Human Beings and Radiation – A Review

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Abstract

Humans live and breathe every day in an environment full of natural and artificial radiation. Radiation's nature is energetic particles and/or electromagnetic waves. The damage to tissue from ionizing radiation is being studied decades ago. In contrast, concerns, about the potential health risk associated with unprecedented exposure to non-ionizing radiation, emerge nowadays. Scientists expect objective results to be revealed after few decades of extended use of many low frequency devices or equipment, as well as wireless net and mobile phones. This paper reviews the sources and the most recent results of the effects of radiation, focusing however on the non-ionizing part and, especially, the radiation from radio waves and mobile phones.

Key words: Environmental radiation, non-ionizing, electromagnetic radiation

Introduction

Radiation is classified according to its effects on matter, namely into (a) ionizing or (b) non-ionizing. In brief, ionizing radiation has the power to ionize atoms. It includes cosmic rays that reach Earth from outer space, radioactivity from atmosphere, human body interior, food, drinks, ground and building materials, as well as X and gamma rays and other types of radiation from radioactive materials. On the contrary, non-ionizing radiation has not enough energy to ionize atoms. It includes wavelengths in the optical, ultraviolet and infrared regions, microwaves and radio waves.

Radiation, from another point of view, is classified according to its origin, into (a) natural or (b) artificial. Natural radiation is due to natural sources. It exists in the environment since the earth's formation, viz., long before life appeared. Radon is the dominant source of environmental radiation. On the contrary, artificial radiation is induced by human activity. It emerges as a result of medical, nuclear, other industrial uses, as well as electric power transfer, cable and wireless communication.

In terms of physical processes, radioactivity is the spontaneous transformation of unstable nuclei in matter towards a more stable structure. Alpha and beta radiation are particles, whereas gamma is electromagnetic radiation. For this reason, radiation can also be classified according to its nature as (a) particles with mass or (b) as electromagnetic waves (photons). It is worth noting that the decay of natural radioactive materials is responsible for Earth's internal heat with major heat-producing isotopes being potassium-40, uranium-238, uranium-235 and thorium-232 (EPA, 2013; UNSCEAR, 2000; IAEA, 2004; Wahl, 2010).

Non-Ionizing Radiation

Humans are being constantly exposed to electromagnetic radiation (EMR), including sunlight, cosmic rays and terrestrial radiation. However, a substantial increase in exposure to non-ionizing radiation and especially to low frequency electromagnetic radiation (LF-EMR), started in the early 20th century with the generation of artificial electromagnetic fields and continued with the development of power stations, radios, radars, televisions, computers, mobile phones, microwave ovens and numerous devices used in medicine, industry and at home. These technological advances have aroused concerns about the potential health risks associated with unprecedented levels of EMR exposure (Ahlbom et al., 2008; HPA, 2004a,b; NRPB, 2003; SCENIHR, 2007, 2009; Valberg et al., 2007).

The amount of energy deposited by non-ionizing EMR and the nature of its absorption are determined by the frequency and type of incident radiation and by the type of tissue that absorbs it. Exposure to multiple sources of non-ionizing radiation (Table 1), including residential exposure to high-voltage power lines, transformers, and domestic electrical installations, varies in duration and depends on the distance from the source. Exposures to extremely low-frequency electric and magnetic fields emanating from generation, transmission and uses of electricity constitute a ubiquitous part of modern life (CENELEC, 2008; EU, 1999). In contrast to ionizing radiation, where natural sources contribute the largest proportion to population exposure, man-made non-ionizing sources tend to dominate the human exposure to electromagnetic fields. In all cases of non-ionizing EMR, exposure depends not only on the strength of the field but also on the distance from the source and, in the case of directional antennas, on the proximity to the main beam. The field strength often decreases rapidly with distance (IEC, 2005; IEEE, 2004, 2005a,b; WHO, 2002, 2006, 2010, 2011).

