istituto per il rilevamento elettromagnetico dell'ambiente

BIOEM-LAB

Biological effects of high frequency electromagnetic fields

Olga Zeni

CNR - Institute for Electromagnetic Sensing of the Environment, Naples – Italy

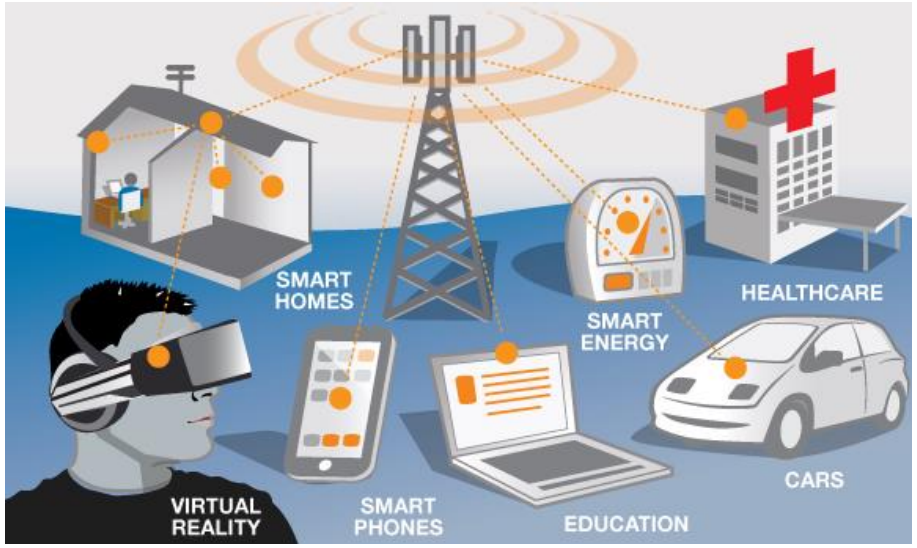
zeni.o@irea.cnr.it

Outline

- Exposure sources
- Biological and health effects
- Summary of the available evidences of non-thermal effects
- Concluding remarks and research recommendation

High Frequency EMF: 100 kHz - 300 GHz

Medicine, industry, domestic, security but mainly communications appliances



2G, 3G and 4G technology

5 G wireless communication technology comprises parts of 3G and 4G technologies + technologies employing MMW for the fast transfer of large amount of data

Frequencies of 5G

< 6 GHz (0.7 – 3.8)

> 6 GHz (24.25 – 71)

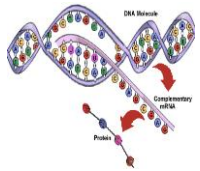
Biological effect

The exposure induces modifications of the physiological conditions of a biological system

Health effect

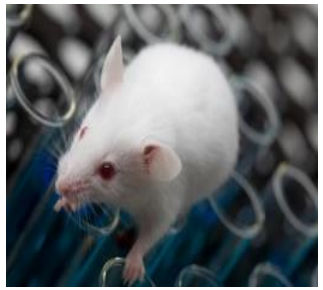
The induced biological effect exceeds the capability of the biological system to compensate the modifications

Tissues, cells and molecules



***In vitro* - cell, biochemical and molecular investigations**

Individual



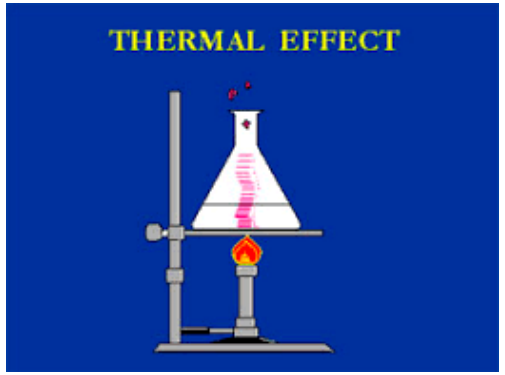
***In vivo* – investigation on animal models and humans**

Population

Epidemiological studies

Extablished biological effects

Evident, replicated and consistent



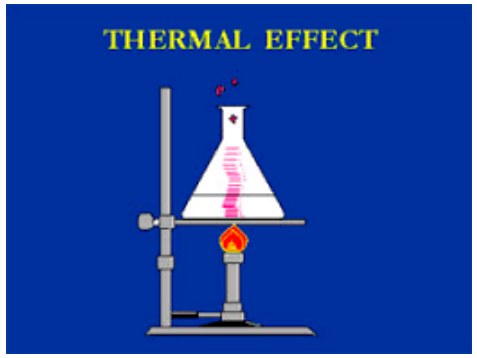
Heating of exposed tissue due to the penetration of the RF EMF into the body causing vibration of ions or polar molecules

The higher the frequency, the lower the penetration depth with surface heating being the predominant effect for frequencies above 6 GHz

Common effects are structural protein damage, cell death, activation of intracellular stress response and disruption of organelles function. They depend on the duration of exposure and can provoke health effects like tissue damage and heatstroke.

