| Landmarks and Limits | µW/m² |
|---|---|
| **Natural Cosmic MW Radiation** | **<0.000001** |
| **Minimum Signal for a Radio Receiver or Cell Phone** | **0.000027** |
| Baubiology, Nighttime | 0.1 |
| Austrian Medical Association, Hyper-Sensitives | < 1 |
| Parliamentary Assembly of the Council of Europe, 2011 (inside limit, future target) | 100 |
| Salzburg Resolution 2000, Bioinitiative Report 2012 [Bioinitiative, 2012], Parliamentary Assembly of the Council of Europe, 2011 (inside limit) | 1000 |
| **Start of Permeability Loss of Blood-Brain Barrier** | **4,000** |
| Ecolog 2000 | 10,000 |
| **30 cm from Smart Meter emitting 1% of the time, with reflection** | **22,000** |
| Switzerland, Russia, Italy, Poland, and Salzburg Resolution (2000) | 100,000 |
| **Inhibition of DNA Repair in Stem Cells** | **920,000** |
| Belgium | 1,200,000 |
| **At 30 cm from Smart Meter emitting 100% of the time, with reflection** | **2,200,000** |
| Code 6, Canada; IEEE C96.1; Germany, England, Finland, Japan | 10,000,000 |

In a first group of countries, thermal recommendations are binding national legislation: Cyprus, Czech Republic, Estonia, Finland, France, Hungary, Ireland, Malta, Portugal, Romania and Spain. The Spanish region of Catalonia has stricter regulation than the federal government. In Germany and Slovakia, the thermal levels have become de facto exposure limits.

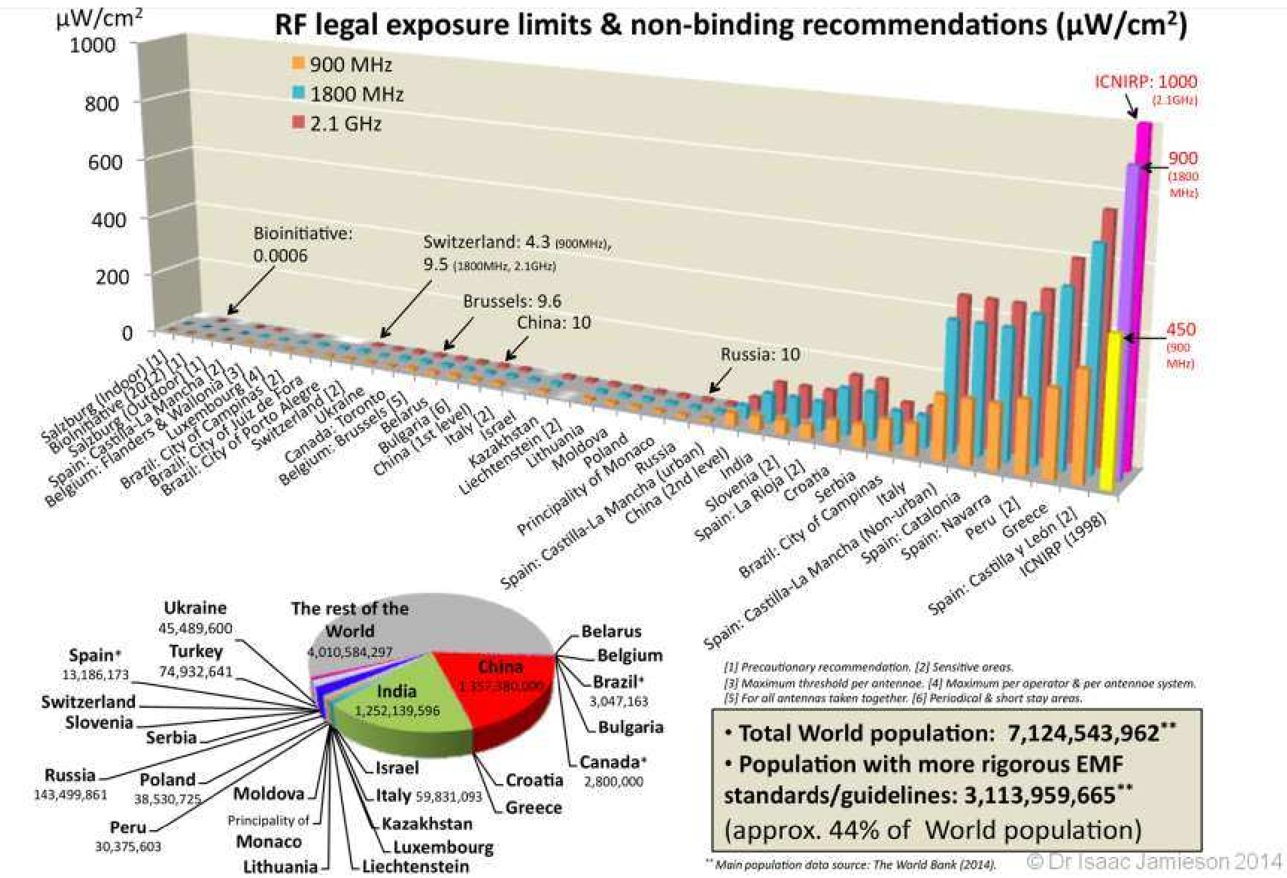
In a second group of countries, limits based on thermal are not binding, there are more lenient limits, or there is no regulation: Austria, Denmark, Latvia, Netherlands, Sweden and United Kingdom.