Table 1. Frequencies and sources of non-ionizing radiation

Frequency	Type of radiation	Sources
0 Hz–300 kHz	Low frequency to extremely low frequency (LF–ELF) electromagnetic radiation	Electrical fields of devices, conventional electrical network, video monitors, sections of AM radio
3 kHz–300 MHz	Radio frequencies (RF)	Sections of AM radio, FM radio, medical short-wave, nuclear magnetic resonance (NMR)
300 MHz–300 GHz	Microwave (MW)	Domestic microwave devices, mobile telephones, microwave for medical physical therapy, radar and other microwave communications
$3*10^{11} – 3*10^{14}$ Hz	Infrared (IR)	Solar light, heat and laser therapy devices
$10^{14} – 10^{15}$ Hz	Visible light	Solar light, phototherapy, laser
$10^{15} – 10^{17}$ Hz	Ultraviolet (UV)	Solar light, fluorescent tubes, food/air sterilization, radiotherapy, etc.

In the everyday environment, RFs are emitted by numerous sources operating in different frequency bands (Table 2). These sources can be subdivided in two broad categories: (a) ambient sources, such as broadcast transmitters (radio, TV), or mobile phone base stations and (b) personal sources, such as mobile phones, in-house bases for cordless phones (DECT - Digital enhanced cordless telephony), microwave ovens, wireless networks. Consequently, exposure to RF varies considerably across persons, space and time (Viel et al., 2009; Frei et al., 2009a,b). There are, therefore, significant challenges in assessing the sources of variation and related uncertainty, but also in identifying exposure relevant factors (Ahlbom et al., 2004; Joseph et al., 2009, 2010a,b, 2012; Mann et al., 2005; Röösli et al., 2008, 2010; Viel et al., 2009; Vrijheid et al., 2008).

Table 2. Personal exposure meter frequency bands (EME SPY 120, Satimo, France)

Band name	Active sources	Range (MHz)
FM	VHF broadcast radio	88–108
TV 3	Digital audio broadcasting	174–223
Tetrapol	Terrestrial trunked radio	380–400
TV 4&5	UHF broadcast television	470–830
GSM[a] Tx[b]	GSM mobile phones (900 MHz)	880–915
GSM Rx[c]	GSM base stations (900 MHz)	925–960
DCS[d] Tx	DCS mobile phones (1800 MHz)	1710–1785
DCS Rx	DCS base stations (1800 MHz)	1805–1880
DECT[e]	Digital enhanced cordless telephony	1880–1900
UMTS[f] Tx	3 G mobile phones	1920–1980
UMTS Rx	3 G base stations	2110–2170
WiFi	Wireless networks and microwave ovens	2400–2500

[a] Global System for Mobile Communications
[b] Transmitted radio signal from the point of view of a mobile phone
[c] Received radio signal from the point of view of a mobile phone
[d] Digital Communication System
[e] Digital Enhanced Cordless Telephone
[f] Universal Mobile Telecommunication System

Exposure to non-ionizing EMR sources is commonly described by the electric and magnetic field strengths, which are however measured in the space around the subject. Any biological effects would be the result of the exposure within the body and this is difficult to be measured directly. The nature of the field and the characteristics of the source differ considerably from each other (HPA, 2004a,b,c, 2012; Frei et al., 2009a,b).

At frequencies below 100 kHz, the physical quantity associated with most biological effects is the electric field strength in tissue (ICNIRP, 1998, 2009). The more appropriate quantity at higher frequencies is the specific absorption rate, SAR, which is related to the second power of the electric field strength in tissue (IEC, 2005; NRPB, 2003; SAR Database, 2012). At frequencies above about 1 MHz, the orientation of the body with respect to the incident field becomes increasingly important, because the body behaves as an antenna, absorbing energy in a resonant manner (for standing adults the maximum absorption occurs when frequency varies between 70-80 MHz, a value that depends on the isolation status relative to the ground). As the frequency increases above the resonance region, energy absorption becomes confined to the surface layers of the body, limited to the skin when frequency reaches a few tens of GHz (NRPB, 2003; SCENIHR, 2007, 2009; ICNIRP, 2009; Ahlbom et al., 2004, 2008; HPA, 2012).

