Seze R, Hours M. Radiofrequency exposure in the French general population: band, time, location and activity variability. Environ Int. 2009b Nov;35(8):1150-4

[36] Viel JF, Clerc S, Barrera C, Rymzhanova R, Moissonnier M, Hours M, Cardis E. Residential exposure to radiofrequency fields from mobile phone base stations, and broadcast transmitters: a population-based survey with personal meter. Occup Environ Med. 2009a Aug;66(8):550-6

[37] Thomas S, Kühnlein A, Heinrich S, Praml G, von Kries R, Radon K. Exposure to mobile telecommunication networks assessed using personal dosimetry and well-being in children and adolescents: the German MobilEe-study. Environ Health. 2008 Nov 4;7:54

[38] Breckenkamp J, Berg-Beckhoff G, Münster E, Schüz J, Schlehofer B, Wahrendorf J, Blettner M. Feasibility of a cohort study on health risks caused by occupational exposure to radiofrequency electromagnetic fields. Environ Health. 2009 May 29;8:23

[39] Joseph W., Frei P., Röösli M., *et al.* Comparison of personal radiofrequency electromagnetic field exposure in different urban areas across Europe. Environ Res. 2010 July 16

2.3.2. ADDITIONAL DATA NEEDS

There is an apparent lack of data on individuals' exposure to EMF across all EU Member States. The lack of direct personal measurement surveys in the ELF range could be compensated by good knowledge about emissions of the major EMF sources, together with data on the numbers of installations and the possibility to calculate magnetic fields based on the characteristics of these installations. Additionally, numerous epidemiological studies have been conducted, providing some insight into prevalence of exposure and the composition of which field sources contribute to the total exposure. However, most of those studies come from Northern and Western Europe and, with the exception of Hungary, little information is available for Eastern European countries. Little is known about the IF EMF; however, it appears that exposure of the general public is occasional as most exposures are occupation-related. Nevertheless, in some instances, compliance with protection guidelines appears to be a problem for some of the anti-theft devices, especially given that pregnant women work in shops equipped with such devices. In the RF range, the focus of measurement surveys is on emission of particular sources and generally little is known about individual exposure. Again, epidemiological studies provide some preliminary insight, but given the diversity of their aims (for example, determination of the incidence of various cancers, study of sleep disturbance, etc.), the measurement results of those studies are difficult to compare. Before large-scale measurement campaigns are set up, there is a need for standardisation, both on the methodology of conducting the field studies and in the reporting of results. The EC-funded EFRHAN project[40] includes a work package dealing with comparability and availability of measurement data.

While all RF measurement surveys of sources and epidemiological studies so far suggest that the everyday exposure levels of the general public are well below the protection guidelines, it is difficult to predict whether groups in the population with elevated exposure exist and, if so, to what extent they are exposed above the normal 'background' level. Technologies are also changing rapidly and the impact of this on total exposure of an individual remains largely unclear. It is assumed that the change from analogue to digital technology in radio and TV broadcasting is associated with a decrease in exposure levels. The change from GSM technology for mobile telecommunication to UMTS technology is also associated with a lower exposure to RF during mobile phone use, as UMTS usually operates with lower emissions. At the same time, new technologies emerge or the use of these technologies by the population becomes more widespread. In addition, the lower the number of transmission stations to serve a certain territory size or the larger the size of the served territory, the higher the strength of emitted signals.

[40] EFHRAN – European health risk assessment network on EMF exposure website: efhran.polimi.it/index.html

Three questions in the RF range are of particular interest:

1) What are average total RF exposure levels in the general population in different locations?
2) Is the composition of total RF exposure level dependent on the location, i.e. which field sources contribute most to the overall exposure?
3) Are exposure levels lower in areas with defined precautionary measures such as lower protection limits than those defined by ICNIRP, like in Brussels, Italy or Switzerland?

A prerequisite for addressing these questions are joint actions for both the design and conduct of measurement campaigns.

2.3.3. Conclusions and methodological issues

The main methodological issues are to further improve personal dosimeters to measure the exposure levels of individuals to RF fields and to develop a standard for a measurement protocol to enable the comparison of measurement surveys across countries. With regard to the devices, there is a need to fulfil the following requirements: i) covering the whole relevant frequency spectrum and providing both total and frequency range measures; ii) minimising measurement artefacts due to device location; iii) obtaining a high acceptance of study participants to carry the device with them for longer time periods, thus it has to be relatively small, light and well designed; iv) long term recording, i.e. enough storage capacity for measured values; v) recording of start and stop of the measurement, GPS logger and interface to personal computers; vi) easy to calibrate; vii) obtaining the highest possible validity and reliability of measurements. With regard to dissemination, there is a high need for standardisation of reported values, as currently the results from surveys are hardly comparable. There are two types of protocols, one for population measurement surveys (the sample has to be representative of the target population and the day of the measurement has to be representative of the participants' usual activity patterns) and one for microenvironment measurement surveys (the target is microenvironments under normal operating conditions and population exposure will be estimated based on time spent in the respective microenvironment). A suggestion for such protocols was developed by Röösli *et al*.[41]

[41] Röösli M, Frei P, Bolte J, Neubauer G, Cardis E, Feychting M, Gajsek P, Heinrich S, Joseph W, Mann S, Martens L, Mohler E, Parslow R, Poulsen AH, Radon K, Schüz J, Thuroczy G, Viel JF, Vrijheid M. Proposal of a study protocol for the conduct of a personal radiofrequency electromagnetic field measurement campaign. Under review

2.4. HEALTH EFFECTS

The health effects of EMF on the human body could not only depend on the field strength and frequency of EMF but also on the level of exposure, as well as individual characteristics such as body size, angle towards the field, or age[42]. Children, for instance, are potentially more vulnerable to RF fields because of the potentially greater sensitiveness of their nervous systems to the heating induced by this category of fields. This is due to the fact that their brain tissue is more conductive than that of adults and to their different physiology and cell growth dynamics. Moreover, it should be considered that they may have a longer exposure during their lifetime compared to adult individuals[43].

Low and high frequency electromagnetic waves affect the human body in different ways.

2.4.1. STATIC FIELDS

After an exposure to static EMF, short term effects have been observed on sensory functions. MRI workers exposed to static fields, for example, noted symptoms of sensorial disturbance such as nystagmus and tonic vestibular asymmetry[44]. These symptoms were present during exposure, but no effect could be detected on the vestibular function thirty minutes after the end of the exposure[45]. An increase in the brain activity and a trend for decreased performance in cognitive-motor tests were observed during exposure to static fields produced by an MRI scanner[46,47]. *In vivo* studies on animals have shown that static fields could induce effects on neuronal functioning, for example changing amplitude and duration of the action potential[48] in neurons. *In vitro* studies also show that low levels of exposure to static EMF may modify membrane properties of neurons. These effects have been reported to be reversible[9].

[42] WHO website, 'EMF current standards: www.who.int/peh-emf/about/WhatisEMF/en/index4.html [Accessed online 25/02/2010]

[43] Kheifets L., Repacholi M., Saunders R., *et al.* The Sensitivity of Children to Electromagnetic Fields. Pediatrics. 2005;116(2):303-313

[44] Nystagmus corresponds to specific involuntary movements of the eyeballs; its presence or absence is used to diagnose a variety of neurological and visual disorders. It often reflects abnormal stimulation of the sensorial organ of equilibrium, i.e. the vestibule of the inner ear. Tonic vestibular asymmetry describes a situation where left and right vestibules are not reacting equally.

[45] Patel M, Williamsom RA, Dorevitch S, Buchanan S. Pilot study investigating the effect of the static magnetic field from a 9.4-T MRI on the vestibular system. J Occup Environ Med 2008; 50:576-83

[46] Toyomaki A, Yamamoto T. Observation of changes in neural activity due to the static magnetic field of an MRI scanner. J Magn Reson Imaging 2007; 26:1216-21

[47] De Vocht F, Stevens T, Glover P, Sunderland A, Gowland P, Kromhout H. Cognitive effects of head movements in stray fields generated by a 7 Tesla whole-body MRI magnet. Bioelectromagnetics 2007; 28:247-55

[48] An action potential (or nerve impulse) is a transient change in the electrical potential of the membrane voltage of an excitable cell such as a nerve or muscle fiber. This electrical charge travels along the axon to the neuron's terminal where it triggers or inhibits the release of a neurotransmitter and then disappears. (Source: mindsci-clinic.com/neuro_jargon.htm)

Static EMF could also affect the expression of genes in humans and other mammalian cells, according to the exposure duration and the field force. In several studies using cultured cell lines, an exposure to several hundreds of mT was observed to induce gene expression alteration or DNA damage. However these results are controversial. For example some *in vitro* studies showed that static fields produce an inhibition of osteoblasts differentiation leading to a decrease of bone formation[49] whereas others studies reported a promotion of osteoblast differentiation *in vivo* and in clinical studies[50].Such genotoxic effects can be repaired and thus are not permanent. In others studies stronger fields, like in MRI (up to several tesla), do not lead to genotoxic effects[9].

Concerning static fields, contradictory data exists regarding the potential effects on blood flow and vessel growth, on foetal development, etc. Moreover, there is no evidence of the carcinogenicity of static EMF in humans and no relevant data are available in experimental animals[51]. Studies in animals exposed for example to 3 T static EMF showed that static EMF could be involved in the decrease of perception of pain but these results have not been confirmed in humans[52].

2.4.2. EXTREMELY LOW FREQUENCY FIELDS

ELF fields are a possible carcinogen which might contribute to the development of childhood leukaemia. The limited association between childhood leukaemia and ELF found in epidemiological studies, along with little evidence of carcinogenicity in cell lines and experimental animals, has led to the classification of ELF by the International Agency for Research on Cancer (IARC) as a 'possible human carcinogen' (group 2B)[53]. A recent molecular and epidemiological study[54] which aimed to have a better understanding of the molecular mechanisms underlying childhood leukaemia effect due to EMF exposure, suggests an association with defects in DNA-repair enzymes that could be caused by transformers and power lines[66]. Nevertheless, no experimental evidence and no plausible causal mechanism have been identified.

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[49] Denaro V., Cittadini A., Barnaba SA., *et al.* Static Electromagnetic Fields Generated by Corrosion Currents Inhibit Human Osteoblast Differentiation. Spine. 2008; 33(9):955-959

[50] Sakurai T., Terashima S., Miyakoshi J. Enhanced secretion of prostaglandin E2 from osteoblasts by exposure to a strong static magnetic field. Bioelectromagnetics. 2007; 29(4):277-283

[51] International Agency for Research on Cancer (IARC). 2002. Monographs on the evaluation of carcinogenic risks to humans (Non-ionizing radiation, Part 1: Static and extremely low-frequency (ELF) electric and magnetic fields. Lyon: International Agency for Research on Cancer, Monograph, vol. 80

[52] László J, Gyires K. Homogeneous static magnetic field of a clinical MR significantly inhibits pain in mice. Life Sci 2009; 84:12-7

[53] International Agency for Research on Cancer (IARC). 2002. Monographs on the evaluation of carcinogenic risks to humans (Non-ionizing radiation, Part 1: Static and extremely low-frequency (ELF) electric and magnetic fields. Lyon: International Agency for Research on Cancer, Monograph, vol. 80

[54] Yang Y, Jin X, Yan C, Tian Y, Tang J, Shen X. Case-only study of interactions between DNA repair genes (hMLH1, APEX1, MGMT, XRCC1 and XPD) and low-frequency electromagnetic fields in childhood acute leukemia. Leuk Lymphoma 2008; 49:2344-50

To date, in ELF health risk assessment, childhood leukaemia is considered as the 'critical effect', meaning that this disease is viewed as the first critical sign of significant adverse health effect appearing after exposure[55].

One of the known impacts of ELF fields is their capacity to excite nerve and muscle cells. As nervous tissues are sensitive to electrical signals, ELF fields could then modify brain electrical signals, and finally change the response time for complex reasoning tasks at high levels of exposure. However, despite some data showing a potential impact on neuronal cells, the link between ELF fields, neurodegenerative diseases and brain tumours remains unclear. Recent *in vivo* studies provided indications for effects on the nervous system; however, there are still inconsistencies in the data and no definite conclusions can be drawn regarding humans. It is notable that *in vivo* and *in vitro* studies show effects at ELF exposure levels (from 0.10 mT and above) that are considerably higher than the levels encountered in the epidemiological studies (µT-levels)[9]. Thus, it is important to stress that important inconsistencies exist between the effects observed *in vivo* and *in vitro* and the results of epidemiological studies in humans.

Recent research articles[56,57] have reported an increase in the incidence rate of Alzheimer's disease in specific groups of workers (seamstresses and tailors, rail workers, electricians) that are highly exposed to ELF. The increased rate of Alzheimer's disease could be linked to the stimulation by ELF fields of the beta-amyloid[58] peptide secretion[59], which plays an important role during the development of the disease, and a decreased production of melatonin, which is influenced by long-term and high levels of exposure to ELF. Falone[60] reported changes in the antioxidant defence system in the brain cortical cells of exposed female rats which might be another relevant explanation of neurodegenerative diseases (like Alzheimer's disease). A study[61] on 4.7 million persons of the Swiss National Cohort during the period 2000–2005, supports the association between residential exposure to magnetic fields from power lines and both Alzheimer's disease and senile dementia, but not of amyotrophic lateral sclerosis (ALS) or other neurodegenerative diseases. Hug[62] confirms the relation between exposure to

55 Kheifets L., Afifi AA., Shimkhada R. Public Health Impact of Extremely Low-Frequency Electromagnetic Fields. Environ Health Perspect. 2006;114(10):1532-1537

56 Davanipour Z., Sobel E. Long-term exposure to magnetic fields and the risks of Alzheimer's disease and breast cancer: Further biological research. Pathophysiology. 2009;16(2-3):149–156

57 Röösli M, Lörtscher M, Egger M., *et al.* Mortality from neurodegenerative disease and exposure to extremely low-frequency magnetic fields: 31 years of observations on Swiss railway employees. Neuroepidemiology. 2007;28(4):197-206

58 Beta amyloid is a small protein (or peptide) which may form aggregates in the nervous system. Such aggregation may reduce synapses function and conduction of nerve impulses and lead to the memory loss and dementia that are features of Alzheimer's syndrome.

59 Del Giudice E, Facchinetti F, Nofrate V, *et al.* Fifty Hertz electromagnetic field exposure stimulates secretion of beta-amyloid peptide in cultured human neuroglioma. Neurosci Lett 2007; 418:9-12

60 Falone S, Mirabilio A, Carbone MC, *et al.* Chronic exposure to 50Hz magnetic fields causes a significant weakening of antioxidant defence systems in aged rat brain. Int J Biochem Cell Biol 2008; 40:2762-70

61 Huss A., Spoerri A., Egger M., *et al.* Residence near power lines and mortality from neurodegenerative diseases: longitudinal study of the Swiss population. Am J Epidemiol. 2009; 169(2):167-175

62 Hug K., Röösli M., Rapp R. Magnetic field exposure and neurodegenerative diseases – recent epidemiological studies. Soz Praventiv Med. 2006;51:210–220

EMF with a magnetic field between 0.2 µT and 1 µT and ALS for electric, electronic work and welding, but not for other occupational groups having a high exposure to low-frequency EMF.

Associations between exposure to ELF electromagnetic fields and stress, suicide or depression, even if suspected, have not been well established, and more research is necessary. *In vivo* studies on hamsters have shown an increased insulin secretion after 2 or 5 days of exposure to ELFs. It has also been suggested that a common and possibly general response to the exposure to ELF fields could be the activation of the genes encoding the heat shock proteins which react to stress[63].

Self-reported symptoms, also called 'electromagnetic hypersensitivity' are symptoms defined on the basis of the experience reported by individuals afflicted by EMF[72]. To date, no study supports a causal relationship between ELF fields and self-reported symptoms, such as fatigue, headache, concentration difficulties, nausea, heart palpitation, dermatological symptoms such as redness, tingling and burning sensations, etc.

Regarding cardiovascular disease, an association was considered unlikely. Nevertheless ELF fields could influence the cardiovascular system, for example by slightly decreasing or increasing the heart rate, by about 3-5 beats/minutes[64]. Studies of pregnancy outcomes in women working with computer screens have provided no consistent evidence for adverse effects on reproduction, no excess risk of spontaneous abortion or malformations. Other studies observe a slight increase of early pregnancy loss, prematurity and low birth weight in the children of workers in the electronics industry, but in this case the symptoms may not be exclusively caused by EMF exposures[66].

2.4.3. INTERMEDIATE FREQUENCY FIELDS

Experimental and epidemiological data on the health effects caused by IF exposure are very sparse. Assessment of acute health risks in the IF range is currently extrapolated on known hazards at lower (ELF range) and higher frequencies (RF range). Therefore the deduced biological effects of IF fields include nerve stimulation at the lower end of the range and heating at the upper end of the range[9].

[63] Sakurai T, Yoshimoto M, Koyama S, Miyakoshi J. Exposure to extremely low frequency magnetic fields affects insulin-secreting cells. Bioelectromagnetics 2008; 29:118-24

[64] WHO. Electromagnetic fields and human health – Static and extremely low frequency (ELF) fields www.who.int/peh-emf/about/en/Static%20and%20ELF%20Fields.pdf [Accessed online 26/02/2010]

2.4.4. RADIOFREQUENCY FIELDS

Heating of body tissues is the main known biological effect of RF. In microwave ovens this property is employed to cook food. However, in general, the environmental levels of RF due to anthropogenic sources are not sufficient to produce observable health effects[65].

To date, scientific evidence does not clearly support a link between exposure to RF and certain self-reported symptoms (headaches, anxiety, suicide and depression, nausea, fatigue, loss of libido) which could rather be due to a nocebo effect (an adverse non-specific effect that is caused by expectation or belief that something is harmful). However, RF fields can influence electroencephalogram patterns and modify the stages of sleep in humans.

There is no significant evidence that RF cause cancer in humans. The use of mobile phones does not seem to increase the risk of cancer, especially when they are used for less than ten years. Studies that were published in the Interphone project which pools data from five EU countries (4 Nordic countries and the UK), support this finding[9]. However, these results can be explained by the fact that the average duration of human exposure to RF fields from mobile phones could be shorter than the time required to induce cancer. Further research is required to identify whether a long-term (well beyond ten years) human exposure to such phones might pose some cancer risk. The potential cancer risk of exposure to RF from transmission towers has been often studied but in most cases, no solid conclusions could be drawn, even if some studies have shown an increased risk of leukaemia in children living close to strong radio or television broadcast transmitters[9]. *In vivo* research in rodents shows that RF are not carcinogenic and *in vitro* studies fail to provide evidence of the genotoxicity (capability to induce DNA-damage) of RF[9].

