

Response to HHS Request for Information on Electromagnetic Fields (EMFs), Radiofrequency (RF) Radiation, and Wireless Radiation Exposure

Robert F. Kennedy, Jr.,
Secretary, Department of Health and Human Services.
[FR Doc. 2026-19252 Filed 9-17-26; 12:30 pm]
BILLING CODE 4164-01-P

Submitted by: Dr Lennart Hardell, MD, PhD, Professor (retired)
Department of Oncology, University Hospital, Örebro Sweden
Present address:
The Environment and Cancer Research Foundation, Örebro, Sweden
E-mail: lennart.hardell@environmentandcancer.com

Federal Register: September 21, 2026, 91 FR 59792
Docket ID: HHS-OASH-2026-0397

I hereby submitted my comments, especially on cancer risks, associated with exposure to radiofrequency electromagnetic field (RF-EMF) exposure, including the fourth generation (4G) and fifth generation (5G) communication systems. My comments are based on the relevant scientific literature, but also clinical and epidemiological research in this area.

The full scientific evidence should be considered by the Department of Health and Human Services (HHS) when evaluating public experiences and reported potential adverse health effects associated with RF-EMF exposure. Of special concern are cancer risks, neurological and neuropsychiatric symptoms, sleep disturbances, and other health effects among people exposed to RF-EMF radiation during work or in the environment. Thereby both clinical observations and epidemiological finding should be considered. Biological relevance as well as vulnerable persons, e.g. children, are of importance.

In our studies from Sweden we have repeatedly found in epidemiological case-control studies that mobile and cordless phone use is associated with an increased risk of glioma and acoustic neuroma. Based primarily on our studies and the result of the WHO Interphone study (13 countries participating) the IARC classified RF-radiation as possibly carcinogenic, group 2B in 2011. I was one of the 31 international experts that evaluated the evidence on behalf of IARC. Our research team has also investigated incidence trends in the Nordic countries of different cancer types potentially associated with mobile phone use and found that the incidence of brain tumors and thyroid cancer has increased. We have analyzed our results and from other research groups on brain tumor risks associated with mobile phone use. Overall the results show an increased risk of brain tumors among the heaviest users of mobile phones and that studies that report no increased risks often have methodological problems in terms of exposure misclassification, or not comparing the highest exposure group with a low exposure group.

During the last decade we have also investigated health effects associated with exposure to RF-EMF radiation close to base stations. We found that individuals living or working close to base station antennas reported a number of symptoms previously associated with exposure to

pulse-modulated RF-EMF radiation Among the most frequent were sleeping problems, fatigue, headache, memory- and concentration problems and other problems related to the nervous system, but also issues related to the cardiovascular system. This has been called the microwave syndrome or radiofrequency illness. We also found that 5G antennas emitted very high RF-EMF radiation in the homes of people living within 100 meters from the antennas. People who had previously tolerated 3G/4G antennas at the same spot became ill within a few days once the antennas were upgraded to 5G. We also found that when the individuals moved away from the close proximity of the antennas to dwellings with lower RF-EMF radiation, most of the symptoms vanished within a short time period. This would be a classic provocation study. Although the exposure close to the 5G antennas was very high, it was still considerably lower than the limits applied today by the FCC and recommended by the ICNIRP.

In addition we have investigated incidence trends of various symptoms associated with the exposure to 5G/4G antennas. We found alarming increase of memory problems among children and adolescents in Norway and Sweden and increased incidence of sleeping problems among children and adolescents in Sweden during the last 10-15 years. During the same time period children's and adolescents exposure to RF-EMF radiation has increased substantially.

Furthermore, we have performed studies of RF-EMF radiation around schools and in public environments in Sweden. We find repeatedly that exposure today after the 5G roll out is alarmingly high, much higher than levels that have previously been associated with increased risk of health effects.

Conclusion

Based on our research and other research results we conclude that RF-EMF radiation from mobile phones may cause cancer, particularly among heavy users. Of concern is also smart phones held for long time periods against the chest or the abdomen and other devices emitting RF-radiation close to the body for prolonged time periods (wireless headsets, smart watches, wireless connected laptops etc.).

Antennas for 4G and 5G may cause symptoms called the microwave syndrome (sleeping problems, headache, fatigue, memory- and concentration problems, cardiovascular effects etc.) among people living close to the antennas. High radiation causing health issues may be found in the proximity 5G antennas. Levels associated with health problems are far below the FCC and ICNIRP limits.

The limits must be significantly lowered and the public informed about potential health risks from exposure to RF-EMF radiation and how to minimize exposure. Safety distance to mobile phone antennas should be established in order to minimize public exposure.

Question 4. Reported Potential Adverse Health Effects

Article: **Summary of seven Swedish case reports on the microwave syndrome associated with 5G radiofrequency radiation (1)**

The Swedish case reports on individuals living close to 5G base stations and exposed to 5G and 4G radiofrequency radiation were summarized by Hardell and Nilsson (1). Symptoms such as neurological, neurobehavioral, and sensory symptoms were described among persons in the proximity to 4G/5G base stations. These included sleep disturbances, headache, fatigue, irritability, emotional distress, impaired concentration and attention, loss of immediate memory, abnormal skin sensations, dizziness, anxiety, depressive symptoms, light sensitivity, and confusion (2-8).

Sleep disturbances were common. On a 10-grade scale mean severity scores were 6.25 for insomnia, 6.58 for waking during the night, and 6.33 for early-morning awakening. All three children that were included in the studies, aged 4, 6, and 8 years, were reported to have insomnia graded at 10 on the study's symptom-severity scale, representing the most severe category (7).