Studies to evaluate internal exposure are carried out either by using computational methods or by making measurements in phantoms. The computational methods rely on the detailed anatomical information, in addition to information on the electrical properties of the different tissues for each frequency regime. The electric field at various points inside simple phantoms is usually measured via a robotically positioned probe, small enough to minimise the changes in the fields produced by its presence. In simple cases, estimation of the inside exposure can rely on measurement of the field outside the body accompanied by reasonable approximations (NRPB, 2003; HPA, 2012; WHO, 2002, 2006, 2010, 2011).

The power density of an electromagnetic wave is equal to the product of the electric and magnetic fields, although this is not true in near-field regions, i.e. when the distance from the source is comparable to the wavelength. In the near-field region the electric and magnetic fields are neither perpendicular to each other nor in phase. In general, the fields can be divided into two components: radiative and reactive (NRPB, 2003). The radiative component is that part of the field which propagates energy away from the source, while the reactive component can be thought of as relating to energy stored in the region around the source. The reactive component dominates close to the source and the stored energy can be absorbed by people standing in the near-field region. Distances of about one-sixth of a wavelength from the source define approximately the near-field boundary (NRPB, 2003; ICNIRP, 2009; HPA, 2012; Valberg et al., 2007; Lauer et al., 2013).

The average magnetic flux density (in μT) is, generally, considered to be below the maximum exposure limits established by different organizations, such as the International Council of Non-Ionizing Radiation Protection (ICNIRP, 1998) or the National Radiological Protection Board (NRPB, 2003).

The International Commission on Non-Ionizing Radiation Protection and the National Radiological Protection Board, together with the Health Protection Agency (HPA), the Institute of Electrical and Electronics Engineers (IEEE), the International Telecommunication Union Recommendation (ITU-R, 2005) and European Union committees, reviewed many relevant studies and recommended guidelines on restrictions for exposure to electromagnetic fields.

Recommended restrictions are based on biological data relating to thresholds for adverse direct and indirect effects of acute exposure. As compliance with the basic restrictions cannot be easily determined, ICNIRP recommends reference levels as values of measurable field quantities for assessing whether compliance with the basic restrictions is achieved (ICNIRP, 1998; NRPB, 2003). Table 3 summarises the reference levels for electric field intensity (in V/m), magnetic flux density (in μT) and power density (in W/m^2). Corresponding values for occupational exposure are about five times higher (ICNIRP, 1998; NRPB, 2003; HPA, 2012).

Table 3 ICNIRP reference levels for general public exposure to time-varying electric and magnetic fields (rms values). 'f' stands for frequencies as indicated in the column of frequency range

Frequency range	E-field intensity (V/m)	B-field intensity (μT)	Wave Power Density (W/m^2)
0–1 Hz	–	4×10^4	–
1–8 Hz	10,000	$4 \times 10^4 / f^2$	–
8–25 Hz	10,000	5000 / f	–
0.025–0.8 kHz	250 / f	5/ f	–
0.8–3 kHz	250 / f	6.25	–
3–150 kHz	87	6.25	–
0.15–1 MHz	87	0.92 / f	–
1–10 MHz	$87 / f^{1/2}$	0.92 / f	–
10–400 MHz	28	0.09	2
400–2000 MHz	$1.375 \times f^{1/2}$	$0.0046 \times f^{1/2}$	f / 200
2–300 GHz	61	0.2	10