However, numerous studies have shown that RF fields are teratogenic[66] at exposure levels sufficiently high to cause significant increase of temperature, but there is no consistent evidence of RF field effects at non-thermal exposure levels[67].

To date, no effects on functions/aspects of the nervous system, such as cognitive and sensory functions, structural stability, and cellular responses, have been shown[9].

[65] WHO website, electromagnetic fields – Summary of health effects: www.who.int/peh-emf/about/WhatisEMF/en/index1.html [Accessed online 25/02/2010]

[66] Relating to substances or agents able to disturb the growth and development of an embryo or foetus (Source: www.medterms.com/script/main/art.asp?articlekey=22266 [Accessed online 12/03/2010]

[67] Juutilainen J. Developmental effects of electromagnetic fields. Bioelectromagnetics. 2005;Suppl 7:S107-115

2.4.5. Preliminary conclusions

Carcinogenic evidence is only present for ELF fields which might contribute to an increase in childhood leukaemia, but at present, *in vitro* studies did not provide a mechanistic explanation of this epidemiological finding. If the association is causal, it is estimated that about 1% of childhood leukaemia cases in Europe might be attributable to ELF fields.

According to *in vivo* studies exposing animals to high levels of EMF, there is no doubt that short-term exposure to very high levels of EMF can be harmful to health – e.g. causing eye irritation. However, experiments with healthy volunteers indicate that, in general, the low levels of exposure in the open space or in the home do not cause any apparent detrimental effects. There is little scientific evidence to support the idea of electromagnetic hypersensitivity, even if it is often self-reported. Even if some biological effects exist, they do not result in health consequences: the compensatory mechanism of the body must be exceeded to show an impact on health. For example, RF exposure increases the temperature of the body; however, the temperature increase will only have detrimental health consequences if it exceeds 2-3°C[68]. In mammals, most studies have shown no effects of prenatal exposure to ELF or IF fields on development. However, additional studies on the effects on development might increase our understanding of the sensitivity of biological organisms to EMF[68].

There are still significant knowledge gaps, namely concerning the effects of long-term exposure to RF. Scientists have no hindsight on the recent EMF exposure and to date effects of long-term exposure are not known. It is worth noting that the effects of EMF can be cumulative and build up in the body over time[69]. Despite the number of studies on EMF health impacts, there is still a lack of adequate data for a proper risk assessment of each frequency of EMF. More research is necessary, especially to clarify the many mixed and sometimes contradictory results[9].

[68] Health effects on electromagnetic fields. Expert Group on Health Effects of Electromagnetic Fields: www.dcenr.gov.ie/NR/rdonlyres/9E29937F-1A27-4A16-A8C3-F403A623300C/0/ElectromagneticReport.pdf

[69] Health and electromagnetic fields, European commission. 2005

3. EVALUATION OF THE CURRENT EU APPROACH

3.1. THE EVOLUTION OF PUBLIC PERCEPTION

Widespread public concerns have been one of the drivers for continuous policy development and scientific research related to the health effects of EMF. Surveys show that even if the public is more concerned about chemicals, food, air and water quality, around half of EU public is also seriously concerned about the potential health risks of EMF. The public opinion is evenly divided between those who are very much or fairly concerned (46%) and those who are not very concerned or not at all concerned (51%)[70].

Thus, despite the existing EU regulatory framework which is based on the precautionary principle and the absence of conclusive scientific evidence on the potential health effects of exposure to EMF, public concern about the potential health risks from EMF persists. In particular, surveys show that wireless communication technology and the construction of base stations near homes seem to be the main sources of worry. As a result, the construction of new power and distribution lines or mobile communication networks face significant public opposition. Some categories of population (e.g. parents of young children) are particularly worried and demand risk-benefit assessments.

It is difficult to ascertain the reasons for the concern about EMF but the following factors should be considered in explaining the significant growth of public concern:

- **Unfamiliar technology:** Advancements in "smart" technology and telecommunications (WiFi, DECT phones, GPS systems, etc.) could mean that more visible structures that produce EMF are being constructed. The ubiquitous and invisible presence of EMF and their mysterious nature favour psychological stress caused by unfamiliar objects and technologies.
- **Lack of control:** many concerned citizens feel helpless in controlling their exposure levels to EMF or in determining where base stations or power lines should be constructed, which has expressed through numerous organised actions from citizens groups. Groups of citizens that identify as being electro-hypersensitive are also making their voices heard by taking legal action against various actors causing EMF exposure (e.g. resistance to the installation of new power lines and mobile phone base stations as well as against WiFi hotspots in schools and libraries).

[70] EC 2010, Special Eurobarometer – Electromagnetic fields. ec.europa.eu/public_opinion/archives/ebs/ebs_347_en.pdf [Accessed online 16/08/2010]

- **Complexity of the issue and scientific controversies:** the understanding of measurement procedures and quantification of exposure are particularly difficult to understand by the general public. The potential effects of a multi-exposure are also very complex to ascertain. Moreover, the results of scientific studies that sometimes appear to be contradictory, coupled with the lack of conclusiveness of many studies, trigger endless scientific debates. Facing such controversies, the public cannot decide to forget the risk and get free from associated responsibility nor decide to challenge it. Such situation is exacerbated when the risk relates to severe disease, such as cancer, or specific groups such as children.

A possible approach to understand public perception is based on risk-benefit analyses that are more or less consciously performed by each individual. Schematically, such individual risk-benefit analyses drive one to reject an individual risk if it is not counterbalanced by an individual benefit. Even a very low or poorly demonstrated risk will require a compensating advantage. Interestingly, a collective benefit, such as access to technology, does not compensate for an extra individual risk. On the contrary, it may trigger the feeling that “others benefit from the risk that I take”. For example, if someone thinks “the fact that the base station is close to my house increases the risk for me”, he or she will need to perceive a compensating benefit for him or herself, and not only for the neighbourhood, in order to accept the risk. Thus, he or she will request that in the absence of benefit, the risk is cancelled (request for policy based on precaution principle) or its absence demonstrated (request for more information). Of course, this schematic analysis is modulated by the cultural context which may vary across different MS.

Under this scheme, another possible request (in theory) would be to associate an increased individual benefit or compensation (perceived or real) to the increase of individual risk (perceived or real). It is also possible to reduce the concern by associating the risk exposed individuals to the decision that creates the risk: it is difficult to take risks resulting from others’ decision whereas dialog and stakeholder consultation may allow better acceptance. Communication is an obvious necessity to answer public concern in a situation of uncertainty (see chapter 3 and 4). These mechanisms explain the different attitudes concerning exposure to mobile phones, which provides an individual benefit and can be individually controlled, and exposure to a base station which provides a collective benefit and cannot be individually controlled. Answers to public concerns about individual phones are easier to implement than those related to collective equipment.

The tables below summarise the risk acceptance of collective equipment, such as base stations (Table 3-1), and individual equipment such as mobile phones (Table 3-2) by individuals and the community, according to the risk and the benefit of these devices for both individuals and the community.

Table 3-1 : Risk acceptance for collective equipments

	For individuals	For the community
Risk	In the best cases, very low or absent	In the best cases, very low or absent
Benefit	None	Present : access to technology
Risk/benefit	**Concern**	**Acceptable**

Table 3-2 : Risk acceptance for individual equipments

	For individuals	For the community
Risk	In the best cases, very low or absent	In the best cases, very low or absent
Benefit	Important	Important: access to technology
Risk/benefit	**Acceptable**	**Acceptable**

The tables show that even if the risk is very low, if individuals perceive absolutely no balancing benefit, they will not accept the risk: when the benefit is zero, the risk / benefit ratio is always too high. In contrast, in the three other cases, some benefit is present; therefore the risk / benefit ratio may be accepted.

The 2010 Eurobarometer survey highlighted that the majority of EU public would like to receive more information through common media such as the TV, radio and press releases, instead of needing to look for information on the internet and in specialised publications. Only 20% of the respondents in the Member States have received information on the potential health effects of EMF. Out of this percentage, 58% were satisfied with the information (compared to 28% in 2006), but 15% considered the information as not objective[70]. It is worth noting that people who are not satisfied with the information provided are in general those who are the most concerned about the EMF issue (56% versus 37%). In some MS, where a lot of attention has been attributed to public consultation, authorities are more aware of specific areas of concern[71]. Thus it emerges that high-tension power lines (35%), mobile phone base stations (33%), mobile phone handsets (26%), computers (20%) and household electrical equipments (17%) are the EMF sources that are perceived as having a significant impact on health. These percentages decreased with two or three points over the past four years, except the percentages for computers and household electrical equipments which increased. The awareness of existing sources of EMF has decreased. In 2006, 23% of the respondents identified all the items proposed in the survey to emit EMFs whereas only 9% were aware of this fact in 2010. Persons with a higher level of education are significantly more aware of the fact that each of the sources mentioned generates electromagnetic fields[70].

The majority of the European citizens (58%) do not consider national public authorities to be efficient enough in protecting them from potential health risks linked to EMF. 48% of the respondents would like the European Union to inform them on the

[71] EC 2008, Second Implementation Report 2002-2007 on the Application of the Council Recommendation (1999/519/EC) on the limitation of the exposure of the general public to electromagnetic fields. www.ec.europa.eu/health/ph_risk/documents/risk_rd03_en.pdf [accessed 11/03/2010]

potential health risks of EMF. Respondents think that the EU should develop standards for products (39%) and guidance to protect public health (36%)[70].

The reliability of scientific experts is also sometimes debated, as in the case of Sweden, where many people are worried and suspect that the opinions of experts and scientists should not be trusted, that they are either scientifically unjustified or that experts are paid by industry to say what they say[72].

Interestingly, in the Swedish population, personal risks (the risks people pose to themselves) are typically considered to be smaller than general risks (risks posed to others) for both mobile phones and transmission lines. This shows that people believe they can protect themselves against EMF but they do not believe that others can or want to protect themselves to the same extent (Figure 3-1).

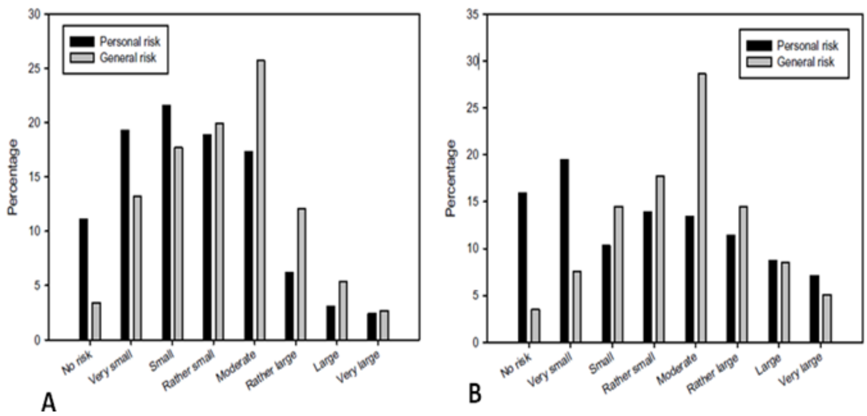

Figure 3-1 : Distribution of risk ratings for mobile telephones (A) and transmission lines (B)[72]

3.2. CURRENT EU APPROACH

In the early 1990s, the knowledge of health effects at very high levels of exposure coupled with the fast development of wireless technologies, prompted policy makers to develop a precautionary framework for electromagnetic fields. Remaining uncertainties regarding the health effects of EMF also led to financing scientific research on the subject. However, this has failed to reduce citizen concern about exposure to EMF.

[72] JRC/EMF-NET. Electromagnetic Field Exposure: Risk Communication in the context of Uncertainty, Pages 35-44: Sjöberg L. EMF Hazards and Principles of Risk Perception. www.web.jrc.ec.europa.eu/emf-net/doc/pubblications/Book_Risk%20communication.pdf [accessed 11/03/2010]

3.2.1. EU Policy and legal framework

3.2.1.1 EU regulatory framework

The general framework for EU legislation on products and devices emitting EMF is provided by the **Council Recommendation 1999/519/EC**[73]. The Recommendation fixes restrictions and reference levels for the exposure of the general public to EMF, based on the best available scientific evidence, and provides a basis for monitoring the situation. These restrictions and reference levels are based on the International Commission on Non Ionising Radiation Protection (ICNIRP) guidelines[74] and include a safety factor of 50 for the general public, resulting from the application of a factor 5, corresponding to the reduction of public exposure values compared to those applicable to occupational exposure, and a factor of 10 to cover variations of sensitivity and exposure conditions in the whole frequency range.

The Recommendation incites Member States to promote research into the possible health impacts of EMF, to review regularly the exposure limits in the light of new research results and to keep the public informed of the risks and the measures being taken to address them[69]. In 2000, through a questionnaire, all Member States notified the Commission of having implemented the provisions of the Council Recommendation. In 2009 a new questionnaire was sent to the 27 Member States to update the report of the implementation of the Recommendation[9].

The framework proposed by the recommendation was used to develop EU legislation and safety requirements that are necessary for all products emitting EMF. As a result, harmonised framework is in place in the EU to limit EMF exposure.

3.2.1.2 EU legal instruments

Directive 2004/40/EC on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (EMF), defines thresholds to protect all workers from adverse effects of EMF with frequencies from 0 Hz to 300 GHz. The exposure limits are expressed in terms of intensity of current flowing through the human body and set to protect against acute effects of exposure in the nervous system. Nevertheless this Directive does not consider the use of EMF in medicine and particularly in MRI whereas the static field, the gradient field, and the RF field are encompassed in the Directive. Within the limits set by the Directive, doctors and nurses who are close to the MRI while scanning is taking place are exposed at levels substantially above the exposure limits. The consequence of this Directive is to make it illegal for any worker to work in close proximity to MRI. However there is absolutely no evidence that the exposure to EMF from an MRI system is more dangerous for patients than the x-rays that are scattered from a scanner thus the

[73] Council recommendation of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz)

[74] International Commission on Non-Ionizing Radiation Protection. ICNIRP Guidelines, Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz). 1998

efficiency, benefits to patients and risks to patients and staff of MRI must be considered to define exposure limits. Therefore, in most EU Member States, scientific institutions and societies in the field of imaging and health have requested a postponement of the implementation of the Directive into national law, originally forecasted for 2008 and deferred until 2012, as well as an amendment of this Directive to take into account the characteristics and benefits of MRI[75].

Directive 1999/5/EC[76] on radio equipment and telecommunications terminal equipment (R&TTE) and the mutual recognition of their conformity, defines the rules for the placing on the market and putting into service of Radio and Telecommunications Terminal Equipment. It ensures free movement of radio equipment and terminals, guarantees they are safe and do not disturb existing radio services or other equipment, and protects from the health effects of radio waves.

This Directive attempts to introduce innovative products on the market and thus induces a sustainable competitiveness of the EU radio and telecommunications industries.

Directive 2006/95/EC[77] is focused on the harmonisation of the laws of Member States relating to electrical equipment designed for use within certain voltage limits. This Directive, also called the Low Voltage Directive (LVD), defines a conformity assessment procedure for the EMF emissions of products before placing them on the market, and defines Essential Health and Safety Requirements which such equipment must meet, either directly or by means of harmonised standards. **Directive 2004/108/EC**[78] is focused on the Member States' implementation of the rules on electromagnetic compatibility (EMC). The EMC Directive limits electromagnetic emissions of equipment in order to ensure that such equipment does not disturb radio and telecommunication as well as other equipment and reciprocally the Directive also governs the immunity of such equipment to interference and seeks to ensure that this equipment is not disturbed by radio emissions[79]. The EMC Directive does not regulate the safety of equipment in respect of people, domestic animals or property but is only concerned with the electromagnetic compatibility of equipment.

[75] Hill DLG., Mcleish K., Keevil SF. Impact of Electromagnetic Field Exposure Limits in Europe: Is the Future of Interventional MRI Safe? Acad Radiol. 2005; 12(9): 1135-1142

[76] Directive 1999/5/EC of the European Parliament and of the Council of 9 March 1999 on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity

[77] Directive 2006/95/EC of the European Parliament and of the Council of 12 December 2006 on the harmonisation of the laws of Member States relating to electrical equipment designed for use within certain voltage limits

[78] Directive 2004/108/EC of the European Parliament and of the Council of 15 December 2004 on the approximation of the laws of the Member States relating to electromagnetic compatibility and repealing Directive 89/336/EEC

[79] EC – Enterprise and Industry – Electrical Engineering. Electromagnetic Compatibility (EMC): ec.europa.eu/enterprise/sectors/electrical/emc/index_en.htm [Accessed online 08/03/2010]

3.2.1.3 Policy actions

In June 2003, the Commission adopted the **European Environment & Health Strategy** to reduce the disease burden caused by environmental factors in the EU, to identify and to prevent new health threats caused by these environmental factors and to strengthen EU capacity for policymaking in this area[80]. In June 2004 the Strategy was followed up by the **European Environment and Health Action Plan[81]**, covering the period of 2004-2010, which includes action on exposure to EMF and was based on extensive consultations with experts and stakeholders from the environment, health and research sectors. The aims are to improve the information chain and the cooperation between actors in the environment, health and research fields, to fill the knowledge gap by strengthening research on environment and health and identifying emerging issues, to review risk reduction policies[71].

The European Parliament resolution of 2 April 2009[82] on health concerns associated with electromagnetic fields (2008/2211(INI) supports the consideration of biological effects and the review of the scientific basis and adequacy of the EMF limits of the Recommendation 1999/519/EC. The aim of this is to reduce the exposure levels to EMF.

3.2.1.4 EU technical standards

In order to conform to the EU legislation on EMF, several standards have been established to demonstrate compliance with the EU EMF emission requirements and to specify limits of exposure and test and measurement methodologies (Table 3-3). Standards cover the whole spectrum of EMF frequencies and limit both the exposure of the general public and workers. Some of these standards fall under the Directives mentioned above on radio and telecoms equipment (Directive 1999/5) and the Low Voltage Directive (2006/95).

Harmonised standards play an important role in the operation of the corresponding Directive. Products, which are conformed to harmonised standards, are presumed to comply with the corresponding Directive. When manufacturers do not use harmonised standards, they should demonstrate how they respect the essential requirements of the associated Directive[83].