In a third group of countries, there are ***stricter*** restrictions than thermal, based on the precautionary principle, sometimes based on the principle of "as low as reasonably achievable without endangering service".

**Belgium**: Flemish legislation limits the electrical field strength per antenna for telecommunication to 7% of the thermal level in places of stay like homes, schools, rest homes and nurseries. The maximum exposure per location is 50% of the thermal level for frequencies 10 MHz-10 GHz. The Brussels Region limits total exposure in residences for frequencies 100 kHz- 300 GHz to a power density of 0.5% of the thermal (corresponding with 7% for the E field strength). For the same frequency range, Wallonia sets a fixed limit for the E field strength per antenna in residences which is 7% of the thermal level at 900 Hz.
**Bulgaria**: limits for power density are 2% of thermal at 900 MHz and less than 2% for higher frequencies.
**Greece**: 70% of those in thermal and 60% when antenna stations are located closer than 300 meters from the property boundaries of schools, kindergartens, hospitals or eldercare facilities. Installation of mobile phone antenna stations is
not allowed within the property boundaries of aforementioned facilities.
**Italy**: Under Italian law, ICRIRP levels have become *de facto* exposure limits. In contrast with the limits of thermal, these are fixed (not frequency dependent) between 3 MHz- 3 GHz. The limit for B field strength at 900 MHz is 45% of the thermal level (22% for power density). In homes, schools, playgrounds and places where people may stay for longer than 4 hours, an "attention value" for B field applies that is 14% of the thermal level at 900 MHz (2% for power density).
The "quality goal" for new installations is identical to the attention value.
**Lithuania**: There are fixed limits for power density at frequencies 300 MHz-300 GHz. The limit is 2% of the thermal level at 900 MHz and less than 2% for higher frequencies.
**Luxembourg**: Precautionary policy applies to mobile telephony through a law on classified locations and technical standards. These set a fixed exposure limit for the E field strength of 3 volt per meter per antenna which is 7% of the thermal level at 900 Hz. The limit for the total number of antennas in one location equals the thermal reference level.
**Poland**: In locations that are accessible to the public, frequency-dependent exposure limits lower than thermal are set for E field strength and power density. At 900 MHz the limit for E field strength is 17% of thermal level (2% for power density).
**Slovenia**: For frequencies higher than 10 kHz, exposure limits for E and B field strength to 31% of the thermal levels (10% for power density) apply in "sensitive areas" (homes, schools, hospitals etc.). In all other locations the thermal levels are applied.

**Spain**: The Spanish autonomic region of Catalonia has exposure limits for E and B field strength that are 65% of those in thermal (44% for power density) and minimal distances to antennas.
**Australia's** radiation protection standard are identical to those in thermal.
In **Russia**, general conditions for protection of the population are set in a 1999 framework law. Limits for specific frequency ranges are set in subsequent "Hygienic-epidemiological requirements". The exposure limit for power density for EMR between 300 MHz-300 GHz is 2% of the thermal levels. The reason is to prevent biological effects that are not generally seen as a health risks in Western countries.
In **Switzerland**, an ordinance on non-ionizing radiation is in force since 2000. Mandatory exposure limits identical to the thermal levels apply in all areas accessible to the public. A stricter, precautionary limit for the E field strength of 10% of thermal applies to mobile phone masts. A frequency-dependent exposure limit for E field strength of 11% to 3% of the thermal level applies to other transmitters and to radar.
**United States** sets basic restrictions identical to thermal.
**China**'s restrictions are analyzed here [Peipei, 2016].