1. Radiofrequency Exposure

The relative contribution of radiofrequencies (RFs) to exposure depends on individual home and workplace circumstances. For a given source, the actual exposure to RF depends on a number of factors. Regarding mobile phones, the characteristics of a certain phone (particularly type and location of the antenna), the way the phone is handled, the distance from the base station, the frequency of handovers and RF traffic conditions are of prime importance (Ahlbom et al., 2004, 2008; Briggs et al., 2012; Inyang et al., 2008). Similarly, RF fields from mobile phone base stations also exhibit a complex pattern, influenced by numerous factors, such as, the output power of the antenna, the direction of transmission, the attenuation due to obstacles or walls, and any existing scattering from buildings and trees (Neubauer et al., 2007; Joseph et al., 2009, 2010a,b, 2012; Mann et al., 2005). There are, therefore, significant challenges in assessing the exposure of individuals in the general population to RF signals, including the number and range of sources involved and the effect of the environment on signal strength as people move around. In principle, two different types of radio frequency electromagnetic fields (RF-EMF) exposure sources can be distinguished: (a) sources which are applied close to the human body usually causing high and periodic short-term exposure mainly to the head (e.g. mobile phones) and (b) environmental sources which, in general, cause lower but relatively continuous whole-body exposure (e.g. mobile phone base stations). While exposure from mobile phones can be assessed using self-reported mobile phone use or operator data (Vrijheid et al., 2008), valid assessment of exposure to environmental fields is more challenging.

Frei et al studied temporal and spatial variabilities of personal exposure to radio frequency electromagnetic fields. They concluded (Frei et al., 2009a) that exposure to RF-EMF varied considerably between persons and locations but was fairly consistent within persons. Mobile phone handsets, mobile phone base stations and cordless phones were important sources of exposure in urban Switzerland. Their results revealed mean weekly exposure values to all RF-EMF sources equal to 0.13 mW/m^2 (0.22 V/m) with the range of individual means between 0.014–0.881 mW/m^2).

Exposure was mainly due to mobile phone base stations (32.0%), mobile phone handsets (29.1%) and digital enhanced cordless telecommunications (DECT) phones (22.7%). Mean values were highest in trains (1.16 mW/m^2), airports (0.74 mW/m^2) and tramways or buses (0.36 mW/m^2) and higher during daytime (0.16 mW/m^2) than night-time (0.08 mW/m^2). However Frei et al in a later publication (2010) claim that "exposure to radio frequency electromagnetic fields (RF-EMF) in everyday life is highly temporally and spatially variable due to various emitting sources like broadcast transmitters or wireless local area networks (W-LAN).

Joseph et al reported their research (2012) about in situ electromagnetic radio frequency exposure to existing and emerging wireless technologies by using spectrum analyzer measurements at 311 locations (68 indoor, 243 outdoor), subdivided into six different categories (rural, residential, urban, suburban, office and industrial), geographically spread across Belgium, The Netherlands and Sweden. The maximal total value was measured in a residential environment and found to be equal to 3.9 Vm^{-1}, mainly due to the GSM900 signal (11 times below the ICNIRP reference levels).

Conclusion

Any man would receive significant radiation dose if radiotherapy was necessary. Considerable care is required to deliver accurate doses: too low or too high doses may lead to incomplete treatment or unacceptable side effects respectively.

As far as exposure to non-ionizing radiation is concerned, absorbed energy from human body is very low, but becomes significant if it is continuous for very long periods of time accounting the fact that the related effects are not yet well known.

The environmental radiation, ionizing or non-ionizing, is unambiguous. However, people should protect themselves by avoiding spending time in regions 'rich' with radon and its products, as well as regions with any kind of antennas.

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References

1. Ahlbom,A., Green,A., Kheifets,L., Savitz,D., Swerdlow,A., 2004. Epidemiology of health effects of radiofrequency exposure. Environ. Health Perspect. 112, 1741–1754.

2. Ahlbom,A., Bridges,J., deSeze,R., Hillert,L., Juutilainen,J., Mattsson,M.O., et al., 2008. Possible effects of electromagnetic fields (EMF) on human health—opinion of the scientific committee on emerging and newly identified health risks (SCENIHR). Toxicology 246, 248–250.

3. Bolte, J., Pruppers,M., Kramer,J., VanderZande,G., Schipper,C., Fleurke,S., Kluwer, T., VanKamp,I., Kromhout,J., 2008. The Dutch exposimeter study: developing an activity exposure matrix. Epidemiology 19(6), S78–79.