[80] European Commission – Environment: ec.europa.eu/environment/health/index_en.htm [Accessed online 12/10/2010]

[81] Document available at : www.eu-humanbiomonitoring.org/doc/actionplan.pdf [Accessed online 12/10/2010]

[82] European Parliament resolution of 2 April 2009 on health concerns associated with electromagnetic fields (2008/2211(INI))

[83] EC, Enterprise and industry - Radio and telecommunications terminal equipment. Harmonised standards under Directive 1999/5/EC: ec.europa.eu/enterprise/sectors/rtte/documents/standards/index_en.htm [Accessed online 09/03/2010]

Table 3-3: European standards relating to EMF requirements[85]

European standard	Specifications
EN 50366:2003	Household and Similar Electrical Appliances—Electromagnetic Fields—Methods for Evaluation and Measurement; limits the electromagnetic fields produced by electrical household appliances in order to protect human beings, animals and plants. This standard is listed under the LVD Directive.
EN 50360:2001	Product Standard to Demonstrate the Compliance of Mobile Phones with the Basic Restrictions Related to Human Exposure to Electromagnetic Fields (300 MHz–3 GHz). This standard has been in force under the R&TTE Directive.
EN 50371:2002	Generic Standard to Demonstrate the Compliance of Low-Power Electronic and Electrical Apparatus with the Basic Restrictions Related to Human Exposure to Electromagnetic Fields (10 MHz–300 GHz). This standard is listed under both the LVD and the R&TTE Directive.
EN 50364: 2001	Limitation of Human Exposure to Electromagnetic Fields from Devices Operating in the Frequency Range 0 Hz–10 GHz, Used in Electronic Article Surveillance (EAS), Radio-Frequency Identification (RFID), and Similar Applications. This standard appears under the LVD and under the R&TTE Directive.
EN 50385:2002.	Product Standard to Demonstrate the Compliance of Radio Base Stations and Fixed Terminal Stations for Wireless Telecommunication Systems with the Basic Restrictions or the Reference Levels Related to Human Exposure to Radio-Frequency Electromagnetic Fields (110 MHz–40 GHz). This standard is listed only under the R&TTE Directive.
EN 50444:2008	Basic standard for the evaluation of human exposure to electromagnetic fields from equipment for arc welding and allied processes. This standard is listed under the R&TTE Directive.
EN 50401:2006	Product standard to demonstrate the compliance of fixed equipment for radio transmission (110 MHz - 40 GHz) intended for use in wireless telecommunication networks with the basic restrictions or the reference levels related to general public exposure to radio frequency electromagnetic fields, when put into service. This standard is listed under the R&TTE Directive.

However, innovative products tend to employ new RF transmitter technologies, which often mean a lag in the development of appropriate standards and measurement techniques. For example, there are still no published standards for measurement methods of the absorption rate of EMF by the body to be used on 5.2–5.8 GHz cordless phones and wireless devices used in close proximity to the human body. IEC 66209-2 is under development and is expected to fill this gap when published[85].

3.2.1.5 Merits and limitations of the current EU regulatory framework

With regards to the basic restrictions and reference levels, Council Recommendation 1999/519/EC ensures that the public is protected against both acute and long-term effects of EMF. Basic restrictions of the Recommendation include a large safety factor (50) which takes into account potentially more fragile members of the population, such as children, pregnant women, elderly and sick people[84]. Moreover as required by the Council Recommendation, the Commission has to review continuously the validity of the proposed limits, which it does periodically through the SCENIHR. Thus ongoing research is taken into account in the elaboration of exposure limits and the framework proposed by the Recommendation is still valid.

The European legislation on EMF, including the R&TTE Directive and the LVD, requires producers and distributors to put safe products on the market and into service. These Directives mandate essential requirements for the protection of the health and safety of users and the general public. The LVD requires that users of household electrical equipment be protected from the possible harmful effects of EMF that may arise from RF transmitters or from the EMF associated with high currents and ferromagnetic applications[85]. European manufacturers of electrical and electronic equipment agree to comply voluntarily with the EMF exposure limits set in the Council Recommendation 1999/519 for all their devices[86].

Directive 2004/40/EC defines 10 kV/m as the highest value of an electric field in a 50 Hz occupational environment. However, in the ICNIRP guidelines this limit is doubled when workers are not in contact with electrical grounds because the limit here is based on avoiding spark discharges rather than induced current intensity limit. Therefore, the threshold of the Directive is very low and the compliance with the limits of Directive 2004/40/EC for the intensity of induced currents seems impossible to test in every workplace because of the time and budget needed[87].

In addition, the basic problems related to calculating workers' exposure levels are related to defining realistic representations of the workers' postures; of the electrical grounding conditions at the workplace; of realistic impedance of near-field produced by, e.g., electro-surgery or welding devices; and of dynamic changes in EMF levels in the course of application. Proper calculations in assessing exposure require advanced skills, specialised software, and can be both very time-consuming and expensive. Validation and verification of the skills of personnel who carry out the calculations are also necessary[87].

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[84] Lambrozo J., Souques M., Magne I. Champs magnétiques de très basses fréquences 50-60 Hz : quelles valeurs limites d'exposition retenir ? Environnement, Risques & Santé. 2008, 7(3) :181-189

[85] Zombolas, C. Functional Safety: Understanding the New EMF and EMC Requirements. Available at: www.ce-mag.com/archive/06/ARG/zombolas.htm [Accessed online 08/03/2010]

[86] Orgalime European approach to the protection of public health applied to the exposure of the general public to electromagnetic fields (EMF) – Orgalime position paper. 04/10/2000

[87] Mild KH., Alanko T., Decat G., *et al.* Exposure of Workers to Electromagnetic Fields. A review of open questions on exposure assessment techniques. International Journal of Occupational Safety and Ergonomics (JOSE) 2009, 15(1): 3–33

The precautionary principle (PP) is a tool for policy-makers to manage risks in the case of scientific uncertainties about the existence or magnitude of a risk. The PP is adopted into European policy actions on EMF only through exposure standards, regular review of safety recommendations, support of the research to consider possible health effects of EMF, etc[88] so that policy makers are not forced into critical decisions on human health protection in cases where scientific evidence is insufficient but perception of risk is strong[89]. The PP can be used in risk management to anticipate, prevent harm, and to react before the risk is established[88]. Therefore, three components are included in the PP: hazards, uncertainties concerning the hazards, and the possibility to act[88].

In the context of EMF, two approaches are possible in which the level of scientific evidence needed to trigger protective actions is not the same. On the one hand, policy makers can consider that no health hazard has been established, thus the application additional precautionary actions is not justified[88]. In fact, the Council Recommendation can already be interpreted as consistent with the Precautionary Principle, since they contain a significant level of precaution based on the current knowledge, i.e. a safety factor of 50.

On the other hand, as uncertainties exist, in addition to the application of Council Recommendations, further precautionary actions can be taken[88]. In both cases, ethical considerations and value judgments of policy-makers play a role[90]. Additional precautionary actions can be taken only in dichotomous situations, or see as the implementation of a basic principle which can be applied in every policy action[90].

Table 3-4 compares the consideration of different criteria (PP, subpopulations, etc.) in the main policy actions.

Table 3-4 : Comparative table of the main policy actions

Criteria	Recommendation 1999/519	Directive 2004/40	Directive 1999/5	Directive 2006/95	Directive 2004/108
Risk reduction	Yes	Yes	Yes	Yes	No
Consideration of subpopulations	Yes	All workers without others subgroups	No	No	No
Respect to the precautionary principle	Yes	Yes	Yes	Yes	Not relevant
Response to a public concern	Yes	Yes	Yes	Yes	No

[88] Dolan M., Rowley J. The precautionary principle in the context of mobile phone and base station radiofrequency exposures. Environmental Health Perspectives. 2009;117 (9):1329-1332

[89] Rapporteur report - Application of the Precautionary Principle to Electromagnetic Fields (EMF) – Conference of 24-26 February 2003 in Luxembourg: www.who.int/peh-emf/meetings/en/Lux_final_rapp_report.pdf

[90] Kundi M., Hardell L., Sage C., *et al.* Electromagnetic fields and the precautionary principle. Environ Health Perspect. 2009; 117(11): A484–A485

As seen in Table 3-4, almost all the policy actions take into account the precautionary principle except Directive 2004/108, which is a technical regulation on the electromagnetic compatibility of equipment that does not concern human health.

3.2.2. Scientific actions

Different types of scientific action (research projects, scientific committees, scientific projects, workshops and conferences), each having different objectives, have been performed at the European level.

3.2.2.1 Research projects

The main EU research projects include:

COST (European Cooperation in the Field of Scientific and Technical Research) is a framework for international research and development cooperation, allowing the coordination of national research at European level but not providing funding. Different actions are conducted and the more recent project is COST BM0704 (2008-2012) which allows a better understanding of health impacts of EMF, of new characteristics of emerging technologies and of the tools of risks communication and management[91].

The Interphone Study (1999-2005) was a case control study assessing whether RF exposure from mobile telephones is associated with an increased risk of brain tumours, acoustic neurinoma and parotid gland tumours in relation to RF exposure. The study is funded by EU FP5, the International Agency for Research on Cancer (IARC) and nine EU Member States[68].

The Reflex project (2000-2004) studied *in vitro* the impact of ELF fields and RF on DNA and cells development. While results of Reflex project do not prove hazards from EMF, they indicate promising lines of investigation for further work[92].

The Cemfec project (2000-2004) looked at if EMF (particularly from mobile phones) increase the genotoxicity of known cancer-causing chemicals that can be found in drinking water in small amounts. The study found that RF did not enhance the development of cancer[93].

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[91] COST – European cooperation in science and technology website: www.cost.esf.org/ [Accessed online 19/03/2010]

[92] EU Research on Environment and Health – Results from projects funded by the Fifth Framework Program. The REFLEX Project: Risk evaluation of potential environmental hazards from low energy electromagnetic fields (emf) exposure using sensitive in vitro methods: ec.europa.eu/research/environment/pdf/env_health_projects/electromagnetic_fields/e-reflex.pdf

[93] CEMFEC - Combined Effects of Electromagnetic Fields with Environmental Carcinogens website: www.uku.fi/cemfec/ [Accessed online 12/03/2010]

The Ramp 2001 project (2002-2005) studied the possible biological effects of RF on brain and nerve cells to identify the molecular mechanisms through which the nervous system could be impaired by EMF[94].

The Guard project (2002-2004) assessed potential effects in auditory function as a consequence of long-term exposure to RF produced by GSM cellular phones, performing studies on both animal models and humans[95].

The Perform-A project (2000-2005) led by the Fraunhofer Institute for Applied Science from Germany used *in vivo* experiments to determine if mobile phones frequency cause cancer or promote the spread of pre-existing tumours[68]**.**
Research on potential health effects induced by EMF has been proposed by the Commission to continue in the **Seventh Framework Programme** (FP7) that will run from 2007 to 2013[96]. This include **MOBIKIDS (2009-2014)** which is a collaborative project under EU FP7 that aims to assess the potential carcinogenic effects of childhood and adolescent exposure to RF from mobile phones on the central nervous system, in particular brain tumours[97].

3.2.2.2 Scientific advice

Scientific advice to policy makers can be provided through scientific committees and scientific projects.

Scientific Committees review periodically the evidence on the health effects on EMF. The **Scientific Committee for Emerging and Newly Identified Health Risks (SCENIHR)** was created to provide opinions on questions concerning emerging or newly identified health and environmental risks. One of the goals is to periodically review the available scientific evidence on the potential health effects of EMF to ensure that the Recommendation 1999/519/EC is based on the most up-to-date knowledge, concerning the possible effects of EMF and the exposure limits[98]. The Commission uses scientific knowledge to revise basic restrictions and reference levels. In addition, the SCENIHR identified gaps in the relevant scientific knowledge and priority areas where further research is needed, indicating to Member States and the Commission which areas should be prioritised for financing through the Framework Programme (FP)[9].

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[94] EU Research on Environment and Health – Results from projects funded by the Fifth Framework Program. The Ramp 2001 Project: Risk assessment for exposure of nervous system cells to mobile telephone EMF: from in vitro to in vivo studies: ec.europa.eu/research/environment/pdf/env_health_projects/electromagnetic_fields/e-ramp2001.pdf [Accessed online 12/03/2010]

[95] Guard website – potential adverse effects of GSM cellular phones on hearing 2002-2004: www.guard.polimi.it/home/home.html [Accessed online 12/03/2010]

[96] European Commission – Research - What is FP7? The basics: ec.europa.eu/research/fp7/understanding/fp7inbrief/what-is_en.html [Accessed online 12/03/2010]

[97] European Commission – Research – Environment - MOBI-KIDS: a follow-up study to the INTERPHONE study to be launched by the EU: ec.europa.eu/research/environment/newsanddoc/article_4090_en.htm [Accessed online 12/03/2010]

[98] Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR). Health Effects of Exposure to EMF. 2009

Before the SCHENIHR and with the same objectives, the **Scientific Committee on Toxicity, Ecotoxicity and the Environment Translations (CSTEE)** reviewed in 2001 the possible effects of EMF, RF and microwave radiation on human health.

In addition, the European Commission finances many scientific projects to improve knowledge on health impacts of EMF and risk management. EU scientific projects in the area of EMF have been strongly focused on the potential link between health effects and EMF exposure, with a particular attention to RF fields caused by mobile phones. Examples of EU financed scientific studies include:

- **EMF-NET (FP6) (2002-2006):** is a large coordinated action financed under the 6th Framework programme that aims to collect and evaluate the results on EMF health effects, considering also the potential risks related to occupational exposure and to set appropriate safety standards. The majority of these research projects focus on EMF from mobile telephones and are cancer-related, and a smaller number investigate possible effects on hearing, memory and behaviour[99]. EMF-NET provides advice to the European Commission on new research results and their relevance to public health and safety issues and contributes to information activities for the general public.
  Since 2004, EMF-NET have organised nearly 30 events (workshops, meetings, round tables, seminars, etc.) on health effects of EMF, potential sensitive sub-groups of population and exposure levels.
- **EFRHAN (2009-2012)**: follows EMF-NET and will establish a network to allow the health risk assessment of EMF exposure. This project uses the risk analysis of EMF-NET and will provide information for risk management of EMF[100].

3.2.2.3 Workshops and conferences

Workshops of experts are established to improve the exchange of information and identify ways of improving coordination and cooperation between Member States. In September 2005 for example, a workshop organised by the Central Institute for Labour Protection – National Research Institute (CIOP-PIB) took place in Poland, where the aim was the review of knowledge related to EMF hazards from occupational exposure and methods of electromagnetic risk evaluation and reduction[101]. Certain workshops are organised to review EMF guidelines, for instance in 2007 in the ICNIRP International EMF Dosimetry Workshop, scientists assessed the existing guidelines and highlighted weaknesses of European regulation[102]. Every two years, an international workshop on biological effects of EMF is organised; the last (the 5th) took place in 2008 in Sicily where researchers, engineers, public authorities, ecologists, public health workers, industrials, etc. share their information on EMF and discussed about research,

[99] EMF-NET website: web.jrc.ec.europa.eu/emf-net/ [Accessed online 10/03/2010]
[100] EFHRAN - European health risk assessment network on EMF exposure website: efhran.polimi.it/ [Accessed online 19/03/2010]
[101] CIOP-PIB website: www.ciop.pl/10522.html [Accessed online 19/03/2010]
[102] Roy CR. Rapporteur report : Icnirp international workshop on EMF dosimetry and biophysical aspects relevant to setting exposure guidelines. Health physics. 2007;92(6):658-667

experimental results, modelling and simulation, policy, safety and standardisation, etc[103].

In 2009, the organisation of an **international scientific conference** on EMF and health was proposed to discuss the remaining questions and to lead to a strengthened scientific consensus on future actions[108]. Some conferences have already been organised, such as the International Conference on Electromagnetic Fields, Health and Environment (EHE'09) where medical and technical researchers and authorities of the WHO and the ICNIRP brought together to discuss about the impact of EMF on health and environment[104].

Table 3-5 shows a summary of scientific European actions. This analysis will take into consideration the usefulness of the scientific framework for policy makers.

[103] 5th International Workshop on Biological Effects of Electromagnetic Fields website: xoomer.virgilio.it/5internatwshopbioeffemf/ [Accessed online 19/03/2010]

[104] Abricem - International Conference on Electromagnetic Fields, Health and Environment – EHE: www.abricem2.com.br/web3/index.php?option=com_content&view=article&id=46&Itemid=292 [Accessed online 19/03/2010]

Table 3-5 : Comparative tables of scientific European actions

Scientific initiative	Type of data	Publications	Collaborations	Communication to the general public (examples)	Interest for the policy makers	Contribution to an higher protection level
RESEARCH PROJECTS						
COST BM 0704	*In vitro, in vivo,* epidemiological studies (EMF in general)	5 workshops scheduled 40 reports 2 publications of action members on specialised journals	27 countries	Newsletter available on the project website: www.cost-bm0704.eu/ (section Publications – Action Newsletter)	One objective is to provide a scientific evaluation of the available data for decision makers involved in risk management of EMF	Exposure levels of people are quantified but the main objective of this project is the sharing of knowledge on health effects
MOBIKIDS	Epidemiological study (communication technologies [RF])	Not yet available	18 scientific partners	1 article in press	This study will provide scientific support for the decisions of public health policy	Protection of adolescents
Interphone Study	Epidemiological study (RF)	22 publications in specialised journals	8 countries involved	Many medias	Conclusions concerning mobile telephones could be used in regulations	The occurrence of cancers of the head and neck was monitored.
Reflex project	*In vitro* studies (ELF, RF)	Not found	12 partners	Not found	The results will have to be complemented by whole animal studies before the results are used by policy makers	The overall aim was to find the biological processes at cellular and molecular level to explain health effects, human exposure has not been studied.