Extablished biological effects

Evident, replicated and consistent



Thermal effect occurs above a given exposure threshold

ICNIRP INTERNATIONAL COMMISSION ON NON-IONIZING RADIATION

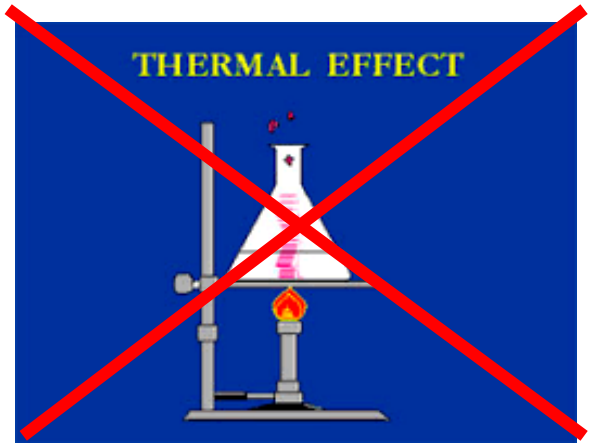
Basic restrictions

Parameter	Frequency range	ΔT	Spatial averaging	Temporal averaging	Health effect level	Reduction factor	Workers	Reduction factor	General public
Core ΔT	100 kHz-300 GHz	1° C	Whole body average	30 min	4 W/kg	10	0.4 W/kg	50	0.08 W/kg
Local ΔT(Head and Torso)	100 kHz-6 GHz	2° C	10 g	6 min	20 W/kg	2	10 W/kg	10	2 W/kg
Local ΔT (Limbs)	100 kHz-6 GHz	5° C	10 g	6 min	40 W/kg	2	20 W/kg	10	4 W/kg
Local ΔT (head and torso, limbs)	>6-300 GHz 30-300 GHz	5° C	4 cm^2 1 cm^2	6 min 6 min	200 W/m^2 400 W/m^2	2	100 W/m^2 200 W/m^2	10	20 W/m^2 40 W/m^2

The ICNIRP RF EMF guidelines (2020) protect against all potential adverse health effects relating to exposure to RF-EMF, including from 5G technologies by specifying basic restrictions for general public and workers

https://www.icnirp.org/cms/upload/publications/ICNIRPrfgdl2020.pd

Non-thermal biological effects



The existence of acute and long-term effects of RF-EMF exposure below the thermal threshold has been extensively investigated and is still controversial

- **Huge amount of studies that differ greatly for biological models, exposure conditions (frequency, SAR level, exposure duration) and endpoints**

2G, 3G and 4G technology

Frequencies of 5G

< 6 GHz (0.7 – 3.8) – already explored for health risk evaluation

> 6 GHz (24.25 – 71) – mainly explored for biomedical applications

Extensive Literature review on biological effects

Evaluating the database of studies at different levels
Evidence appraisal and health risk evaluation

- **SCENIHR Opinion (2015)**
  https://ec.europa.eu/health/scientific_committees/emerging/opinions_en
- **IEEE C95.1 (2019) –** ***https://standards.ieee.org/standard/C95_1-2019.html***
- **ICNIRP Guidelines (2020) –** ***Health Physics 118 (5): 483-524, 2020***

The main conclusions are basically consistent with each other

Non cancer related endpoints

- **RF hearing**

  Well established biological effects in humans resulting from brief (35-100 μs) RF pulses causing thermoelastic expansion that is detected by sensory cells in the choclea.
  It does not exert known adverse health consequences

- **Hematological and immunological effects**

  The larger body of evidence report no effect on related endpoints in *in vitro* and *in vivo* experimental models. Effects detected in few studies are inconsistent with each other

Non cancer related endpoints

➢ Ocular effects

Mainly no effects on ocular functions

Some evidence of superficial eye damage has been shown in rabbits at exposures of at least 1.4 kW/m^2

➢ Teratogenesis effects

The results of a few studies reporting teratogenic, reproductive and developmental effects below 4 W/kg SAR are weak in experimental design and have not been confirmed independently

Non cancer related endpoints

- **Effects on brain physiology and functions**

No consistent evidence of effects on cognitive function and memory, on sleep disturbances, headache and fatigue in the provocation studies

Studies analyzing frequency components of EEG have reliable shown that the 8-13 Hz alpha band in waking EEG and the 10-14 Hz «sleep spindle» frequency range in sleep EEG are affected by RF-EMF exposure at a SAR < 2W/kg