4. Briggs D, Beale L, Bennett J, Toledano MB, de Hoogh K., 2012. A geographical model of radio-frequency power density around mobile phone masts. Sci Total Environ 426, 233–243.

5. CENELEC (European Committee for Electrotechnical Standardisation), 2008. TC 106x WG1 EN 50492 in situ. Basic standard for the in-situ measurement of electromagnetic field strength related to human exposure in the vicinity of base stations. Brussels, Belgium.
6. EPA Environmental Protection Agency, 2009. Radon: Health risks. Available at: http://www.epa.gov/radon/healthrisks.html . Accessed May 2013.
7. EPA Environmental Protection Agency, 2013. Radiation: Non-Ionizing and Ionizing. Available at: http://www.epa.gov/rpdweb00/understand/index.html#nonionizing. Accessed May 2013.
8. EU European Union, 1999. Council Recommendation (1999/519/CE) of 12 of July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz). Official Journal of the European Communities.
9. Frei,P., Mohler,E., B¨urgi,A., Fröhlich,J., Neubauer,G., Braun-Fahrl¨ander,C., Röösli,M., and the QUALIFEX team, 2009a. A prediction model for personal radiofrequency electromagnetic field exposure, Sci.Total Environ. 408,102–108.
10. Frei,P., Mohler,E., Neubauer,G., Theis,G.,B¨urgi,A., Fr¨ohlich,J., Braun-Fahrl¨ander,C., Bolte,J., Egger,M., Röösli, M., 2009b. Temporal and spatial variability of personal exposure to radiofrequency electromagnetic fields. Environ.Res.109, 779–785.
11. Frei P, Mohler E, Bürgi A, Fröhlich J, Neubauer G, Braun-Fahrländer C, et al., 2010. Classification of personal exposure to radio frequency electromagnetic fields (RF-EMF) for epidemiological research: evaluation of different exposure assessment methods. Environ Int 36, 714–720.
12. HPS Health Physics Society, 2009. Update on perspectives and recommendations on indoor radon. http://hps.org/documents/radon_position_statement.pdf. Accessed May 2013.
13. HPS Health Physics Society, 2011. Radiation exposure during commercial airline flights. Available at: http://hps.org/publicinformation/ate/faqs/commercialflights.html. Accessed May 2013.
14. HPA Health Protection Agency, 2004a. Advice on Limiting Exposure to Electromagnetic Fields (0-300 GHz) http://www.hpa.org.uk/Publications/Radiation/NPRBArchive/DocumentsOfTheNRPB/Absd1502/ Accessed May 2013.
15. [17] HPA Health Protection Agency, 2004b. Advice on Limiting Exposure to Electromagnetic Fields (0-300 GHz) http://www.hpa.org.uk/Publications/Radiation/NPRBArchive/DocumentsOfTheNRPB/Absd1503/ Accessed May 2013.
16. HPA Health Protection Agency, 2004c. Mobile Phones and Health: Report by the Board of NRPB. Documents of the NRPB: Volume 15, No. 5. http://www.hpa.org.uk/web/HPAweb&HPAwebStandard/HPAweb_C/1254510624582 Accessed May 2013.
17. HPA Health Protection Agency, 2012. Health effects from radiofrequency electromagnetic fields. Report of the independent Advisory Group on non-ionizing

radiation. http://www.hpa.org.uk/webc/hpawebfile/hpaweb_c/1317133827077 Accessed May 2013