Scientific initiative	Type of data	Publications	Collaborations	Communication to the general public (examples)	Interest for the policy makers	Contribution to an higher protection level
CEMFEC	*In vivo* and *in vitro* studies	Two publications in specialised journals	5 partners from universities and research institutes	Not found	Results used by international bodies such as the IARC and the WHO for the health risk assessment of RF.	These evaluations formed the scientific basis for possible revisions of RF exposure limits to reduce harmful effects[105].
Ramp 2001 project[106]	*In vivo* and *in vitro* studies (RF)	Not found	Not found	Not found	The results provided research support for EU public health policies Some of the experimental protocols developed could be adopted by national health care services as reference methods for assessing biological susceptibility to RF exposure and potential health risks	The results were used to evaluate the effects of the exposure

[105] EU Research on Environment and Health – Results from projects funded by the Fifth Framework Program. The CEMFEC Project: Combined effects of electromagnetic fields with environmental carcinogens: ec.europa.eu/research/environment/pdf/env_health_projects/electromagnetic_fields/e-cemfec.pdf
[106] The site of Ramp 2001 project (www.rampproject.org/) is being updated. The analysis of this project will complete later

Scientific initiative	Type of data	Publications	Collaborations	Communication to the general public (examples)	Interest for the policy makers	Contribution to an higher protection level
Guard project	*In vivo* and *in vitro* studies (RF)	10 publications in specialised journals, participation in 2 international conferences and 2 congress	9 participants	1 article in Italian press found	Provide the evidence base for the development of environmental and health European policy measures	This project was established under the 5th framework programme entitled "Quality of life and management of living resources, key action 4: environmental and health"
Perform-A project	*In vivo* studies (RF)	Not found	6 partners	Not found	The results help the IARC to determine if long-term exposure to high-frequency EMF present a carcinogenic risk	For long term exposure
SCIENTIFIC COMMITTEES						
SCENHIR	Review of knowledge of static fields, ELF, IF and RF using *in vivo*, *in vitro*, epidemiological studies	Reports in 2007 and 2009	9 persons in the working group: 3 members of the Scenhir and 6 scientific experts coming from 6 countries	Not found	Policy makers use Scenhir's reports to prepare policy concerning consumer safety, public health and environment	Results are used to review basic restrictions and reference levels
CSTEE	Review of knowledge of EMF, RF and microwaves using *in vivo*, *in vitro*, epidemiological studies	Report in 2001	10 persons in the working group: 3 members of the CSTEE, 4 external experts and 3 Members of other scientific committees of the Commission (SCP and SCC)	Not found	Policy makers use the conclusions of the CSTEE to adapt the regulations.	Results are used to evaluate if the revision of the exposure limits (basic restrictions and reference levels) of Council Recommendation 1999/519/EC are necessary.

Scientific initiative	Type of data	Publications	Collaborations	Communication to the general public (examples)	Interest for the policy makers	Contribution to an higher protection level
SCIENTIFIC PROJECTS						
EMF-NET	Experimental studies (ELF, IF, RF, interaction mechanisms and medical applications) and epidemiological studies	About 40 reports on new studies on biological effects, mechanics of action, epidemiological studies, health policy and management. 3 books of JRC or WHO, The 3 publications in RTD info – Magazine for European research	- Coordinators of research projects (Finland, France, Germany, Greece, Hungary, Italy, UK), - Representatives of COST ACTION 281 and of the WHO EMF project, - Associations of Indus-tries and manufactures, of scientific and regulatory bodies	9 articles in Italian press, 1 in Swedish press and 1 in Slovenian press	One aim of the project is to provide for the European Commission and other bodies, the appropriate information for the facilitation of policy development options	The results are used to define appropriate safety standards
EFRHAN	*In vitro*, *in vivo*, and epidemiological studies (on EMF in general)	Not yet available	22 participants (institutes of research, universities, associations)	Not found	Efrhan will provide a health risk assessment procedure helping policy makers to react quickly if there is a problem with EMF	The main aim is to monitor and assess the health risks associated with EMF exposure
WORKSHOPS AND CONFERENCES						
Workshops of experts	Not relevant	Reports of workshops	In the workshop organised by CIOP-PIB: 150 participants from 18 countries but in other workshops the number of participants can be limited and invitations can be sent	Can be high: depend on the audience, if public associations or journalists are present, etc.	The improve of the debate and public concerns can be useful for policy makers	In most cases the subject of workshops is health effects and exposure of EMF thus conclusions are used in regulations to protect the public
Conferences	Not relevant	Minute of the conferences and articles of speakers	Several new scientific collaborations are facilitated by this kind of meetings	Depend on the audience, if public associations or journalists are present, etc. and if the access if free	If policy makers are present, in general limited to scientists	Possible: depending of the participants and the subject of the conference (public exposure or not)

3.2.3. Science-policy interface

The management of this interface is particularly important in the case of public health issues which are not completely understood by scientists. A number of gaps in the scientific knowledge on EMF remain and Policy makers have to take decisions in situations of uncertainty. However policy actions are not based only on scientific evidence but they also take into account the social and cultural context. Consequently, essential tools to support decision-making, such as risk assessment, may not be sufficient[107].

The importance of the science-policy interface for instance can be measured in relation to public perception, in the case of mobile phone base stations. Despite the several scientific assessments which consider that the current exposure to RF does not seem to be dangerous, demands to revise exposure limits regularly occur. In the case of mobile phones base stations the number of operator authorisations is then restricted by the law due to public pressure on policy makers. Nevertheless, it has to be considered that the decrease of exposure limits is difficult to implement because decreasing the power of such installations would mean that additional base stations would be needed as compensation. In addition, when the power of base stations is lower, the power of mobile phones needed to establish connection is higher[108]. This contradiction can be effectively resolved by science-policy interfaces.

Interactions with all the relevant stakeholders and the development of a properly functioning science-policy interface are thus necessary (Table 3-6[109]).

Table 3-6 : Six potential ways of organising the science-policy interface[109]

Policy and science are diverging/ converging	Primacy of science	No primacy/dialogue	Primacy of policy
Diverging	Science delivers ideas	Science delivers arguments	Science delivers data
Converging	Technocracy model (scientists have political power and technical knowledge)	Policy oriented learning model (societal debate)	Engineering model (contract research, social technology)

In several of the European sources of scientific advice quoted above (Scenihr, EMF-NET, COST 281, etc.), a large EU network of scientists and experts reviews and evaluates the emerging scientific evidence on possible health impacts from human exposure to EMF. They provide policy relevant interpretation and advice for the development of policy regulations. For example, EMF-NET compiled and analysed in a

107 Martuzzi M. Science, policy, and the protection of human health: A European perspective. Bioelectromagnetics. 2005;26(7):151-156

108 Bontoux L., Bromen K. Controlled exposure. Public Service Review: European Union - Medical science and research incorporating biotechnology, Issue 18. 2009

109 Riskbridge (Coordination Action on Building Robust, Integrative inter-Disciplinary Governance models for Emerging and Existing risks). Final report, 2009

consistent way results of research projects to provide information, assistance and answers to regulatory bodies and industries. In addition, it supports the development of international standards for EMF exposure and provides reliable information about EMF effects, in order to support decision-making by health, environmental and other authorities[110]. Moreover, a specific project finalised in 2005, entitled EIS-EMF, was developed to adapt the EMF-NET issues into risk communication for policy makers and the public, and built a network of EU policy makers on EMF issues[111].

In June 2003, the Commission adopted the European Environment & Health Strategy, to reduce the disease burden caused by environmental factors in the EU, to identify and to prevent new health threats caused by these environmental factors and to strengthen EU capacity for policymaking in this area[112]. In June 2004 the Strategy was followed up by the European Environment and Health Action Plan, covering the period of 2004-2010, which includes action on EMF and was prepared through extensive consultations with experts and stakeholders from the environment, health and research sectors. This Plan gives the EU scientific information to reduce the adverse health impacts of certain environmental factors and to endorse better cooperation between actors in the environment, health and research fields. The aims are to improve the information chain, to fill the knowledge gap by strengthening research on environment and health and identifying emerging issues, to review risk reduction policies[71]. For 2007-2010, workshops on targeted environment and health issues will be organised to highlight the research results and to identify research needs for proposals to be implemented in Community Programs.

The Strategy and the Action Plan have underlined the integration of human health concerns into environmental policies and have highlighted the need for a coordinated approach between scientists and policy makers.

The Commission has planned to continue to integrate environment and health concerns and to involve many different actors in the policies. In order to strengthen EU capacity for policymaking, the Commission will use the outcomes of research projects and their translation into policy. However, the science-policy interface should be improved by facilitating the transfer of research results to policy makers.

The science-policy interfaces promote exchange of knowledge between scientists and policy makers and allow inter-disciplinary links. These interfaces can involve debates about assumptions, choices and uncertainties, and about the limits of scientific knowledge. They are tools for decision makers to understand the issues, exploring

[110] EC, Research – Scientific Support for Policy. Environment and health - Healthy citizens in healthy surrounding, EMF-NET - Are electromagnetic fields hazardous to health?: ec.europa.eu/research/fp6/ssp/emf_net_en.htm [Accessed online 09/03/2010]

[111] European Commission, Joint Research Center website, European Information System on Electromagnetic Fields Exposure and Health Impacts: web.jrc.ec.europa.eu/eis-emf/home.cfm [Accessed online 01/03/2010]

[112] European Commission – Environment: ec.europa.eu/environment/health/index_en.htm [Accessed online 12/10/2010]

options for political action, and develop justifications. Moreover with these processes, research priorities are suggested.

3.3. INITIATIVES IN MEMBER STATES

Regarding policy activities on the limitation of the exposure of the general public to electromagnetic fields in the MS, the chosen approaches vary. Each MS is responsible for providing adequate health protection for its citizens, and is free to decide how to do so[113].

The main objective of this section is to describe the differences in national actions taken in the period 2004-2009, existing across European countries, at the policy, scientific and science-policy interface level. Monitoring and research are important complementary scientific tools for the implementation and the definition of policy action. The different scientific approaches and their interface with policy are discussed in section 3.3.2. and section 3.3.3.

3.3.1. POLICY ACTIONS

In this section, national actions following implementation of the EU Policy actions or being a national initiative have been reviewed for a number of MS. Most MS have adhered to the EU recommendations while others have developed stricter legislation, mandatory or voluntary recommendations. The exposure thresholds may cover the whole, or parts of, the range from 0 Hz to 300 GHz. Such thresholds may be issued by one or several authorities/bodies such as the Building and Planning Board, National health Board, a Radiation Protection Institute or others, depending on the applications considered. The measures taken nationally to monitor exposure and carry out research of exposure may vary widely, and be driven by different interests such as public and political debate, national business interests or available funding.

The exposure limits can differ by factors of 10 or more, depending on the frequency range and the exposed public (workers, general public)[114]. Among the factors that contribute to the differences between countries are the selection and interpretation of data, the reasons for which standards have been set, and the socio-political context which may influence the level of application of precautionary principle. For example, many Eastern European (EE) countries have traditionally taken into account the possible, though still uncertain, long-term effects of low-level EMF exposures when setting standards. Thus, current EMF standards in EE countries (Bulgaria, Poland,

[113]European Commission website www.ec.europa.eu/health/electromagnetic_fields/role_eu_ms/index_en.htm [Accessed online 03/03/2010]

[114] Worldwide standards on exposure to electromagnetic fields: an overview, Martino Grandolfo, Environmentalist (2009) 29:109–117 Published online: 26 February 2009, Springer Science + Business Media, LLC 2009

Romania, and Slovakia) as common elements[115] generally allow considerably lower exposure levels than Western Europe countries. For instance, they consider the time of exposure during the life-time, especially for occupational exposure (e.g. RF exposure). Moreover, the concept of frequency dependent absorption is generally[116] not implemented[117].

Finnish authorities have used the precautionary principle in a different way, giving advice directed to parents about the use of mobile phones by their children, and German authorities, similarly, have published advice on the precautionary principle for mobile phone use[118], but without specifying age groups.

In 2008, with an overview[119] on how Member States have implemented the Council Recommendation (1999/519/EC), the Commission has reported the way basic restrictions and national reference levels are applied in the MS. While few countries implemented basic restrictions stricter than the Recommendation (Belgium and Greece, though not in the whole frequency range), the majority had implemented measures at the same level as the guidelines given in the Recommendation, and some had an implementation level that was less strict than in the Recommendation.

Regarding national reference levels, the majority of the MS comply with the reference values specified in the Recommendation, sometimes providing additional guidelines and promoting initiatives for further monitoring or research, or information to the public. Six MS have implemented reference levels that are stricter than in the Recommendation for the whole frequency range: Bulgaria, Italy, Lithuania, Luxemburg, Poland, and Slovenia. Like these MS, Switzerland also applied stricter levels. A few MS have implemented stricter recommendations only for specific intervals of the frequency range, namely Greece (stricter for RF, IF), Belgium (stricter for RF) and the Netherlands (stricter for ELF)[120]. The actions taken during the studied period of time are of course also dependant on the pre-existing guidelines, monitoring and information programmes before 2004. Germany, for instance, had developed a detailed and restrictive legislation on exposure to EMF since 1997. Bulgaria has, until

[115] Gajsˇek P, Pakhomov AG, Klauenberg BJ (2002) Electromagnetic field standards in central and eastern european countries: current state and stipulations for international harmonization. Health Phys 82(4):473–483.

[116] Nikonova KV (1998) Status and implementation of russian hygienic radiofrequency standards. In: Repacholi MH, Robutsova NM, Muc AM (eds) Proceedings of the international meeting on biological effects and hygienic standardization, Moscow. World Health Organization, Geneva, pp 477–483.

[117] Worldwide standards on exposure to electromagnetic fields: an overview, Martino Grandolfo, Environmentalist (2009) 29:109–117 Published online: 26 February 2009, Springer Science + Business Media, LLC 2009

[118] Webpage for German The Federal Office for Radiation Protection www.bfs.de/en/elektro/hff/grenzwerte.htm, [Accessed online 08/03/2010]

[119] EC 2008, Second Implementation Report 2002-2007 on the Application of the Council Recommendation (1999/519/EC) on the limitation of the exposure of the general public to electromagnetic fields: www.ec.europa.eu/health/ph_risk/documents/risk_rd03_en.pdf [Accessed online 03/03/2010]

[120] EC 2008, Second Implementation Report 2002-2007 on the Application of the Council Recommendation (1999/519/EC) on the limitation of the exposure of the general public to electromagnetic fields: www.ec.europa.eu/health/ph_risk/documents/risk_rd03_en.pdf [Accessed online 03/03/2010]

2009, been developing new legislation on EMF and organising monitoring programmes at the national level.

The competent authorities in Sweden only recommend the precautionary principle to be applied for ELF from power lines and electric installations[121], while in Finland, due to the fact that the country is relatively sparsely populated, only a small percentage of the public is exposed to ELF fields from power lines, and the restrictions concerning the exposure to this class of fields are less strict[122].

In parallel, due to the fact that in Finland, mobile phones are of common use and that the mobile phone industry is highly developed, the main concern for both surveillance and recommendations between 2004 and 2009 was focused on RF, compared to other frequency ranges.

In Italy, measures have been focused on power plants and, similarly to Greece, on fixed telecommunication equipment. Both countries apply recommendations on land based antennas that are stricter than the guidelines given in the Council Recommendation.

In the following section several examples of national political approaches are presented. Apart from their geographical distribution, the chosen countries, namely Bulgaria, Greece and Finland could also in some respect represent countries with different socio-political contexts influencing the public perception to the EMF exposure issue (Table 3-7).

3.3.1.1 Bulgaria

In 2009, The Council Recommendation (1999/519/EC) was still under implementation[123] in Bulgaria. The ICNIRP Guidelines were accepted for the general population as minimal requirements. Lower limits were set in frequency ranges 0 Hz to 300 GHz for areas where people stay periodically or continuously and areas for sensitive groups (including children, pregnant women, elderly and ill people). Accordingly, higher limit values were set for zones where human exposure is rare or practically impossible due to their specific location.

The national database for sources of mobile communication technologies was in 2009 under development[123], partly on initiative of the Ministry of Health. The database is to provide information on technical characteristics, situation maps, safety zones and data from measurements.

[121] Report on EMF activities, 11th international Advisory Committee on EMF, June 2006, Kjell Hansson Mild, NIWL, Umea, Janez Marinko, SWEA, Solna, Lars Mjones, SSI, Stockholm ; Sweden. Available at: www.who.int/peh-emf/project/mapnatreps/Sweden_2006_EMF_activity_report.pdf [Accessed online 08/03/10]

[122] Webpage of STUK, Radiation and Nuclear Safety Authority Finland, facts on Power Lines: www.stuk.fi/sateilytietoa/sateilevat_laitteet/magneettikentat/en_GB/voimalinjat/ [Accessed online 09/03/10]

[123] Bulgarian National Program Committee (BNPC) International EMF Project REPORT, 14th International Advisory Committee Meeting WHO, Geneva, 11–12 June 2009, available at www.who.int/peh-emf/project/mapnatreps/BULGARIA_IAC_2009_report.pdf [Accessed online 08/03/10]

3.3.1.2 Greece

Greece implemented the EU Council Recommendation (1999/519/EC) in the year 2000 through a national legislative act. For ELF fields, the EU recommendations were followed, but stricter reference levels were set for public exposure to all kinds of land-based antenna stations in the IF and RF frequency range. The safety limits for the electromagnetic fields emitted by antenna stations, were set to 70% and to 60% of ICNIRP's values if the antenna station is closer than 300m from kindergartens, schools, hospitals or eldercare facilities. A ministerial act was published in March 2008, defining the technical aspects and all relevant details concerning the measurements, which should amount, on an annual basis, to at least 20% of all the antenna stations in urban areas[124].

In Greece, the national authority for the protection of the general public to artificially produced non-ionising radiation is the Atomic Energy Commission (EEAE). The authority, or other authorised laboratories, carries out measurements of all kinds of sources emitting RF electromagnetic fields, in order to monitor the compliance to the legislation. Over one and a half thousand audits have been performed till now. About 70% of the RF measurements concern cellular phone base stations (1200 stations). Measurements are also performed on request from the public. The results generally show levels from tens to thousands times below ICNIRP's reference levels. The cases where higher levels were observed regarded only powerful radio or TV broadcasting antennas[125].

3.3.1.3 Finland

The Finnish authorities comply with the guidance given by the EU Council Recommendation and the ICNIRP, but also give specific instructions for magnetic fields to be kept as low as reasonably possible in the areas where the general public, particularly children, may stay for a significant length of time. For the limitation of exposure to non-ionising radiation Finnish authorities, give, for instance, a maximum value of electric and magnetic fields with frequencies above 100 kHz (IF, RF radiation) and recommended values for the electric and magnetic fields with frequencies below 100 kHz (ELF radiation)[126].

STUK -the Finnish Radiation and Nuclear Safety Authority- states that the SAR value (i.e. heat energy absorbed per kg tissue) absorbed by head and body must not exceed

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[124] RF Electromagnetic Fields Measurements in Greece; E. Karabetsos, G. Filippopoulos, D. Koutounidis CH. Govari, N. Skamnakis, Non ionizing radiation office, Greek atomic energy commission. COST 281 / EMF-NET seminar on The Role of Dosimetry in High-Quality EMF Risk Assessment Ljubljana, Slovenia September, 13 2006; Zagreb, Croatia September 14 – 15 2006

[125] RF Electromagnetic Fields Measurements in Greece; E. Karabetsos, G. Filippopoulos, D. Koutounidis CH. Govari, N. Skamnakis, Non ionizing radiation office, Greek atomic energy commission. COST 281 / EMF-NET seminar on The Role of Dosimetry in High-Quality EMF Risk Assessment Ljubljana, Slovenia September, 13 2006; Zagreb, Croatia September 14 – 15 2006.