Several studies on cell lines addressed endpoints such as intra and intercellular signalling, membrane ion channels currents Ca^{2+} dynamics, signal transduction pathways, cytokines expression, biomarkers of degeneration, hsps and oxidative stress with often contradictory results

Cancer related endpoints – long term animal studies

- ✓ **No evidence of disease-specific effects**
- ✓ **Some positive studies not replicated when more accurate exposure systems and dosimetry are used**
- ✓ **NTP and Ramazzini studies claimed on carcinogenic potential of long term exposure to RF associated to mobile phone and base stations: large number of animals exposed for the whole life but lack of adequate statistics to differentiate the effect from the normal differences between the treatment conditions. Very high exposure levels.**

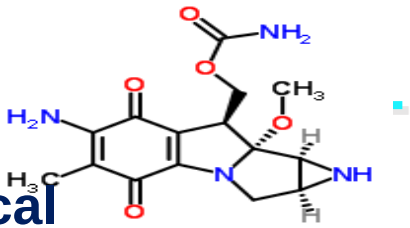
Cancer related endpoints – cellular studies

No reliable effects on

- ✓ **Genotoxicity**
- ✓ **Proliferation and cell cycle analysis**
- ✓ **Gene and proteins expression and activities**
- ✓ **Oxidative stress**

When present, the effect is small and within the normally occurred range of variability. Even if independently replicated, health implication unclear.

Combined exposure to RF and other agents



- ✓ **Sensitization of mammalian cells/animals with chemical/physical treatments allows to evidence possible weak, non-thermal effects of RF EMF exposures**
- ✓ **Combined exposure to RF might potentiate or mitigate the biological effects of exposure to known toxicological agents**
- ✓ **Factors influencing the response are: cell type, exposure/co-exposure characteristics (frequency, CW, modulation, SAR, exposure duration and modality, type of co-agent, its concentration and schedule, sequence of exposure/treatment)**
- ✓ **Beneficial effects have been demonstrated to be induced by pre-exposure to RF EMF against subsequent treatment with chemical and physical agents**

Brief analysis of the effects of MMW

- **Mainly explored to elucidate mechanisms of interaction underlying the reported therapeutic efficacy**

- **A wide range of endpoints investigated in *in vivo* and *in vitro*: cell proliferation, viability, cell cycle progression, morphology, DNA integrity, genotoxicity, gene and protein expression, protein function, cell signalling, metabolism, oxidative stress**

- **Two very recent review papers by the same research group**

Brief analysis of the effects of MMW

A state of the science review of studies above 6 GHz at exposure levels below the ICNIRP general public limits

107 papers *in vitro* and *in vivo* identified

Many of the studied reporting effects come from the same research group and the results are not independently reproduced

The majority suffers of low quality methodologies for dosimetry but also in terms of temperature control, blinding of analysis, positive control

Many of the effects reported may be related to high RF energy deposition

Karidipis et al., J Exp Sci. & Env. Epid, 2021

Mattsson, Zeni, Simko
J InfraredMilli TerahzWaves
DOI 10.1007/s10762-018-0483-5

Brief analysis of the effects of MMW

More in depth analysis of the same 107 papers

Only studies with sham control included in the analysis

No dose response relationship identified between the exposure (PD, SAR) and the effect size (ES): the largest difference between exposed and sham exposed divided by the SD of sham control

Large ES in the frequency range 40-55 GHZ (MMW for therapeutic purposes)

A negative correlation between the ES and the quality score (QS) derived by using the the following criteria: sham, appropriate dosimetry, temperature monitoring, positive control, blinding analysis.

Wood et al.., 2021 J Exp Sci & Environ Epidemiol 31 (4): 606-613

Concluding remarks

- **The only recognized non-thermal effects are RF hearing and alteration of specific frequency component of the EEG at SAR levels < 2W/kg**
- **The overall results below the thermal threshold are still controversial and suffer of inconsistency**
- **Methodological limitations affect the quality of the studies**
- **There is no accepted mechanisms that would explain the existence of low-level non-thermal biological effects**
- **Studying the effects of combined exposure can help elucidating interaction mechanisms**

Concluding remarks

- **To exclude heating as the main reason for the observed effects in the MMW studies:**

✓***In vivo*** **studies on the influence of a possible tissue temperature increase**

✓***In vivo*** **dose-response studies of heat development**

✓**Use of *in vitro* models (3D models) of the skin**

Concluding remarks

- **WHO is pursuing the systematic review approach to analyse and synthesize the evidence for the study of the biological effects to be informative for the health risk evaluation**

- **Design and implementation of the studies must be significantly improved (the presence of sham control and appropriate dosimetry and temperature controls are minimal requirements)**

- **Common protocols shared among laboratories**

Thank you for your attention!!

ICOH-ISSA November 24, 2021