18. IAEA International Atomic Energy Agency, 2004. Radiation, people and the environment. IAEA/PI/A.75/04-00391, Division of public information, Austria.
19. IAEA International Atomic Energy Agency, 2011. Safety Standards, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards. Interim edition for protecting people and the environment. No. GSR Part 3 (Interim). General Safety Requirements Part 3. http://www-pub.iaea.org/MTCD/Publications/PDF/p1531interim_web.pdf. Accessed May 2013.
20. ICNIRP International Commission on Non-Ionizing Radiation Protection, 1998. Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up 300 GHz). Health Phys 74 (4):494–522.
21. ICNIRP International Commission on Non-Ionizing Radiation Protection, 2009. Exposure to high frequency electromagnetic fields, biological effects and health consequences (100 kHz–300 GHz). International Commission on Non-Ionizing Radiation Protection. Available: http://www.icnirp.org/documents/RFReview.pdf . Accessed May 2013.
22. IEC International Electrotechnical Commission, 2005. Human Exposure to Radio Frequency Fields from Hand-Held and Body-Mounted Wireless Communication Devices – Human Models, Instrumentation, and Procedures to Determine the Specific Absorption Rate (SAR) for Hand-Held Devices Used in Close Proximity to the Ear (Frequency Range of 300MHz to 3 GHz). International Standard 62 209.
23. IEEE Institute of Electrical and Electronics Engineers, 2004. Standard for local and metropolitan area networks Part 16: air interface for fixed broadband wireless access systems. Piscataway, NY: IEEE; IEEE 802.16d-2004.
24. IEEE Institute of Electrical and Electronics Engineers, 2005a. Standard for local and metropolitan area networks part 16: air interface for fixed and mobile broadband wireless access systems. Amendment 2: physical and medium access control layers for combined fixed and mobile operation in licensed bands and corrigendum 1 corrigendum to IEEE Std 802.16-2004 (Revision of IEEE Std 802.16-2001). Piscataway, NY: IEEE; IEEE 802.16e-2005.
25. IEEE Institute of Electrical and Electronics Engineers, 2005b. Standard for safety levels with respect to human exposure to radio frequency electromagnetic fields, 3 kHz to 300 GHz. Piscataway, NY: IEEE; IEEE C95.1-2005.
26. Inyang,I., Benke,G., McKenzie,R., Abramson,M., 2008. Comparison of measuring instruments for radiofrequency radiation from mobile telephones in epidemiological studies: implications for exposure assessment. J. Expo. Sci. Environ. Epidemiol. 18, 134–141.
27. ITU-R International Telecommunication Union Recommendation SM. 1708, 2005. Field-strength measurements along a route with geographical coordinate registrations. Geneva: ITU-R; 1708.
28. Joseph,W., Verloock,L., Tanghe,E., Martens,L., 2009. In-situ measurement procedures for temporal RF electromagnetic field exposure of the general public. Health Phys. 96, 529–542.

29. Joseph,W., Verloock,L., 2010a. Influence of mobile phone traffic on base station exposure of the general public. HealthPhys. 99, 631–638.

30. Joseph,W., Frei,P., Röösli,M., Thuroczy,G., Gajsek,P., Trcek,T., et al., 2010b. Comparison of personal radio frequency electromagnetic field exposure in different urban areas across Europe. Environ Res 110, 658–663.

31. Joseph,W., Verloock,L., Goeminne,F., Vermeeren,G., Martens,L., 2012. Assessment of RF exposures from emerging wireless communication technologies in different environments. Health Phys. 102, 161–172.

32. Lauer,O., Frei,P., Gosselin,M.-C., Joseph,W., Röösli,M., Riederer,M., Fro¨hlich,J., 2013. Combining Near and Far Field exposure for an organ-specific and whole-body RF-EMF proxy for epidemiological research: a reference case. Bioelectromagnetics 33(1), 75–85.

33. Mann, S.M., Addison,D.S., Blackwell,R.P., Khalid,M., 2005. Personal dosimetry of RF radiation: laboratory and volunteer trials of an RF personal exposuremeter. Health Protection Agency HPA-RPD-008.

34. Neubauer,G., Feychting,M., Hamnerius,Y., Kheifets,L., Kuster,N., Ruiz,I., Schuz,J., Uberbacher, R., Wiart,J., Röösli,M., 2007. Feasibility of future epidemiological studies on possible health effects of mobile phone base stations. Bioelectromagnetics 28, 224–230.