[126] Helsingfors den 4 april 2002, Social- och hälsovårdsministeriets förordning om begränsning av befolkningens exponering för icke-joniserande strålning (Social Affairs and Health Decree on the limitation of exposure to non-ionizing radiation)

2 W/kg, and by arms and legs 4 W/kg, respectively[127]. Further, they state that it is reasonable to restrict children's use of mobile phones. Parents are recommended to advise their children to use text messages rather than mobile phone calls, to restrict the number of their children's mobile phone calls and their duration, to guide their children to use a hands-free set and to keep the mobile phone at least a few centimetres away from the body. STUK does not find it justifiable to entirely prohibit children's use of mobile phones, since there is a safety aspect in facilitating children's communication with parents[127].

STUK, since 2003, also carries out the surveillance of mobile phones on the market by spot-check testing SAR values of different phone models, to ensure that the maximum value is not exceeded.

Table 3-7 : Policy actions in Bulgaria, Greece and Finland

Countries	Bulgaria	Greece	Finland
EC recommendation implementation	EC Recommendation (1999/519/EC) under implementation Stricter limits were set in all frequency ranges Limits were differentiated depending on exposure	EC Recommendation (1999/519/EC) implemented in 2000, national legislative act Stricter reference levels in the IF and RF frequency range, 70% and to 60% of ICNIRP's values Limits were differentiated depending on exposure	Authorities comply with EC Recommendation (1999/519/EC) Maximum value for IF, RF radiation and recommended values for ELF radiation Maximal SAR value regarding mobile telephony equipment Recommendation to restrict children's use of mobile phones
Other national initiatives	Monitoring programmes under development, measurements are also being done on demand	Ministerial act in 2008, on monitoring at least 20% of all the antenna stations in urban areas	Surveillance is carried out of mobile phones on the market by spot-check testing SAR values

3.3.2. Scientific actions

On the MS level, many different research initiatives exist and it is difficult to analyse them exhaustively. However, some major research areas can be identified. The research projects involving the largest number of MS in the period of 2004-2009 were focused on the potential impacts of the vastly increased use of mobile telephonic equipment emitting RFs. Several studies have been carried out on this and related topics in different MS countries, regarding exposure environments, conditions and biological effects. A number of epidemiological studies were also reported. Studies on monitoring, field measurements and engineering have also been carried out in several

[127] Statement of Finnish Radiation and Nuclear Safety Authority on 7th January 2009. Website: www.stuk.fi/sateilytietoa/sateilyn_terveysvaikutukset/matkapuhelin_terveysvaikutus/en_GB/stukin_matkapuhelinkannanotto/ [Accessed online 03/03/2010]

MS. Among others, Finnish and German research on mobile phones has been prominent with involvement of national telecom industry.

Another large research area during this period evolved in response to the EU Directive 2004/40 on occupational exposure. The reference levels determined in the Directive stirred a lot of discussion and induced research activities in several countries. One of the main questions concerned the exposure to EMF in medical environments, mainly due to the use of MRI equipment.

In some MS (e.g. Italy), the EU or other international research programmes constitute the main financial resource for the research activity on EMF. In others (e.g. Bulgaria), the need for a structured risk communication targeting the public, and the national authorities as well as the creation of a public database organisation have triggered various scientific initiatives at the national level involving several research institutions (see following section) (Table 3-8).

3.3.2.1 Germany

The German Federal Office for Radiation Protection (BfS) developed a research programme[128] on high frequency electromagnetic fields within the scope of the German Mobile Telecommunication Programme (DMF)[129]. The Programme, which lasted from 2002 to 2008, comprised research projects on the topic of "Mobile Telecommunication" including the fields of "Biology", "Dosimetry", "Epidemiology", and "Risk Communication". Apart from the DMF project, further research in the EMF field is initiated and coordinated by BfS within the scope of the BMU Environmental Research Plan. The research was motivated by the fact that, according to BfS, there is some indication that High frequency electromagnetic fields can cause biological effects even when the levels are below required German limit values (corresponding to ICNIRP). The Programme also aimed at finding potential causes of electro sensitivity.

3.3.2.2 Italy

No national programme on biological and health effects was running during 2009, but a number of studies were being carried out in collaboration between institutes from Italy and other countries. Research on biological effects of exposure to GSM[130]-like RF fields on gene expression in human cells- was carried out *in vitro*, and the effects of exposure to WiFi signals on the immune system of newborn mice were described[131]. In 2007, the Italian Institute for Prevention and Safety at Work (ISPESL) promoted a

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128 Webpage for German Mobile Telecommunication Research Programme (DMF), www.emf-forschungsprogramm.de/ [Accessed online 08/03/10]

129 Webpage for German The Federal Office for Radiation Protection www.bfs.de/elektro/hff?setlang=en, [Accessed online 08/03/10]

130 GSM =Global System for Mobile communications, a network for mobile phones

131 Measures for the exposure of new born animals to WiFi signals. C. Marino, Paolo Galloni, Francesca Nasta, Rosanna Pinto, Claudio Pioli and Giorgio A. Lovisolo, Unit of Toxicology and Biomedical Sciences, Casaccia Research Center, ENEA, Rome, Italy. Abstracts for Workshop in Stuttgart 2008: www.fgf.de/english/research_projects/reports/workshops/abstracts/Abstractbook-FGF-Workshop-Stuttgart-2008.pdf [Accessed online 08/03/10]

research project to analyse the Italian scenario of the practical implementation of the EU Directive 2004/40. An additional aim was to standardise procedures of measurement and numerical dosimetry, as tools to assess exposure of medical staff in the proximity of MRI systems[132]. Epidemiological research has also been carried out through the Interphone study. Italian researchers have also studied childhood lympho-haomatopoietic tumours (leukaemia, neuroblastoma and others) in relation to some environmental agents such as EMF[133].

3.3.2.3 Sweden

The number of researchers in Sweden dealing with EMF and health issues had decreased in 2008 in respect to previous years due to lack of funding[135]. Many of the studies were conducted in an international collaboration and most concerned mobile telephony equipment. Apart from exposure from handsets for mobile telephony, in Sweden, mobile phone base stations, especially GSM900[134], caused the highest contribution to increased RF exposure[135]. Söderqvist *et al.* performed a population-based study to assess the use of mobile phones and cordless phones among children aged 7–14 years. A questionnaire comprising 24 questions was sent to 2000 Swedish persons, using a stratified sampling scheme[136]. The study showed that children used mobile and cordless phones early in life and that very few use hands-free equipment. It also showed that girls use mobile phones significantly more than boys.

Like in Germany, hypersensitivity has been recognised as an area where more scientific research is needed. A number of summaries from Swedish authorities[137] have examined whether the RF electromagnetic fields could produce symptoms such as headache, fatigue and sleep disturbances. So far, no study has confirmed that the symptoms of people who feel affected are caused by radiofrequency fields generated by mobile phones or base stations. The scientific evidence is, however, much smaller than those of extreme low frequency field[138]. Hillert *et al.* studied the effect of GSM exposure on self-reported symptoms and detection of fields by participants during

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[132] Paolo Vecchia, National Institute of Health, Rome Electromagnetic fields and Italy; 2008-2009 www.who.int/peh-emf/project/mapnatreps/ITALY_report_EMF_Activities.pdf [Accessed online 08/03/10]

[133] Italy, Present status of EMF activities, 11th international Advisory Committee Meeting on EMF, 11th of June 2006. Notes by Paolo Vecchia, National Institute of Health, Rome. Accessible on www.who.int/peh-emf/project/mapnatreps/Italy_2006_EMF_activity_report.pdf [Accessed online 09/03/10]

[134] GSM 900 is a type of network in Europe using the band 890-915 MHz for sending data and the band 935-960 MHz for receiving information.

[135] Sweden Report on EMF Activities 13th International Advisory Committee on EMF June 2008 .Kjell Hansson Mild, Department of Radiation Physics, Umeå University, Janez Marinko, Swedish Work Environment Authority (SWEA), Lars Mjönes, Swedish Radiation Protection Authority, (SSI), Stockholm, Sweden. Available on www.who.int/peh-emf/project/mapnatreps/sweden/en/index.html, [Accessed online 09/03/10]

[136] Söderqvist F, Hardell L, Carlberg M, Hansson Mild K. Ownership and use of wireless telephones: a population-based study of Swedish children aged 7-14 years. BMC Public Health. 2007 Jun 11;7(147):105

[137] IEGEMF. Recent Research on EMF and Health Risks. Fifth annual report from SSI's Independent Expert Group on Electromagnetic Fields,2007. Revised edition 15 April, 2008. Stockholm: Statens Strålskyddsinstitut, 2008. SSI Rapport 2008:12

[138] Swedish Environmental Health Report 2009, Miljöhälsorapport 2009, Socialstyrelsen, Karolinska Institutet, 2009-126-70, Västeras, Sweden, Mars 2009

GSM exposure time (real or sham). The study followed a well defined study group including people who had reported symptoms attributed to mobile phone use[139]. The result showed that the study group could not detect RF exposure better than by chance. However, the non-symptom group reported a higher prevalence of headache towards the end of RF exposure period, which (according to the author) justifies further investigation of possible physical correlations.

3.3.2.4 Summary table

Table 3-8: Scientific actions in Germany, Italy and Sweden

Germany	Italy	Sweden
National research programme on RF fields within the German Mobile Telecommunication Programme DMF (2002 to 2008) Research initiated by the state within the BMU Environmental Research Plan	No national programme on biological and health effects was running during 2009 Research project to analyse Italian implementation of the EU Directive 2004/40, also assessing exposure of medical staff in the proximity of MRI systems	Decreasing number of EMF researchers Scientific summaries initiated by Swedish authorities, examining possible risks/effects, and causes for symptoms such as hypersensitivity
Studies include: Mobile Telecommunication; Biology, Dosimetry, Epidemiology, Risk Communication Possible effects of RF fields below required German limit values Potential causes of electro sensitivity	Studies in international collaboration including: Biological effects of exposure to GSM-like RF fields; Effects of exposure to WiFi signals on the immune system; Epidemiological research through the Interphone study	Studies in an international collaboration including: Mobile telephony equipment; Population-based survey on use of mobile phones among children

[138] The effects of 884 MHz GSM wireless communication signals on headache and other symptoms: an experimental provocation study. Hillert L, Akerstedt T, Lowden A, Wiholm C, Kuster N, Ebert S, Boutry C, Moffat SD, Berg M, Arnetz BB.Bioelectromagnetics. 2008 Apr;29(3):185-96.

3.3.3. SCIENCE-POLICY INTERFACE

A number of MS (e.g. Italy, Greece, and Bulgaria) report high levels of public concern regarding the potential health effects of EMF. Several measures have thus been taken to inform and educate the public and policy makers. Therefore, various approaches to manage the science-policy interface have been developed to facilitate this important information exchange.

3.3.3.1 National scientific bodies

National scientific bodies are most commonly the advisors both for government and the public in several countries, such as, for instance, the Nordic countries[140] and Germany[141]. These authorities are often responsible for the implementation of EC recommendations into national context. They identify eventual needs for further research, sometimes performing parts of the research and the monitoring in the country. Such institutions also manage the communication with the public (commonly through internet and media), and organise conferences and meetings.

Although the existence of a national scientific body is not a tool in itself, a number of factors indicate that it may be one of the keys to successful interactions in the interface between science, government and the public. For instance, in 2002 the Italian Government appointed an International Committee to provide advice on the health risks of EMF and related policies. Following the recommendations of the appointed experts, the Italian Ministry of Health launched a project aiming at the creation of a single scientific body at the ministry of health responsible for advice to the government, health authorities and the public[142].

An essential prerequisite in risk communication is that the recipients have sufficient trust in the information provider[143]. This is of course especially important when acting on a governmental mandate, while the governmental mandate itself may be a prerequisite for public confidence. Further, there is an advantage, in the decision-making process, of being aware of public and stakeholders' opinions. For a successful interaction of all the involved parties, a reasonable level of understanding of the problem and the risks involved is necessary. As a consequence, it can be an advantage if the information is disseminated to the public and stakeholders through one trusted

[140] For example Danish National Board of Health (Sundhedsstyrelsen), Radiation and Nuclear Safety Authority of Finland (Säteilyturvakeskus), Icelandic Radiation Protection Institute (Geislavarnir Ríkisins), Norwegian Radiation Protection Authority (Statens strålevern), Swedish Radiation Protection Authority (Statens strålskyddsinstitut

[141] German Federal Office for Radiation Protection (BfS)

[142] Italy, present status of EMF Activities, 11th international Advisory Committee Meeting on EMF, 7-9 June 2006, www.who.int/peh-emf/project/mapnatreps/Italy_2006_EMF_activity_report.pdf [Accessed online 09/03/2010]

[143] JRC/EMF-NET. Electromagnetic Field Exposure: Risk Communication in the context of Uncertainty, Pages 15-25/ The Building Blocks of Risk Communication, Peter Wiedemann, Research Centre Juelich, MUT – INB, Germany. Available on:
www.web.jrc.ec.europa.eu/emf-net/doc/pubblications/Book_Risk%20communication.pdf
[Accessed 11/03/2010]

source of information, instead of many different expert groups, and thus, a single national scientific body may favour the information spreading and communication among scientists, public and policy makers.

The existence of an independent agency or scientific institution can be an important factor in this respect, as has been observed in Spain[144] and Bulgaria (see below). Among many other functions, the body can also have an important function in suggesting research organisation and funding, and also in communicating with the international scientific community.

The national science-policy interface may also take place through other more informal initiatives. For example, in Italy, communication and initiatives on EMF are partly being carried out through a Foundation (Ugo Bordoni)[145].

3.3.3.2 Regional or national meetings/workshops

Meetings that addressed human exposure to EMF have been organised in several countries, including Bulgaria, Greece and Italy. In Bulgaria these were carried out in regions where the general public is particularly concerned with or critical of national EMF policies. The Bulgarian National Programme Committee also organises meetings with media as well as with the governmental administration of the Ministry of Health, the Parliament and the regional authorities.

Only 2 percent of Europeans prefer[146] local courses or seminars as a source of information on EMF.

3.3.3.3 Training and seminars for the general public

It is important to consider that only a limited amount of people can allocate time and economic resources to learn more about EMF. Nevertheless, education is crucial for some groups of population, for example those responsible for human resources in work places where occupational exposure may occur. When a few responsible staff members have been trained, they can advice the executives as well as the rest of the staff on EMF safety issues and thus spread the information further.

3.3.3.4 Public consultation

Public consultation may be a well-defined platform for the dialogue between concerned parties. It may be performed through, for example blogs or other debate forums for dialogue, or meetings with citizens' committees and local authorities. Special environmental impact assessment meetings are also organised in some

[144] JRC/EMF-NET. Electromagnetic Field Exposure: Risk Communication in the context of Uncertainty, Pages 111-119 / Evolution in the social perception of risk associated with EMF in Spain" by Maria Jesús González.Available on www.web.jrc.ec.europa.eu/emf-net/doc/pubblications/Book_Risk%20communication.pdf [Accessed 11/03/2010]
[145] Foundation Ugo Bordoni website, www.fub.it, [Accessed online 09/03/10]
[146] EC 2010, Special Eurobarometer – Electromagnetic fields. ec.europa.eu/public_opinion/archives/ebs/ebs_347_en.pdf [Accessed online 16/08/2010]

countries in parallel with the new installation of power lines. Through public consultation process, which is a part of, for example, the Swedish legislation on urban planning, the public who are concerned can be involved in the planning process and contribute to the decision of constructing new buildings near power lines or not[147]. Public consultation may also give useful input to decision-makers, and at the same time allow concerned public or stakeholders to be informed and involved.

3.3.3.5 Internet

Internet is a commonly used source of information, and is easily updated. Information can be expressed at different levels of detail, from very general 'first page' information to subsections and links providing more information. In the Finnish web page on EMF, for example, data on each mobile telephone model tested by the authorities can be found[148].

Moreover, the internet, as a media, has developed several interactive tools where information exchange and debate can take place, for example through blogs, where people can express their opinion publicly and receive answers and comments. About 10 per cent of the European population prefers this channel for information on EMF[151].

3.3.3.6 Fact sheets, prints

In several countries, fact sheets informing on EMF have been translated and printed, to the advantage of the people with no internet access. In Sweden and Finland, the government has prepared information leaflets that are easily understandable by lay people (Figure 3-2). Around 10 per cent[151] of Europeans preferred official or specialist publications as a source of information.

A disadvantage of this kind of tool is that it is one-sided information and does not reply directly to the concerns of the reader, thus not favouring successful risk communication. Accordingly to a study on the public awareness of two leaflets produced by the Department of Health in the UK[149], there is a large difference between the information provided on the sheet and the information the receiver takes in, as well as the risk perception. In the study, over half of the people who claimed to have come across the studied leaflet were not able to recognise any of the key recommendations it contained. Rather than reassuring, the information was linked with concern. The results indicate the importance of policy makers developing a clear understanding of the possible effects of communicating precautionary advice.

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[147] Internet collection of Swedish Law and regulations (Notisum, in Swedish)Planning and Building Regulation (1987:383)
www2.notisum.com/Pub/Doc.aspx?url=/rnp/sls/lag/19870383.htm [Accessed online 22/03/10]

[148] Webpage of Radiation and Nuclear Safety Authority Finland
www.stuk.fi/sateilytietoa/sateilevat_laitteet/laitteiden_valvonta/en_GB/matkapuhelimet/ [Accessed online 09/03/10]

[149] Barnett J., Timotijevic L, Shepherd R and Senior V (2006) Public Responses To Precautionary Information From The Department Of Health (UK) About Possible Health Risks From Mobile Phones, Health Policy, 82, 240-250

Figure 3-2: Fact sheet from Finnish Radiation and Nuclear safety Authority, STUK[150]

Printed items also have the disadvantage of quickly becoming out of date and their distribution may be both resource consuming (or inexistent) and produce waste.

3.3.3.7 TV, radio, newspapers

According to the Eurobarometer survey[151] television is the most preferred medium through which to receive information on risks regarding EMF (55%), followed by newspapers and magazines (38%), and Internet (19%). While being the preferred information source for the public, often very informative and available, these media serve as a weak scene for the science-policy interface in many other aspects. Apart from a perception of what makes people worried, it generally does not favour exchange of knowledge, suggest future areas of scientific interest or give response to governmental bodies.