Most toxic agents have multiple effects. Toxicology traditionally aims to find the *Critical Variable* (the particular health effect) that should determine the acceptable human exposure. This materializes in terms of determinations of the NOEL (No Observed Effect Level) and NOAEL (No Observed Adverse Effect Level). The No Observed Effect Level for EMR is approximately 0. What is *adverse* then becomes pivotal.
A significant expansion of assessment problems comes from the role of time in revealing toxicity. In other words, is suppression of a relatively acute action, such as alteration of the blood-brain barrier at 4,000 $\mu W/m^2$, sufficient to defend the organism against all other possible risks, such as cancer and chronic neurological diseases as well as EHS?
Because of a strong engineering tradition in electromagnetism, there has been undue emphasis on carrier frequency and power of EMR signals, as opposed to the more important and physiologically relevant modulation (GSM vs CDMA) and time-course of exposures. There is a real possibility of unusual dose-responses, and frequency or modulation specificities.



RF legal exposure limits & non-binding recommendations (µW/cm²)
µW/cm²
1000
800
600
400
200
0
900 MHz
1800 MHz
2.1 GHz
Bioinitiative: 0.0006
Switzerland: 4.3 (900MHz), 9.5 (1800MHz, 2.1GHz)
Brussels: 9.6
China: 10
Russia: 10
ICNIRP: 1000 (2.1GHz)
900 (1800 MHz)
450 (900 MHz)
Salzburg (Indoor) [1]
Bioinitiative (2012) [1]
Salzburg (Outdoor) [1]
Spain: Castilla-La Mancha [2]
Belgium: Flanders & Wallonia [3]
Luxembourg [4]
Brazil: City of Campinas [2]
Brazil: City of Juiz de Fora
Brazil: City of Porto Alegre
Switzerland [2]
Ukraine
Canada: Toronto
Belgium: Brussels [5]
Belarus
Bulgaria [6]
China (1st level)
Italy [2]
Israel
Kazakhstan
Liechtenstein [2]
Lithuania
Moldova
Poland
Principality of Monaco
Russia
Spain: Castilla-La Mancha (urban)
China (2nd level)
India
Slovenia [2]
Spain: La Rioja [2]
Croatia
Serbia
Brazil: City of Campinas
Italy
Spain: Castilla-La Mancha (Non-urban)
Spain: Catalonia
Spain: Navarra
Peru [2]
Greece
Spain: Castilla y León [2]
ICNIRP (1998)
Ukraine 45,489,600
The rest of the World 4,010,584,297
Spain* 13,186,173
Turkey 74,932,641
Switzerland
Slovenia
Serbia
Russia 143,499,861
Poland 38,530,725
Moldova
Peru 30,375,603
Principality of Monaco
Lithuania
India 1,252,139,596
China 1,357,380,000
Israel
Italy 59,831,093
Kazakhstan
Luxembourg
Liechtenstein
Croatia
Greece
Belarus
Belgium
Brazil* 3,047,163
Bulgaria
Canada* 2,800,000
[1] Precautionary recommendation. [2] Sensitive areas.
[3] Maximum threshold per antennae. [4] Maximum per operator & per antennae system.
[5] For all antennas taken together. [6] Periodical & short stay areas.
• Total World population: 7,124,543,962**
• Population with more rigorous EMF standards/guidelines: 3,113,959,665**
(approx. 44% of World population)
** Main population data source: The World Bank (2014).
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#### 5.5.1.1. Restricted Scope of Heat Recommendations

The large range of opinions on appropriate measures of protection (5.5.1) results from an inter-disciplinary problem: specialists ignore other sciences, leading to the deployment of engineering solutions that unnecessarily imperil human health.

**1.** Thermal standards are limited in scope to **short-term heating**, something that is easy to measure, but avoids the issue of chronic diseases, not accessible to engineering culture.
**2.** The **set of technical publications** considered relevant to standard setting is deliberately narrowed by industry-influenced reviewers. Effects of fields not involving human health rarely arouse controversy[16], while any claim that cellular phones and other commercially valuable applications induce headaches, memory problems, dizziness and cancer are systematically challenged by industry, and labeled as "bad science". The presence of so-labeled *inconsistent* experimental results on EMR risks should have called for more caution, not less, because it indicates insufficient understanding of the agent.
**3.** Thermal standards implement **low-power exemptions** to favor commercialization of portable communications units.

*"For example, if a device functioning between 10 kHz and 1 GHz has an output power of 7 W or less, it is excluded from any further probing."*

[16] It is accepted, for example, that a light-dependent magnetic receptor is at work in the eastern red-spotted newt and in male *Drosophila Melanogaster* [Phillips, 1992]. The receptor can be disturbed by radio-frequency radiation, as predicted theoretically on the basis of interaction between the Earth's magnetic field and electron-nuclear magnetic moments, which energetically are in the radio-frequency range [Leask, 1977]. The RF from a fluorescent lamp can abolish *Drosophila*'s magnetic sense of orientation.