35. NRPB National Radiological Protection Board, 2003. Documents of the NRPB: Health effects from radiofrequency electromagnetic fields, Volume 14, No. 2.

36. Röösli,M., Frei,P., Mohler,E., Braun-Fahrl¨ander,C., B¨ urgi, A., Fröhlich,J., Neubauer,G., Theis,G., Egger,M., 2008. Statistical analysis of personal radiofrequency electromagnetic field measurements with non-detects. Bioelectromagnetics 29, 471–478.

37. 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,A.S., Radon,K., Schuz,J., Thuróczy,G., Viel,J.F., Vrijheid,M., 2010. Conduct of a personal radiofrequency electromagnetic field measurement study: proposed study protocol. Environ. Health 9, 23.

38. SAR Database, 2012. http://www.sardatabase.com/ Accessed May 2013.

39. SCENIHR Scientific Committee on Emerging and Newly Identified Health Risks, 2007. Possible effects of Electromagnetic Fields (EMF) on Human Health. Brussels: European Commission. http://ec.europa.eu/health/ph_risk/committees/04_scenihr/docs/scenihr_o_007.pdf Accessed May 2013.

40. SCENIHR Scientific Committee on Emerging and Newly Identified Health Risks, 2009. Health Effects of Exposure to EMF. Brussels: European Commission. http://ec.europa.eu/health/ph_risk/committees/04_scenihr/docs/scenihr_o_022.pdf Accessed May 2013.

41. Trcek,T., Valic,B., Gajsek,P., 2007. Measurements of background electromagnetic fields in human environment. IFMBE Proceedings 11th Mediterranean Conference on Medical and Biomedical Engineering and Computing 2007, Ljubljana, Slovenia MEDICON, vol.16, pp. 222–225.

42. UNSCEAR United Nations Scientific Committee on the Effects of Atomic Radiation, 2000. Sources and effects of ionizing radiation. Report to the United Nations General Assembly. New York: United Nations.

43. UNSCEAR United Nations Scientific Committee on the Effects of Atomic Radiation, 2009. http://www.unscear.org/docs/Radon-distrib.pdf. Accessed May 2013.

44. Valberg,PA, van Deventer, TE, Repacholi,MH., 2007. Workgroup report: base stations and wireless networks-radiofrequency (RF) exposures and health consequences. Environ Health Perspect 115, 416–424.

45. Viel,J.F., Cardis,E., Moissonnier,M., deSeze,R., Hours,M., 2009. Radiofrequency exposure in the French general population: band, time, location and activity variability. Environ. Int. 35, 1150–1154.

46. Vrijheid,M., Armstrong,B.K., Bedard,D., Brown,J., Deltour,I., Iavarone,I., et al., 2008. Recall bias in the assessment of exposure to mobile phones. J.Expo.Sci. Environ.Epidemiol. 19, 369-381.

47. Wahl E.L., 2010. Environmental Radiation, Lawrence Berkeley National Laboratory, Fact Sheet http://hps.org/documents/environmental_radiation_fact_sheet.pdf. Accessed May 2013.

48. WHO World Health Organization, 2002. Establishing a dialogue on risks from electromagnetic fields. Geneva, Switzerland http://www.who.int/peh-emf/publications/en/emf_final_300dpi_ALL.pdf. Accessed May 2013.

49. WHO World Health Organization, 2006. Electromagnetic fields and public health: base stations and wireless technologies http://www.who.int/peh-emf/publications/factsheets/en/index.html. Accessed May 2013.

50. WHO World Health Organization, 2010. WHO Research Agenda for Radiofrequency Fields. Geneva, Switzerland http://apps.who.int/iris/bitstream/10665/44396/1/9789241599948_eng.pdf. Accessed May 2013.

51. WHO World Health Organization, 2011. Electromagnetic fields and public health: mobile phones. June 2011. Fact sheet N°193. http://www.who.int/mediacentre/factsheets/fs193/en/index.html. Accessed May 2013.