3.3.3.8 Telephone, e-mail

In most countries the citizens may have a personal response to questions on the phone or via e-mail. This source of information, which is quick and allows for questions and explanations, is useful for both authorities and the public. The personal approach to an authority, researcher or other body when seeking advice on EMF may have great advantages in that the question and response will mostly be very exact, and rapid. However, only a few percent of Europeans preferred e-mail as a source of information while 8 per cent preferred other types of personalised correspondence[151]. The effort

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[150] Source: www.stuk.fi, [Accessed online 08/03/10]

[151] EC 2010, Special Eurobarometer – Electromagnetic fields: ec.europa.eu/public_opinion/archives/ebs/ebs_347_en.pdf [Accessed online 16/08/2010]

involved may be partly finding the right recipient for the question, something which is facilitated by the commitment of a dedicated address or phone line. Furthermore, anonymity may be preferred to giving out personal information, particularly if feeling uninformed.

The countries below were chosen for a closer study because they show examples of different approaches in the science-policy interface, and also due to their relative difference in geographical, demographical and socio-political context that may influence the public perception of the EMF issue. Table 3-9 summarises the different national approaches.

- **Bulgaria**

In Bulgaria scientific advice is communicated to public, government and authorities by a National Program Committee of specialists in the topic (BNPC). Public information activities exist including:

- production of brochures and fact sheets,
- regional meetings,
- training courses to different groups of specialists or professional groups,
- a website[152] with regional information for Bulgaria
- a dedicated telephone number for the general population for every kind of questions in the field of EMF safety[153].

Bulgaria reports[153] on a growing public concern regarding EMF produced by base stations. However, the concern may have other reasons than uncertain scientific proof. Since financial benefits are connected to the localisation of base stations, declared health problems have sometimes had economical underlying explanations. Also in Bulgaria, there are indications of problems with private financial interests driving information campaigns, such as private performing risk assessments, profiting from an increased public concern. There are also reports that information is sometimes distorted for political reasons, in which case the media sometimes deliver information that add to public concern. As it appears, scientists sometimes have problems in communicating scientific information[153].

- **France**

In France, The Ministry of Health has published information via internet as well as leaflets on mobile telephones and health[154], and taken the initiative during 2009 of roundtable discussions with stakeholders on the potential dangers of mobile phones and mast[155]. In addition, the Health and Radiofrequencies Foundation[156] is a research

[152] Webpage for National Program Committee, (in Bulgarian), www.emfbg.com [Accessed online 08/03/10]

[153] Bulgarian National Program Committee (BNPC) International EMF Project REPORT, 14th International Advisory Committee Meeting WHO, Geneva, 11–12 June 2009, www.who.int/peh-emf/project/mapnatreps/BULGARIA_IAC_2009_report.pdf [Accessed online 08/03/10]

[154] Information folder « Téléphones mobiles, santé et sécurité » available on Webpage for Ministry of Health and Sports ww.sante.gouv.fr/htm/dossiers/ [Accessed online 08/03/10]

[155] Actu-Environnement, (French web magazine for professionals in the environmental sector)

foundation, established at the initiative of the State, (the Ministry of Research and Industry) in order to define, promote and fund research programmes and to work for dissemination of knowledge on this subject among the public and professionals. A few large industrial companies have contributed to its creation. The foundation organises open scientific meetings as well as exhibitions to give to all types of public a chance to understand what EMF are and how they might affect health. Moreover, the Foundation has organised a "blue bus" that travelled through France in 2007 with information on the topic, and an interactive website has been developed, where fact sheets and Q&A documentation are distributed[156].

A number of mobile telephone operators selling on the French market have also formed a cooperative, the AFOM (French Association of Mobile Operators), with the mission to spread information on the deployment of mobile telephone networks, environment and health. One of their actions is for instance to provide an information leaflet distributed when buying mobile telephony services and equipment in France[157].

- **UK**

In the UK the Science and Technology Committee exists to ensure that Government policy and decision-making are based on good scientific and engineering advice and evidence. The implementation of the EU 2004 Directive in the country has been used as one of the case studies in a recent report[158].

When preparing for the possible implementation of the EU 2004 Directive, the UK reported on an explicit aim of involving stakeholders (e.g. the Royal College of Radiologists, the manufacturers' organisation (EEF), trade unions and others). The UK Health and Safety Executive (HSE) set up two working groups including a broad based cross industry grouping, with members from a range of sectors likely to be affected by the Directive's implementation (medical or technical involved in Magnetic Resonance Imaging, engineering, welding industry). Both groups' outputs were used to inform the HSE and to help develop any detailed regulatory proposals for implementation[159].

Another example of science-policy interfaces in the UK is the Stakeholder Advisory Group, SAGE, which was set up by the Department of Health regarding ELF. The aim is to find practical recommendations for a precautionary approach, in a process for decision-making not only based on reviewed science. The group has representation

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www.actu-environnement.com/ae/news/debat_effet_ondes_electromagnetiques_sante_6961.php4 [Accessed online 08/03/10]

[156] Webpage for French Health and Radiofrequencies Foundation, www.sante-radiofrequences.org [Accessed online 11/03/2010]

[157] Webpage for AFOM, French Association of Mobile Operators www.afom.fr/v4/TEMPLATES/contenus_aqqc.php?doc_ID=894&rubrique_ID=310&rubLimit=268 [Accessed online 11/03/2010]

[158] Scientific advice, risk and evidence: how Government handles them, Select Committee on Science and Technology. Conclusions: PUBLICATION OF REPORT, SCIENTIFIC ADVICE, RISK AND EVIDENCE BASED POLICY MAKING No. 63 of Session 2005-06 8 November October 2006, available on internet : www.parliament.uk/parliamentary_committees/science_technology.cfm, [Accessed on 08/03/10]

[159] Web page of UK Health and Safety Executive, www.hse.gov.uk/radiation/nonionising/electro.htm [Accessed on 09/03/2010]

from public concern groups who advocate greater precaution as well as from the power supply industry, several government departments and the Health Protection Agency. The work is expected to include consideration of ways in which people can reduce domestic exposures to ELF by taking action within their own homes as well as discussions about precautionary approaches to be adopted with respect to power transmission lines and the local supply network[160]. According to the web page, one of the methods used is involving an independent third party to design and run the process, and to facilitate meetings in order to build trust and help create a mutual understanding[161].

- **Summary table**

Table 3-9 : Science-Policy interfaces in Bulgaria, France and UK on EMF

Bulgaria	France	UK
National Committee of specialists spread information by internet, dedicated phone line, brochures, fact sheets, regional meetings and training courses Problem with non scientific informants stirring worries.	Information disseminated by both Government and private initiatives on internet, leaflets, and a travelling information bus. Research foundation (supported by industry) organises meetings and exhibitions Public Consultation on mobile phone technology	Governmental Committee to monitor science-policy interaction (generally) Public Consultation groups with stakeholders on implementation of the EC 2004 Directive Public Consultation scheme on use of precautionary principle and EMF

[160]Webpage of UK Health Protection Agency, www.hpa.org.uk/webw/HPAweb&HPAwebStandard/HPAweb_C/1197637106537?p=1158934607761 [Accessed online 22/03/10]
[161] The SAGE website www.rkpartnership.co.uk [Accessed on line 2010-03-22]

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4. POSSIBLE MEASURES TO AVOID UNNECESSARY EXPOSURE

4.1. DIFFERENT EXPOSURE SCENARIOS

Based on current knowledge, for each of the analysed EMF frequencies it is possible to identify several high exposure scenarios (Table 4-1). High exposure scenarios in the following table comprise two different types of 'high' exposures:

A: possibly exceeding protection limits,

B: elevated compared to the normal background level.

Table 4-1: High exposure scenarios for differnet types of EMF[162]

Scenario	Type	ELF	IF	RF	SF	Comments
Living close to electric installations of power transmission and distribution	B	X				Usually a factor of 100 to 500 below the protection guidelines of 100 µT
Living close to railroads	B	X				Usually a factor of 100 to 500 below the protection guidelines depending on the frequency of the railway system
Electric supply to houses via buried wires or indoor power distribution (indoor wiring)	B	X				Exceptionally above background, usually a factor of 100 to 500 below the protection guidelines of 100 µT
Use of electric devices (hair dryer, electric shaver, vacuum cleaner,...), use of electric vehicles, indoor electric installations	B	X				Possibly in the range of several mT, but only intermittent and therefore below the 24 hours protection limits of average exposure below 100 µT
Occupational exposures as e.g. workers in power plant	A	X				Protection limits may be exceeded
Occupational exposures in the vicinity of welding machines or induction heating furnaces	A	X	X			Protection limits may be exceeded

[162] Hansson Mild K., Alanko T., Decat G., *et al*. Exposure of workers to electromagnetic fields. A review of open questions on exposure assessment techniques. JOSE. 2009; 15(1): 3-33. Information collected in chapter 2.

Scenario	Type	ELF	IF	RF	SF	Comments
Anti-theft devices, security systems	A		X	X		Intermittent exposures, possibly exceeding protection guidelines between the gates; possible longer term exposure of workers
Living near TV or radio broadcast transmitters or mobile phone base stations, having a cordless phone base station at home	B			X		Usually well below protection guidelines which are depending on frequency
Use of mobile phones or cordless phones, WLAN	B			X		Localized exposure to the brain, not exceeding the protection limits
Occupational exposure e.g. RF heat sealers, radio/TV tower workers and radar operators	A			X		Possibly exceeding protection guidelines
Use of induction heating cooking	B			X		Intermittent only during use
Workers operating on magnetic resonance device (MRI, scanners, etc.)	A	X		X	X	Possibly exceeding international safety guidelines

Precautionary measures used in some of the EU Member States are expected to have an impact on EMF exposure, particularly a reduction of the proportion of persons exposed in the high range of the overall exposure distribution. The actions to reduce the exposure can be sub-divided into two categories: technical approaches and policy approaches.

4.2. TECHNICAL APPROCHES

Different technical approaches can be used to reduce exposure to EMF. Potential health effects generated by exposure to mobile phones (RF) and power lines (ELF) have been the object of study more frequently than exposure to other frequencies. Due to this reason and due to the fact that they are at the centre of public concern, technical solutions to reduce exposure from mobile phones and phone lines are more developed than the options to decrease EMF exposure from others sources.

4.2.1. APPROACHES TO REDUCE EXPOSURE TO ELF

The main sources of ELF exposure are power lines and electrical equipment (Table 2-2). There are many ways to reduce exposure to ELF, such as the relocation of overhead power lines away from populated areas or their burying, installation of vector-sequence arrangements, phase conductor splittings[163], etc. These options have been considered by WHO[164] and many other national or international regulatory bodies. Some of these measures have been put in place in some countries, e.g. in the Netherlands since 2005, dwellings cannot be built within 35 meters from power lines[163]. This distance is increased in the case of buildings hosting sensitive population (e.g. children), in order to avoid average exposure levels exceeding 0.4 µT. Similarly, since 1998 in Ireland, the building of electrical power installations and transmission lines is forbidden within 22 metres from schools and day-care centres[164]. In the UK, underground cables are used when the relocation of power lines is not possible[165]. In Norway, Netherlands and Denmark it is also mandatory to leave open space between residences or other places where people might be present in longer term and high-voltage power lines. Often these measures refer only to newly built overhead power lines or to specifically sensitive places like kindergartens or schools, because moving existing buildings is difficult. However, it should be highlighted that there is no clear and widely accepted scientific evidence for definition of sensitive places. Studies on childhood leukaemia, for instance, tend to highlight an association with long term EMF exposure rather than short term. Thus, the rationale for declaring kindergartens but not residential areas where children live as sensitive places is unclear, given the fact that young children may spend more time at home than in a kindergarten at the young age at which children develop leukaemia (age peak between 1-5 years).

Such measures (e.g. to leave a corridor between residences and overhead power lines) enable to avoid long-term ELF exposures above a defined level. If the corridor is 200 m wide, for instance, power line-related exposures above 0.2 µT are not expected[166]. The total impact depends on the contribution of power lines to the overall exposure of the population. For instance, in the UK or in Germany, power lines contribute to approximately one-third of the average 24 hour exposures exceeding 0.2 µT in children. Therefore, corridors would eliminate about one-third of such elevated

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[163] Kelfkens G., Van Wolven J., Pennders R. *et al.* Costs and benefits of the reduction of magnetic fields due to overhead power lines: www.rivm.nl/milieuportaal/images/Costs%20and%20benefits%20of%20magnetic%20field%20reductin.pdf [Accessed online 18/05/2010]

[164] World Health Organization - Extremely Low Frequency Fields Environmental Health Criteria Monograph No.238, Chapter 13: protective measures: www.who.int/peh-emf/publications/Chapter%2013%20v2.pdf [Accessed online 18/05/2010]

[165] Stakeholder Advisory Group on ELF EMFs (SAGE) report. Precautionary approaches to ELF EMFs - First Interim Assessment: Power Lines and Property, Wiring in Homes, and Electrical Equipment in Homes. 2007: www.electric-fields.bris.ac.uk/SAGE1streport.pdf [Accessed online 18/05/2010]

[166] Maslanyj MP, *et al*. Investigation of the sources of residential power frequency magnetic field exposure in the UK Childhood Cancer Study. J Radiol Prot. 2007 Mar;27(1):41-58.

exposures, i.e. the exposure prevalence at 0.2 µT would decrease from about 1.5% to 1%[166,167].

However, keeping a distance between power lines and buildings appears to be more easily applicable in high-resource countries with not too dense urban areas in order to have enough space to have choices when routing power line corridors. This is more difficult to achieve in poorer countries or in densely populated areas. Furthermore, new energy plants are frequently built in remote areas and, hence, power has to be transmitted to the metropolitan regions where the consumers live. This results in the construction of new power lines in some countries to transport energy. It then has to be assessed whether a precautionary approach that avoids building power lines too close to residences is feasible (a case by case approach).

The decision of how to plan power line corridors remains difficult, as precautionary measures to avoid building those lines close to residences are usually costly, while it is currently unclear whether these precautionary actions have any health benefits. Thus, a case by case cost/benefit analysis needs to be performed in order to evaluate what is the best option (e.g. building new underground power lines or to remove existing overhead power lines).

Precautionary measures that do not allow to build new overhead power lines too close to residential areas or, vice versa, that do not allow to build new residential areas too close to existing power lines, are only relevant options if the scenarios of building new power lines are common. As long as no new overhead power lines are built, this recommendation does not apply and the exposure levels in the general public can be assumed to remain the same as no action is taken. As an example, few new high voltage power lines were built in Germany in the last 30 years, thus, a recommendation to stop building new power lines in the vicinity of residential areas would have mattered only to a little extent. Further it needs to be noted that such a recommendation might introduce social inequality: if precaution is taken only in areas where new power lines are built, those living close to existing power lines where no action is taken may feel treated badly by the authorities. Thus, the majority of exposure remains associated with existing lines. Therefore, solutions are needed to reduce the ELF from power lines in general.

Technically, the replacement of some power lines with cables in the soil is possible; thereby electric fields from underground cables are absorbed by the earth above the buried cable. However the decrease of ELF depends on the depth at which the cable is placed and superficially buried power lines can result in direct ELF exposure on the above surface for few metres[168].

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[167] Schüz J,*et al*. Extremely low frequency magnetic fields in residences in Germany. Distribution of measurements, comparison of two methods for assessing exposure, and predictors for the occurrence of magnetic fields above background level. Radiat Environ Biophys. 2000 Dec;39(4):233-40.

[168] Stuk website. Power lines. 2009: www.stuk.fi/sateilytietoa/sateilevat_laitteet/magneettikentat/en_GB/voimalinjat/ [Accessed online 18/05/2009]

Furthermore, power line cables could be twisted together forming what is known as aerial bundled conductor, which neutralises some of the emissions and lowers the ELF[170].

A study about the subsea windfarm power cables showed that as the permeability of the power cable armour increased, the resultant EMF strength outside the cable decreased. In addition, the conductivity of the armour could contribute to reduce the EMF strength. Therefore, the use of power cables having high permeability and high conductivity could help to reduce the generated EMF[169].

As electric fields can be blocked by obstacles (walls, buildings, etc.) another option could be the use of trees to protect the population against ELF. In this case, trees act as a shielding and reduce electric fields. In winter, evergreen trees such as pines are better at decreasing ELF than deciduous trees; nevertheless the effectiveness of trees is poor compared with other options[165,170] and they do not shield the magnetic component of the field in any case.

Removing existing lines or replacing them with buried wire is very costly and would require billions of Euros for re-construction, even in one country. The costs depend on the length and on the voltage level of the power line. It is more and more expensive as the voltage increases. The cost also depends on the levels of urbanisation of the considered area. If the urbanisation is high, relocating power lines underground is difficult and expensive[168,165]. According to the UK Electricity Association, additional costs incurred from moving to underground lines from overhead lines could have to be borne by the consumer[170].

Table 4-2 presents some examples of costs to reduce exposure to ELF.

Table 4-2: Examples of costs of the ELF exposure reduction[165]

Mitigation measures	Unit	Costs (× 1000 €)
Vector-sequence rearrangement	Per power line	350-1300
Phase conductor splitting	Per km section	70-300
Line relocation	Per km section	320-1200
Undergrounding	Per km section	1100-8000

The relocation of power lines will not change ELF exposures from indoor wiring and low-voltage power distribution. Generally, indoor wiring does not lead to exposure to high ELF, but there are exceptions. These exceptions often occur in older houses or multi-storey buildings with many apartments, as these situations increase the chances to have unbalanced currents that may produce elevated ELF. This kind of exposure can

[169] Centre for marine and coastal studies centre for intelligent monitoring systems applied ecology research group. A baseline assessment of electromagnetic fields generated by offshore windfarm cables. 2003: cvi.se/uploads/pdf/Kunskapsdatabas%20miljo/Flora%20och%20fauna/marina%20organismer/forskningsresultat/Elkablars%20inverkan%20-%20Cowrie.pdf [Accessed online 18/05/2010]

[170] Alasdair and Jean Philips. Buying an "EMF Safe" Property - Powerlines and pylons: www.powerwatch.org.uk/library/downloads/emf_property-02-20090604.pdf [Accessed online 18/05/2010]

be reduced by replacing the existing electric system with a new modern system. Following are some of the specific technical options to reduce ELF from indoor wiring[165]:

- Using wire power circuits as radial circuits instead of ring circuits
- Keeping "go" and "return" currents physically close together at all time, particularly for light and underfloor heating cables
- Protecting the whole electrical installation with a residual current device
- Using electronic electricity meters rather than rotating-disc meters
- Using wire cables which has a screen without the sheath
- Putting the wiring in metal conduits
- Using extra-low-voltage circuits at home
- Using earthed metal rather than plastic cases

However, one of the main difficulties is to identify houses with elevated magnetic fields since this can only be identified with longer term (at least several hours) field measurements. In the UK or Germany, it is assumed that magnetic fields above 0.2 µT caused by indoor wiring can be detected in approximately 1 out of every 200 apartments[171]. The costs of such renovations could be high and need to be covered by the owner, which might influence the monthly rent.