In an engineering view, health risks *must* be related to power (Watts), because that is how electronic devices and parts are routinely rated and ranked. Should the chemical industry be allowed to deploy any number of suitably small pills of arsenic?
**4.** *"The standard can also be satisfied if it can be demonstrated that an SAR of less than 0.4 W/kg averaged over the whole body, and peak spatial SARs of less than 8 W/kg over any gram of tissue are produced."*

A biologist would struggle with the notion that there is anything special about **a gram of tissue**. This is pulled out of physics, where the word "specific" usually means "per gram". For a cancer biologist, the relevant unit is at least as small as a cell (1 ng), not 1 or 10 g. Therefore, the highest computed temperature at any point, and for any interval of time in the body should have been relevant. Perhaps engineers did not want to be confronted with the fact that they have no hope of accurately computing real exposures.

**5.** Thermal standards accept higher limits for **partial-body exposures.** The arms are sometimes highly exposed, because of the handling of parts in industrial processes (dielectric heaters), and the ears are pressed against cellular phones. According to the thermal standard, an *extremity* can tolerate more radiation. This is not compatible with basic physiology, as vulnerable cells are present everywhere in the body. A health-based standard might discriminate among body parts according to their known cancer rates. When improved computations showed that the ear was irradiated over the SAR limits, C95.1 simply reclassified it as an "extremity" and averaged exposure over 10 g, as opposed to 1 g. C95.1 changed limits in relation to engineering needs, and adjustments are made to human sensitivity rather than to hardware.

**6. Pulsed exposures,** which are biologically more active, are essentially considered only in terms of their heat content. SAR (W/kg) averaged over 6 or 30 minutes are totally insensitive to crest values of induced electric or magnetic fields in tissues. This shows an unwillingness to tackle the full complexity of EMR interactions. The time variation of EMR, the various codecs and keying techniques that allow the inclusion of analog and digital data unto EMR carriers, are ignored by C95.1, lost within the SAR bubble.
This is particularly troublesome, given that industry designs communications codecs much faster than toxicologists can assess them. Ignoring the pulsative nature of telecommunications signals in assessing their biological activity is incompatible with good science and the demonstrated effectiveness of bone regeneration applications (Chap. 3, Appendix 3).

#### 5.5.1.2. Protection against Heat

In 1975, it was observed that rats stopped working for food when exposed to 4 W/kg of MW radiation. With a safety factor of 10, the thermal standard was set to limit the average whole body SAR to a value of 0.4 W/kg between 1 MHz-300 GHz. Effects were reported at that time at least an order of magnitude below 4 W/kg, but were labeled *inconsistent*.

Unfortunately for this kind of risk limit, recent studies [Deshmukh, 2016] on male Fischer rats over 90 days show that SARs of 0.0006 W/kg lead to hazardous effects on the brain, based on tests for cognitive function. HSP70 levels were elevated, as well as DNA damage as assessed by alkaline Comet assay.

US research groups [Oscar 1977; Albert, 1979] indicated increased permeation of the blood-brain barrier at power levels 1/3 to 1/50 of the thermal standard. Dutta et al. [1989] reported changes in calcium metabolism in cells exposed to 0.05-0.005 W/kg. Ray and Behari [1990] reported a decrease in eating and drinking behavior in rats exposed to 0.0317 W/kg. Kwee and Raskmark [1997] reported changes in cell proliferation at SARs of 0.000021- 0.0021 W/kg. Phillips et al. [1998] observed DNA damage at 0.024-0.0024 W/kg.

Chronically exposed rats even showed increases in primary malignant tumors at exposures (2.45 GHz) half of the limit.

Instead of recognizing that the agent was incompletely understood, and to use caution, the human limit was so set an order of magnitude below the ***least controversial*** of the effects in animals. It is therefore based on a tolerable increase of body temperature corresponding to about 5 times the heat produced by basal metabolism. This in itself is a highly contentious position, as the body is not set to compensate an artificial extraneous agent such as MWs. By relying on absence of ionization capability of MWs as an argument, and by restricting the region-of-scientific-interest exclusively to heat, standard setters only showed a desire to remove all precautions in the deployment of EMR-based commercial and military applications.

The thermally inspired standard has to coordinate a number of interacting factors to limit temperature rises in the body.

- Since the SAR is **proportional to frequency** (5.4.6), the limits generally decrease with frequency to compensate, taking also changes in dielectric properties of biological tissue with frequency into account.
- The SAR is maximal when the long axis of a body is parallel to the electric field vector, and is 0.4 times the wavelength of the incident field. Therefore, **the maximum whole-body resonance for humans 1.75 m tall occurs at**