The report of the Stakeholder Advisory Group on ELF EMFs (SAGE) advised to apply these suggestions only in new homes or in the case of rewiring. These mitigation measures could be equally put in place in any building.

These measures seem financially feasible except for cables that have a screen without the sheath because their price is higher than a standard cable; therefore cheaper version of these cables should be developed. Earthed metal is equally more expensive than plastic cases.

ELF from electrical equipment in homes can also be reduced by changing the user behaviour. For example, one can reduce the ELF exposure by increasing the distance from appliances, locating sockets away from the bed, and switching off devices when not in use[165].

[171] Schüz J, *et al*. Extremely low frequency magnetic fields in residences in Germany. Distribution of measurements, comparison of two methods for assessing exposure, and predictors for the occurrence of magnetic fields above background level. Radiat Environ Biophys. 2000 Dec;39(4):233-40

4.2.2. Approaches to reduce exposure to IF

An example of a successful introduction of self-regulation for EMF emissions is the development of the TCO standard[172] for computer monitors, which was first introduced in 1992. The TCO standard regulates EMF levels and the labelling of monitors complying with TCO standard (Figure 4-1) has become a quality characteristic and was successful on the market.

Figure 4-1 : Logos of the TCO standard for displays and headsets[173,174]

Anti-theft devices and security installations are discussed here but they exist both in the IF and RF ranges. EMF levels of anti-theft devices may be relatively high, to fulfil the aim of detection of stolen goods, preferably also under several layers of clothing. Demanding lower exposure is therefore in contrast to the objective of installing such devices. Nevertheless, it has to be guaranteed that protection levels are not exceeded and employers must make sure that working areas of employees are far enough from the installations to avoid long-term exposures.

EMF from welding devices, heaters, electro-surgery, etc. can expose workers to static fields, ELF or IF and mitigation measures may relate to the work area and/or workers' exposure or to the source. Technical actions include the reduction of unnecessary exposure through an appropriate design of electrical devices or through shielding. Personal protection equipment, such as gloves, safety shoes and electromagnetic shielding structures that are adapted to the characteristics of workers' body and to their activities can then be used[175,176].

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[172] The TCO labelling system was created following observations of an increase in health problems among office employees, related to poorly designed IT equipment. TCO Development is a limited company owned by TCO, Tjänstemännens Centralorganisation (the Swedish Confederation of Professional Employees). TCO Development is a member of GEN, the Global Eco-labelling Network. TCO Development website is available on www.tcodevelopment.com [Accessed online 05/07/2010]

[173] Futura-Environnement. Ordinateurs et téléphones portables : quelques réflexes verts : www.futura-sciences.com/fr/news/t/developpement-durable-1/d/ordinateurs-et-telephones-portables-quelques-reflexes-verts_18775/ [Accessed online 25/05/2010]

[174] Plantronics Sound Innovation. TCO Approved: www.plantronics.com/europe_union/en_GB/company/tco.jsp [Accessed online 25/05/2010]

[175] European Agency for Safety and Health at Work. Working Environment Information - Assessment, elimination and substantial reduction of occupational risks: osha.europa.eu/en/publications/reports/TEWE09001ENC [Accessed online 19/05/2010]

[176] Falsaperla R., Spagnoli G., Rossi P. Electromagnetic fields: principles of exposure mitigation. International Journal of Occupational Safety and Ergonomics. 2006; 12(2): 195–200

4.2.3. APPROACHES TO REDUCE EXPOSURE TO RF

The major contributions of residential RF exposure come from mobile phone base stations and cordless phone base stations. New technologies like wireless computer networks (WLAN)[177] contribute further to this exposure. Cordless phone base stations appear to contribute an unnecessary amount of exposure, because many of the base stations emit RF also when the handset is not in use. This is particularly so with the so-called DECT ("Digital Enhanced Cordless Telecommunications") technology[178]. However, it is technologically feasible to produce base stations generating EMF only during use. To date the market share of such products is low.

With regard to the location of mobile phone base stations, similar considerations apply as in regard to power lines. Precautionary measures, such as demanding technologically feasible lower emissions as in Switzerland, might be applied. However, this might increase costs for setting up mobile phone networks and might result in additional base stations. These aspects should also be communicated to the public.

The system of power adaption of mobile phones also has a direct effect on exposure. With an excellent connection to the nearest base station, the power level is reduced by a factor of up to 1000 times compared with a very bad connection to the nearest base station when the mobile phone is on full power. For instance, the GSM ("Global System for Mobile Communications")[178] 900 MHz mobile phones operate with 15 power levels from 2 W to 0.003 W. If the phone is receiving a strong signal from a particular base station, mobile phones will require less power to communicate. The new UMTS (Universal Mobile Telecommunications System)[179] technology is already related to lower mean power levels than the GSM technology, and as a consequence of the replacement of GSM by UMTS, the average exposure levels by amount of use become lower.

User behaviour and network optimisation can equally influence individual EMF exposure. Indoor use of mobile phones or use while moving or in very busy networks is usually related to higher exposure. Asking operators to optimise networks may result in more base stations.

The benefits of moving mobile phone base stations are complex to evaluate. Removing mobile phone base stations from residential areas would reduce the number of

[177] A wireless local area network (WLAN) provides a connection to Internet and allows the communication of different devices via a wireless method. Wi-Fi is an example of WLAN.

[178] DECT (Digital Enhanced Cordless Telecommunications) is a standard for digital cordless phones. Like another important wireless standard, Global System for Mobile communication (GSM), DECT uses time division multiple access (TDMA) to transmit radio signals to phones and to access a fixed telecoms network via radio. Whereas GSM is optimized for mobile travel over large areas, DECT is designed especially for a smaller area with a large number of users, such as in cities and corporate complexes. A user can have a telephone equipped for both GSM and DECT.

[179] Universal Mobile Telecommunications System (UMTS) is the European standard for the third-generation (3G) mobile communication systems which provides an enhanced range of multimedia services using radio spectrum.

persons who live in the main beam[180] of the base station. Conversely, exposures of individuals might also increase if the mobile phone has to increase emission power to communicate with a base station which is further away. Average exposure levels might also increase if such an approach requires the building of additional base stations to achieve the same coverage. No general assessment can be made since this generally depends on the local situation.

As explained above, in respect to the sitting of mobile phone base stations, it is not clear what the impacts of avoiding higher exposures by the base station are, with regard to the exposure from mobile phones which need to increase their emission power, or by needing additional base stations, on the vast majority of persons not living in the main beam of an antenna. Systematic studies are urgently needed to prove or refute the usefulness of such precautionary measures.

Figure 4-2 shows that at a higher distance, the lower exposure to EMF from the base station may be counterbalanced by increased emissions from the mobile phone.

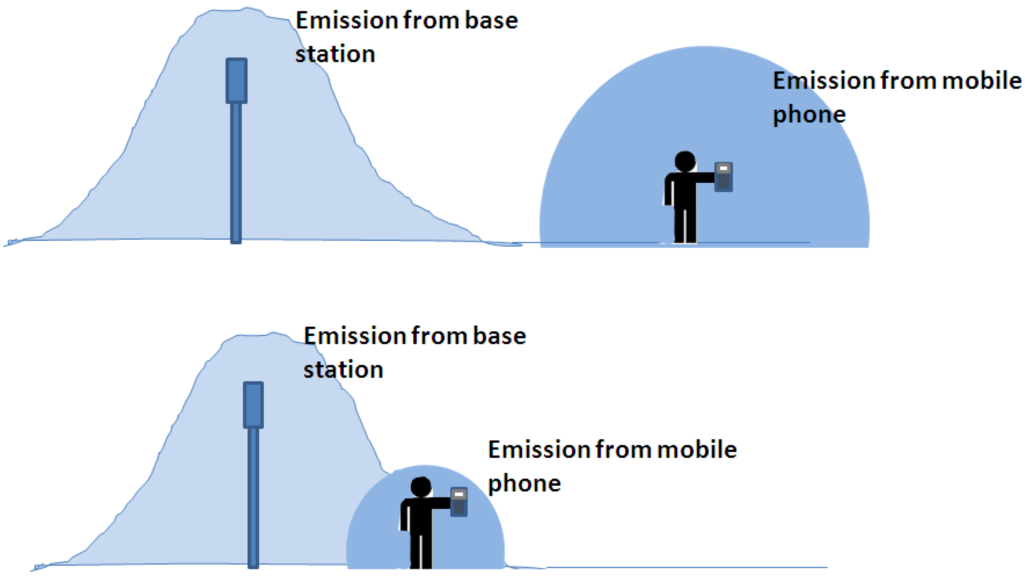

Figure 4-2: Exposure from base stations and mobile phones according to their relative location

Users should receive clear instructions on how to use mobile phones with reduced power and adapt their behaviour (see also section 4.3.3.). Furthermore, mobile phones should always be sold together with headsets which permit to reduce head exposure even if the absorption in other parts of the body close to the mobile phone may increase[181].

[180] The main beam is the zone of EMF emission caused by mobile phone base stations.
[181] Health Protection Agency. Mobile telephony and health exposures from mobile phones. 2008: www.hpa.org.uk/webw/HPAweb&HPAwebStandard/HPAweb_C/1195733844923?p=1158934607786 [Accessed online 18/05/2010]

People can also reduce their exposure to EMF by limiting the length and the number of their calls. In cordless phones a loudspeaker can be used to take the phone away from the head and the body[182].

Moreover, other communication systems also have to be considered. There is a clear benefit in good communication systems for the police, fire fighters and ambulances, and here exposure reduction measures have to be balanced against this benefit. Analogue broadcast stations for radio and TV often operate in the mega-watts range and therefore lead to much higher exposure levels than the other communication systems; however, they are currently being replaced by digital systems with lower EMF levels. Military installations often operate high power antennas, but little information is publicly available on their exposure distributions.

4.2.4. Approaches to reduce exposure to SF

Not many technical options exist to reduce the exposure to SF. Conductor materials can be used to protect against electric static fields but magnetic static fields are difficult to shield, they can be mitigated with ferromagnetic materials such as iron, nickel and cobalt. The choice of the material is important because the value of magnetic permeability of ferromagnetic materials changes with magnetic field strength[175].

4.3. POLICY APPROCHES

Policy options which could be chosen to lower EMF exposure include:

- Setting up legislation on limit values for emission or exposure, monitoring or technical actions in planning, renovation and new construction of buildings and power lines.
- Legislative recommendations on emission or exposure.
- Advice on precautions targeting general public.

Exposure limits may be established by policy makers in order to limit human exposure to EMF in a living or working environment. These types of limits normally incorporate safety factors. Guidance of best practices limiting personal exposure can also be developed[183].

Policy actions can therefore be set up through entirely new policies or regulations, but also through the modification of existing policies or regulations as well as the revision of existing guidelines or recommendations. To this aim, policy makers in the MS could

[182] Australian Mobile Telecommunications Association. Practical Advice on Reducing Exposure from Mobile Phones: www.amta.org.au/pages/Practical.Advice.on.Reducing.Exposure.from.Mobile.Phones [Accessed online 19/05/2010]

[183] WHO, Extremely Low Frequency Fields Environmental Health Criteria Monograph No.238, 2008. Chapter 13. Accessible on the WHO website: www.who.int/peh-emf/publications/elf_ehc/en/index.html [Accessed online 25/03/2010]

choose to implement international guidelines such as the EU guideline or the ICNIRP recommendations, or, at the national level, choose to decrease exposure limits using even stricter guidance. This was the case, for example for Greece, where exposure limits were defined for sensitive groups to 60 or 70 % of the ICNIRP guideline values (see section 3.3.1.).

Legislation demanding protection of the public could alternatively be used to motivate the production of recommendations or guidelines by competent authorities. Existing international limit values or guidelines (e.g. Directive 2004/40/EC, Council Recommendation 1999/519/EC) can be used in national administration, or be adjusted to stricter levels depending on the evolution of epidemiological studies studying the exposure effects linked to long- or short term exposure. Another aspect to consider is that guidelines or recommendation are easier to revise than legislation as more scientific information on possible health effects becomes available.

Setting EMF emission standards for technical equipment is another option of policy action. Policy options could also include funding or promoting research programmes on the topic of exposure and potential need for protection. Furthermore, policy makers may choose to improve the science/policy interface communication and promote coordination between political and scientific stakeholders. They can also take action to improve the dissemination of information on EMF associated risks, or purpose action plans involving different types of stakeholders.

4.3.1. Policy approaches to reduce exposure to ELF

4.3.1.1 Policy measures to reduce the exposure to power lines

There are several possible policy options to set up corridors (see section 4.2.1 above) between buildings and power lines. Of course, the most evident option is to provide general procedures for planning and restrict the construction permits accordingly. Legislation on corridors may be built up to provide either indications on maximum exposure limits, or a minimal distance from each respective type of power line. The enforcement of a minimal distance is generally easier to apply when conceiving an urban planning rather than later on (e.g. during renovation), because no EMF measurements or expert advice are needed *in situ*.

In urban planning, a case-by-case approach can often be useful in decisions concerning the location of new buildings or power lines. When assessing the overall impacts of a project on health and environment there are many aspects to take into account. There may be situations where it is relevant to demand stricter or less strict exposure levels, depending on what other health or environmental issues are taken into account. Legislative action in the form of legally enforceable exposure limits does not allow flexibility in planning which may be needed in such cases, but on the other hand it provides a strong support for the local authorities.

The use of recommendations/guidelines to set up corridors between buildings and power lines could take different forms. For example, in Sweden, the National Board on Health and Welfare (Socialstyrelsen) recommend[185] that exposure should be limited through design or location of the power line, and that exposure should not be elevated for the public compared to reference values. This may, in practice, be implemented through the creation of corridors when constructing new buildings. However, power line owners, when applying for permission to build a new power line, would have to ensure that once the new line is built, no new homes are constructed within the specified distance, by demonstrating rights over land adjacent to the line[184]. Whether this policy option will impose a cost on power line operators will also depend on the value of the land, i.e. whether the demand for land (and thus prices) on a certain location is high or not. However, it must be remembered that the size of the corridor needed will depend on the type of power line, and the recommended exposure level. In the case of Sweden, the currently recommend reference value for acute exposure normally does not impose changes on the planning process. Under the largest power lines (400 kV) the field strength normally amount[185] to 20 – 30 µT, and the reference value for 50 Hz is 100 µT. Swedish authorities generally recommend that long term exposure to ELF exceeding 0.4 µT should be avoided. The Figure 4-3 gives an idea of the corridor normally needed to avoid exceeding the recommended limit value.

Another aspect to consider is the psychological aspect of residing too close to a power line which, independently of the real risk, can affect the urban development of a specific area. In the early planning and permission stages, authorities could thus advice the electricity company seeking to build a new power to look for locations in non populated areas, in order to avoid such undesirable effects.

In any case, the use of the best available technique could be requested by policy makers. Thus, for instance, the power line owner may be demanded to use a specific, low emitting, technical design to reduce EMF exposure. Utility companies could be encouraged through legislative tools to choose the optimal design (with regard to EMF emission) for all new lines, and also be encouraged to convert existing lines where possible and justifiable. It can be an option to ban the specific types of power lines known to create high exposure levels and existing power lines may be improved in the context of general repairing and maintenance schemes.

Of course, for any policy option, the implementing authorities need a suitable administrative framework. This should be coupled to some technical information, implying an additional cost for training and eventual monitoring campaigns.

[184] R K Partnership Ltd, SAGE, Stakeholder Advisory Group on ELF EMFs (SAGE) Precautionary approaches to ELF EMFs First Interim Assessment: Power Lines and Property, Wiring in Homes, and Electrical Equipment in Homes, UK, 2007

[185] The Swedish National Board of Health and Welfare, (Socialstyrelsen) Meddelandeblad, Electromagnetic fields from power lines Communication on Elektromagnetiska fält från kraftledningar, June 2005

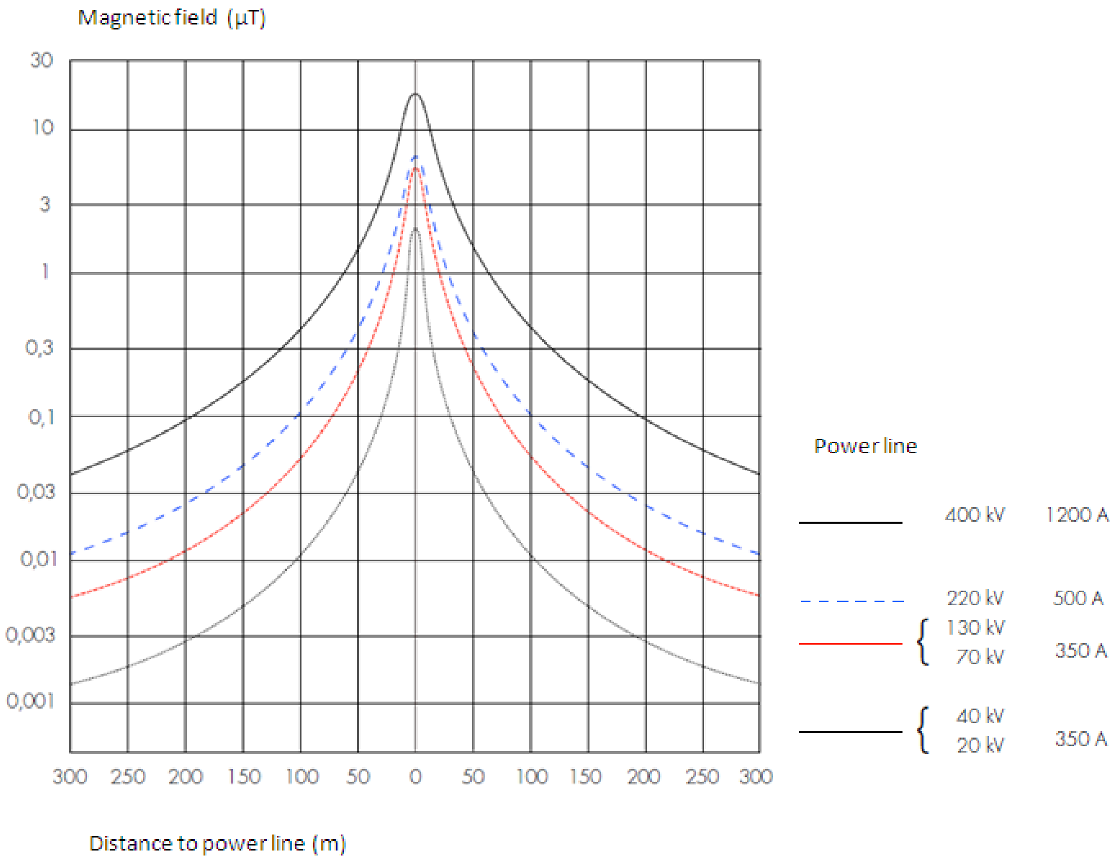

Figure 4-3 : ELF magnetic field values based on the distance to power line[185]

Another factor to consider is that, due to logistic and cost issues, the implementation of this kind of policy option will only be feasible in the case of future urban structures, with little or no effect on the present overall exposure of the European population. The majority of exposure will thus remain associated with existing lines. This means that recommendations applied on new lines may not significantly affect the current public exposure, but avoid its increasing in the future.

4.3.1.2 Policy measures to reduce the exposure from indoor wiring and other electrical devices

Standardisation of electrical equipment already exists in many countries. In order to limit, as far as possible, exposure to ELF from indoor wiring and other electrical devices, introduction of new technical standards or modification of the existing standards may be used. In countries where specific organisation for standardisation of electrical equipment exist, the administrative cost of creating new standards or modifying the existing ones is of course lower than for other countries. However, the definition of new technical standards may demand a multi-stakeholders consultation process which can be time and resource consuming.

The implementation of a technical standard on electrical equipment is generally well received by the public because it contributes to an increased feeling of security. The negative side is that standards take time to develop, and the best available technique may quickly be replaced by an even better one before the finalisation of the decision process. This means that sometimes 'just' fulfilling a standard may not demand from the producer or electrician to use the best available technique available at that moment. Standards may also give a false sense of security, or may, if they differ a lot from the indications of risk in current science, undermine the possibilities to make a science based assessment[164].

Through policy actions, local authorities could be encouraged to promote specific monitoring and measurements in their areas. For example, in the same way as public estates are sometimes screened to find buildings leaking heat and thus causing unnecessary energy consumption, authorities could monitor the ELF exposure levels for sensitive groups and remove indoor high current structures. Through municipality action plans, wire code inspections in homes, schools, offices, etc. could be performed. This again increases the feeling of security among citizens, but may also increase insecurity for people in properties where no action is taken. The need for information and communication with the public may therefore be rather large. Wiring and other equipment can often be replaced within renovation schemes for properties, see section 4.2.1.

Other possible policy measures include:

- Programmes of education and information for electricians
- Information to public on precaution on how to limit exposure of ELF EMF in homes, for instance by turning off devices, choosing the right location of beds, etc. This could be a useful tool to encourage the population to take precautionary action.

4.3.2. POLICY APPROACHES TO REDUCE EXPOSURE TO IF

Several preventive measures could be taken to reduce IF exposure especially in the working environment. Occupational exposure to IF is generated, for example, by anti theft devices in shops, by MRI scanners in hospitals and by computers in offices (Table 2-3). A policy measure could be to implement an action programme to prevent and measure the exposure of specific groups of workers. Such a scheme could be implemented as legislation or a voluntary scheme on State initiative.

A reorganisation of the working environment, for instance, may allow avoiding the presence of workers close to IF emitting devices or electric cables. These measures can be generally implemented at moderate cost and their effectiveness is strengthened by workers' education and training. This kind of measures could be strengthened by *ad hoc* inspections to verify that the safety instructions are appropriately followed.

Another possible action could be to have a mandatory medical register for exposed workers who should be regularly examined to determine whether they present harmful health effects[186]. Worker Unions could be a possible stakeholder in developing a suitable programme in agreement with industrial R&D scientific staff, occupational medical doctors and policy makers. There is also the option to plan preventive health examinations for exposed workers and set up a specific follow up in coordination with occupational doctors. As lack of such information is relatively common, occupational doctors should be considered an important target group for information on EMF sources and highly exposed professions[187].

Relatively little research has addressed the issues related to IF (and indeed also SF) frequency ranges, and the specific exposure situations that may occur following the development of new types of technology. Therefore policy options in these frequency ranges could include funding or initiating research programmes, as well as improving the research-stakeholder interface on the topic of exposure and potential need for protection regarding occupational exposure. The advantages of promoting research are the outputs which can be used as a basis for considerations in decision-making, as well as in the development of technical solutions[185]. However, the development of new scientific programmes is often time consuming, and the results may not always be directly applicable in policy making.

Other possible policy measures include:

- Standardisation could be used for computer screens, induction hobs and hotplates and telephonic equipment, computer and television screens containing cathode ray tubes, compact fluorescent lamps and more
- Programmes of education and information for staff exposed to elevated levels of exposure, on IF-related risks and the requirements of safe work procedure such as those working close to devices (e.g. in shop exit doors), electric engines, and card readers or in industrial processes such as welding, medical applications such as electrosurgery. Educating key personnel may also mean that these persons can choose low-emitting equipment on purchases, which in turn puts a pressure on producers.
- Information to public on exposure of IF EMF in homes, for example the effect of turning off devices, choosing location of beds etc., could be a useful tool to encourage the population to take precautionary action.

Regarding advantages and disadvantages of legislation and recommendations see the discussion on power lines in section 4.2.1. On a workplace, however, the employer may have smaller interest in taking recommendations into account than legislation. Again, it

[186] Independent Expert Group on Mobile Phones (UK), Mobile Phones and Health. 2000 Available online at www.iegmp.org.uk/report/text.htm [Accessed online 08/03/2010] The Independent Expert Group on Mobile Phones, was formed following a decision of the UK Government in 1999 to establish an independent expert group to examine possible effects of mobile phones, base stations and transmitters on health. The group was operative until 2000, with input from a large range of stakeholders.

[187] Jolanta Karpowicz, Central Institute for Labour Protection – National Research Institute, Poland, Maila Hietanen, Finnish Institute of Occupational Health, Finland, Krzysztof Gryz, Central Institute for Labour Protection – National Research Institute, Poland. International EU Directive, ICNIRP Guidelines and Polish Legislation on Electromagnetic Fields. Journal of Occupational Safety and Ergonomics (JOSE), Vol. 12, No. 2, 125–136, 2006.

is important that the staff has access to information and can put pressure on the management in case IF related risks are ignored in the work place.

4.3.3. Policy approaches to reduce exposure to RF

4.3.3.1 Limiting exposure from mobile phones and similar devices

The question of exposure caused by the vast and increasing use of mobile phones and similar devices may be addressed in several ways by policy measures. When it comes to personal use, one policy option is information and recommendations to public on amount of use, type of equipment to use, and how to use it to reduce exposure, as a matter of precaution. German authorities, for instance, have published advice on the precautionary principle for mobile phone use[188]. Such advice could be part of the user manual, and could include instructions on how to reduce output power while using the mobile phone for example by keeping a certain distance between the mobile phone and the body (15 – 25 mm), or the benefits of avoiding the use of mobile phones while moving. Stricter policy actions could involve prohibiting of certain types of services which result in increased exposure for sensitive groups. An example could be a ban on offers from mobile phone operators of flat rates for children and teenagers. Advice could also be a relatively inexpensive option, whereas a ban on certain services would involve considerable processes of communication with stakeholders, namely the mobile telephony services sector. There may also be a problem on international market if services that are banned in one country are available in a neighbouring country.

The social aspect of security and communication linked to mobile phones is also an important aspect to be taken into account. Many parents and children feel safer if they know that they can reach each other if something unexpected occurs. The use of ICE numbers[189] on the mobile phone is also an example of how mobile devices can improve the feeling of security. The benefits of such measures may be debated, since there is to date no clear scientific proof of adverse effects from using mobile phones. On the other hand, guidance on many precautionary or mitigation measures is usually a low cost policy option.

Another policy option is the mandatory labelling of equipment to inform consumers and control exposure. For example, all mobile phones sold in Germany must comply with a limit value for SAR[190] radiation (which must not exceed 2 W/kg). Usually the manufacturers provide the SAR value of each phone in the instruction manual and on their website. A list of SAR values for the available mobile phones can be found on the

[188] German Federal Office for Radiation Protection, Webpage: www.bfs.de/en/elektro/faq/emf_faq_vorsorge.html, [Accessed online 08/03/2010]

[189] ICE is an abbreviation of ‘In Case of Emergency’. By registering a phone number to your closest relation under the contact name ICE in your phone address book, an un known person can contact your relatives in case of an emergency, without knowing their names.

[190] Specific Absorption Rate value, i. e. heat energy absorbed per kg body tissue absorbed by head and body. The SAR value is considered the best indicator of the user’s exposure.

Federal Office for Radiation Protection (BfS) website[191]. However, the BfS recommends using mobile phones whose SAR value is as low as possible. As advice to consumers, mobile phones put on the market may carry the eco-label "Blue Angel", which established the criteria for mobile phones in June 2002. The label ensures that emissions from the mobile phone do not exceed a SAR value of 0.6 W/kg, and that it complies with a series of other criteria[191]. However, due to the power adaption of mobile phones, having a good connection to the base station produces a much more effective exposure reduction than a phone with a low SAR value.

French mobile phone operator Orange can be mentioned as an example of voluntary environmental labelling of mobile phones[192]. The label (shown in Figure 4-4) is used for mobile- and cordless phones in France, Spain and Romania. The label includes several environmental parameters, of which the SAR value[190] is 1.

Figure 4-4: Mobile phone operator Orange's environmental -label (DAS is French equivalent of SAR)[193]

Similarly, mandatory measuring and reporting systems for RF emissions from products put into the market is an interesting policy option. For example since 2003, Finnish authorities measure the SAR of the cell phones put on the market[194]. In radiation tests, STUK[195] measures SAR with a testing system which is in compliance with international

[191] The German Federal Office for Radiation, Webpage: www.bfs.de/en/elektro/faq/faq_mobilfunk.html/#3. [Accessed online 08/03/2010])

[192] Orange in france webpage (in French or Spanish) www.orange-en-france.orange.fr/Developpement_durable/etiquetage_ecologique.html?p=4.3.5 [Accessed online 18/06/2010]

[193] This label was conceived by BIO Intelligence Service for Orange and World Wildlife Fund.

[194] Webpage of Finnish Radiation and Nuclear Safety Authority, on mobile phone testing: www.stuk.fi/sateilytietoa/sateilevat_laitteet/laitteiden_valvonta/en_GB/matkapuhelimet/ [Accessed online 08/03/2010]

[195] The Finnish Radiation and Nuclear Safety Authority, www.stuk.fi [Accessed online 08/03/2010]

standard[196]. It is assumed that the measured SAR value is at least as high as the maximum exposure in an actual situation, and thus, for the duration of the test, the mobile phone operates at its maximum power. The technology used in the phone, different user settings, and the anatomic features of the user's head, both children's and adults' are taken into account when testing. The measured phones are chosen randomly, primarily from the top-selling models. The tests, performed according to International (IEC 62209-1) standard and with specially designed equipment, are technically demanding and time-consuming. Therefore, only about 15 models are measured annually[194]. The tests results are available on the authority's (STUK[195]) web page[194] along with information on use and risks. Labelling, measurements, and reporting are all policy options which may be elaborated in cooperation with industry, which may lower the need for resources to be allocated from the public authorities. Furthermore, these options may promote a technical development towards lowering emissions from mobile devices. Because of the wide spread use of mobile and wireless equipment, even small improvements may be of great benefit to the overall IF exposure.

When it comes to indirect exposure to mobile devices, one policy option is to restrict the amount of use of mobile phones in situations where people are forced to stay close to each other over longer periods of time. This could include, for example, work situations or travelling. A more extreme measure to limit overall exposure would be to create EMF free zones. In Sweden, when travelling with Swedish Railways, one can choose to sit in a carriage where mobile phones must be switched off to reduce noise. Although the primary aim of this policy is not to reduce electromagnetic fields, this concept could be extended to EMF. If offered as a voluntary option to travellers, this measure may not have to be very expensive, and may even be used as a competitive advantage by transport companies. Depending of the travellers' awareness of EMF issues, however, the effect may vary.

4.3.3.2 Limiting exposure from antennas and base stations

In some of the Member States, there may not be existing administrative structures for impact assessments, public consultation or information prior to the installation of antennas and base stations for RF equipment. In these countries, therefore, relatively large antennas can be installed in residential areas without the need for a full planning application[186]. This means that although it may be generally accepted by the industry that exposure of people close to base stations or antennas are well within the limits suggested in guidelines, there is no independent body to inform public and ensure that exposure limits station/antenna are not exceeded. The installations may therefore still cause worries among the public[186]. One policy option is to make sure that location of antennas and base stations of a certain size/power shall be treated through existing procedures for planning and permission. This would mean that authorities should have

[196] International standard used: IEC 62209-1

the possibility to demand measurements or calculations for exposure assessment prior to authorising the construction of new antennas and base stations.

Added to this, the setting up of a mandatory periodical monitoring to map areas where there is a high density of base stations could be an interesting option. This would help to identify areas where exposure is potentially high, which could in turn affect permissions for further antennas to be installed, or indicate that precautionary technical actions need to be taken. For example, national databases could be set up by public authorities giving details of all base stations and the emission rates from these[186].

If no administrative authority exists which has the power to give construction permits and perform the monitoring of antennas and base stations, the cost for implementing the necessary legislation or policies may be high. Cooperation with the industry in the development of such systems is important to improve the result, gain acceptance and to reduce the cost. Future evaluation and research would be greatly facilitated by permission- and monitoring schemes, which in the long term will be of benefit in risk assessments regarding EMF.

4.3.3.3 Limiting exposure at home

Location and use of electrical devices and installations in homes, such as cordless phones, wireless network computers, anti theft devices and microwave ovens may affect exposure levels. Exposure from these sources may be difficult to address through policy measures other than information on products and use of products (such as for mobile devices, see 4.3.3.1). Setting up appropriate information programmes on how to choose the location of RF emitting equipment in the room or apartment to reduce RF exposure at home could also be a useful tool to encourage the population to take precautionary action. Such advice could include when to turn off devices, and the optimal location of beds in relation to certain electrical devices (for the policy option of information on precaution in homes, see section 4.3.1.2).

Another policy measure could be the setting up of educational and information programmes targeting salesmen at electronic shops, also advising on EMF when selling cordless mobile phones or wireless computer installations.

4.3.4. Policy approaches to reduce exposure to SF

Static fields are produced in some industrial processes, for example in the aluminium and chlor-alkali industries, welding processes and in certain railway and underground transport systems. Policy measures taken could include the measures described for occupational exposure in the section on IF EMF (see section 4.3.2.). Other possible policy measures include programmes of education and information for staff exposed to elevated levels of exposure (for the policy option of occupational education, see section 4.3.2.).

4.4. CONCLUSIONS AND RECOMMENDATIONS

There is no conclusive scientific evidence of any adverse health effects below the protection limits of exposure to electromagnetic fields proposed by the International Commission on Non-Ionising Radiation Protection (ICNIRP), implemented in Europe by the Council Recommendation 1999/519/EC. The advantage of applying the ICNIRP guidelines is their solid scientific basis of established biological effects.

Nevertheless, there is remaining scientific uncertainty in many fields, reflected by the call for further research by the Commission's Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) over the whole frequency spectrum. In the ELF range, there is a suggestion of a possible increased risk of childhood leukaemia associated with long-term exposures to magnetic fields as low as 0.2-0.4 µT, which – if causal – would explain approximately 1% of all childhood leukaemia cases in the European Union. Further, a modestly increased risk of Alzheimer's disease may be confirmed by future studies, although it is premature to draw any conclusions as available data today are highly controversial. Little research has been done in the IF range with more and more technologies emerging. In the RF range, mobile phone use is a very common source of exposure and even when scientific studies conducted to date do not show increased risks of any disease, data on longer term use of the devices beyond 10-15 years is sparse. Based on this, avoidance of unnecessary exposures, implementation of measures lowering emissions to levels that are currently technically feasible and not related to high expenses, and guidance of the public on how to avoid exposures, if they wish, appear to be the most appropriate options. Nevertheless, as public perception is different for collective (e.g. base stations) and individual (e.g. mobile phones) equipment, the management of concern due to these devices should be different. In parallel, research activities must continue to further reduce uncertainty in this field. Obviously, science-policy interface and public information about research results must be associated to research.

A precautionary lowering of protection limits is a rigorous step to enforce lower exposure, a policy option considered by some regional authorities within the EU. However, there is a lack of data on the impact of stricter exposure levels on the total distribution of exposure levels in the population. In the ELF range, average 24 hours exposure to magnetic fields of the general public rarely exceed 1 µT, thus, protection limits of 1 µT compared to the existing 100 µT would hardly make any difference and appear to rather address public concern than leading to a measurable reduction of exposure. Stricter levels of exposure have to be accompanied by monitoring in order to ensure that these levels are kept, as the technologies remain the same, but introduce additional costs for surveillance. It is a recommendation to perform measurement surveys of exposure in regions of lower protection limits to compare them with exposure distributions in regions of the adopted EC Directive, to quantify the impact of the measure.

There are some technical options to further reduce exposure, ranging from very costly to moderate expenses. An expensive option is removing existing power lines or transmitter stations and it is doubtful this can be achieved on a national level. Only applying the option of minimum distances between such installations and residential areas requires cost-benefit analyses, however, it appears that this is mainly an option for less densely populated areas in high-income countries; it would also introduce social inequality if measures are taken in respect of new installations while existing ones remain unchanged. Some new technologies appear to be related to lower exposures, even when exposure reduction was not the primary aim: examples are the new generation of mobile phones (UMTS versus GSM) or replacing the analogue radio and TV broadcasting systems with the new digital one. Technically unnecessary exposures are related to devices emitting fields when they are not in use, i.e., electric devices in standby modus or DECT cordless phone base stations.

Avoidance of unnecessary exposure is mainly an issue for users of EMF devices. Electric installations in homes should use modern systems, as elevated fields from indoor wiring are often found in older homes. Electric devices should only be switched on when they are used. Landline phones instead of cordless phones or mobile phones should be preferred in families with small children and, further, teenagers should be discouraged to extensively use mobile phones. Such recommendations could be supplemented with policies to prohibit offering of flat rates for children and teenagers. Mobile phones could be sold always with wired hands-free devices, to automatically provide customers the opportunity to reduce exposure when using them. How to use of mobile phones under low power conditions could be a mandatory part of the mobile phone manual and the current output power could be indicated on the screen of the phone.

In conclusion, society and/or decision-makers have to decide which options of exposure reductions are to be applied, given the present scientific uncertainty in relation to some exposure scenarios. However, it is unclear at the moment whether precautionary measures lead to any benefits. For this purpose, the options, their potential benefits, and potential lack of any benefits together with the implementation costs have to be communicated in a transparent manner. At the same time, more data are needed to have a better overview of an individual's total EMF exposure in a modern environment, to better identify where exposure peaks occur, and how they can be avoided.