Fatigue was also common, with a mean score of 5.75, and complaints included headache, with a mean severity score of 4.88; irritability, 4.73; and emotional distress, 4.47 (1). Other reported symptoms were concentration and attention difficulties (mean score 3.69), loss of immediate memory (mean score 3.19), and abnormal sensory experiences (mean score 3.13). If the studied individuals moved to dwellings with considerably lower RF-exposure, most of the symptoms declined or disappeared.

In another study, Hardell and Koppel (9) reported symptoms assessed during an initial evaluation of RF radiation in an office below a base station for 3G/4G and again after two weeks of sick leave. The reported symptoms associated with the RF-radiation in the office included headache, abnormal skin sensations, muscle and joint pain, ear symptoms, tinnitus, dizziness, balance disturbances, concentration difficulties, memory complaints, fatigue, insomnia, emotional symptoms, cardiovascular abnormalities, skin complaints, and gastrointestinal or respiratory symptoms. Several reported symptom scores declined following two weeks of sick leave, thus unexposed to the RF-EMF radiation in the office. Headache declined from 8 to 3; tinnitus from 9 to 1; dizziness from 8 to 3; balance disturbances from 10 to 4; fatigue from 9 to 5; and transient cardiovascular abnormalities from 10 to 3. The same questionnaire was used in both these studies in the assessment of the symptoms.

Such changes may be clinically relevant because they suggest that symptom severity may improve when an individual's RF-EMF exposure is reduced.

Particular attention should be given to children and other potentially susceptible groups. The severe insomnia reported in the three children in the 2024 case series is concerning as a clinical observation (7).

Below follows some quotes, figures and tables from our case studies, incidence trend studies and epidemiological studies on mobile phone use and cancer:

An 82-Year-Old Woman with Longstanding Electromagnetic Hypersensitivity Developed Symptoms Consistent with Microwave Syndrome Following the Installation of Nearby 5G Base Stations: Ethical Considerations in Medicine (8)

Installation of the fifth generation (5G) for radiofrequency radiation started in Sweden in 2020. In this case report we present an 82-year-old woman with EHS since almost four decades. After installation of 5G base stations in the neighborhood her health deteriorated.

Using a questionnaire symptom severity was assessed on 28 August 2023, following the installation of 5G base stations in the vicinity of her residence.

Symptoms were scored on a scale from 0 to 10, where 0 indicates no symptoms and 10 indicates unbearable pain or discomfort. The table compares the reported symptom scores before the installation of the 5G base stations with those recorded in August 2023.

Table. Reported symptom severity before and after the installation of nearby 5G base stations

Symptom	Before 5G installation August 2023	
Neurological and sensory symptoms		
Headache	2	4
Dysesthesia (abnormal skin sensations)	3	9
Myalgia and arthralgia (muscle and joint pain)	2	6
Hyperacusis (increased sensitivity to sound)	2	4
Dizziness	3	7
Balance disorder	3	7
Concentration or attention difficulties	2	4
Confusion	0	2
Fatigue	3	8
Sleep disturbances		
Insomnia	0	2
Waking during the night	0	5
Psychological and emotional symptoms		
Depressive symptoms	1	2
Anxiety or panic	0	2
Emotional distress	1	3
Irritability	1	3
Other sensory and systemic symptoms		
Light sensitivity	3	7
Abnormal temperature sensations throughout the body	3	6

Symptom	Before 5G installation August 2023	
Shortness of breath (dyspnoea)	1	4
Chest tightness	0	2
Nausea	1	3
Skin and related symptoms		
Skin symptoms affecting the face, arms, and legs	2	6
Burning or lancinating sensations in the skin of the hands and arms	3	6
Bruising or haemorrhagic symptoms	3	6

The symptom scores indicate that several complaints were reported as more severe in August 2023 than before the installation of the nearby 5G base stations.

The largest increases were reported for dysesthesia, which rose from 3 to 9, and fatigue, which increased from 3 to 8. Dizziness, balance disturbances, light sensitivity, and abnormal whole-body temperature sensations each increased by four points. Muscle and joint pain, skin complaints, and burning or lancinating sensations in the hands and arms also increased.

New or newly reported symptoms included confusion, insomnia, waking during the night, anxiety or panic, shortness of breath, and chest tightness. Several symptoms, including cardiovascular complaints, visual disturbances, and nosebleeds, remained at zero (not in Table).

Measurements of RF-EMF yielded radiation in the frequency range used for 5G, highest in the kitchen 166,700 $\mu\text{W}/\text{m}^2$. The exposure was high also in the living room, 147,100 $\mu\text{W}/\text{m}^2$, library 20,000 $\mu\text{W}/\text{m}^2$, and office 13,100 $\mu\text{W}/\text{m}^2$.

An Eight Year Old Boy Developed Severe Headache in A School Close to A Mast with 5G Base Stations Case Study (10)

In this case study we present an eight year boy who developed severe headache, but also some fatigue and dizziness at school after the implementation of 5G base stations close to the school. During the week 50, 2023 RF-EMF radiation measurements were made both at school and at the boy's home during daytime. Table 1 shows lowest and highest results of maximum values (peak) of the ten measurements each during 1 minute. At the schoolyard the levels varied between 83,332 and 267,536 $\mu\text{W}/\text{m}^2$ and in the classroom including corridor between 2,560 and 76,590 $\mu\text{W}/\text{m}^2$. Considerably lower levels were found in the home varying from 25 to 1,040 $\mu\text{W}/\text{m}^2$.

Table 1: Measured levels of RF radiation at school and at home, Results are given in $\mu\text{W}/\text{m}^2$.

School	Min	Max
Schoolyard	83,332	267,536
Classroom (leisure, corridor)	2,560	76,590

Home

Bedroom (pillow)	25	259
Desk	45	553
Living room (regular seat)	26	270
Kitchen table (common place)	39	1,040

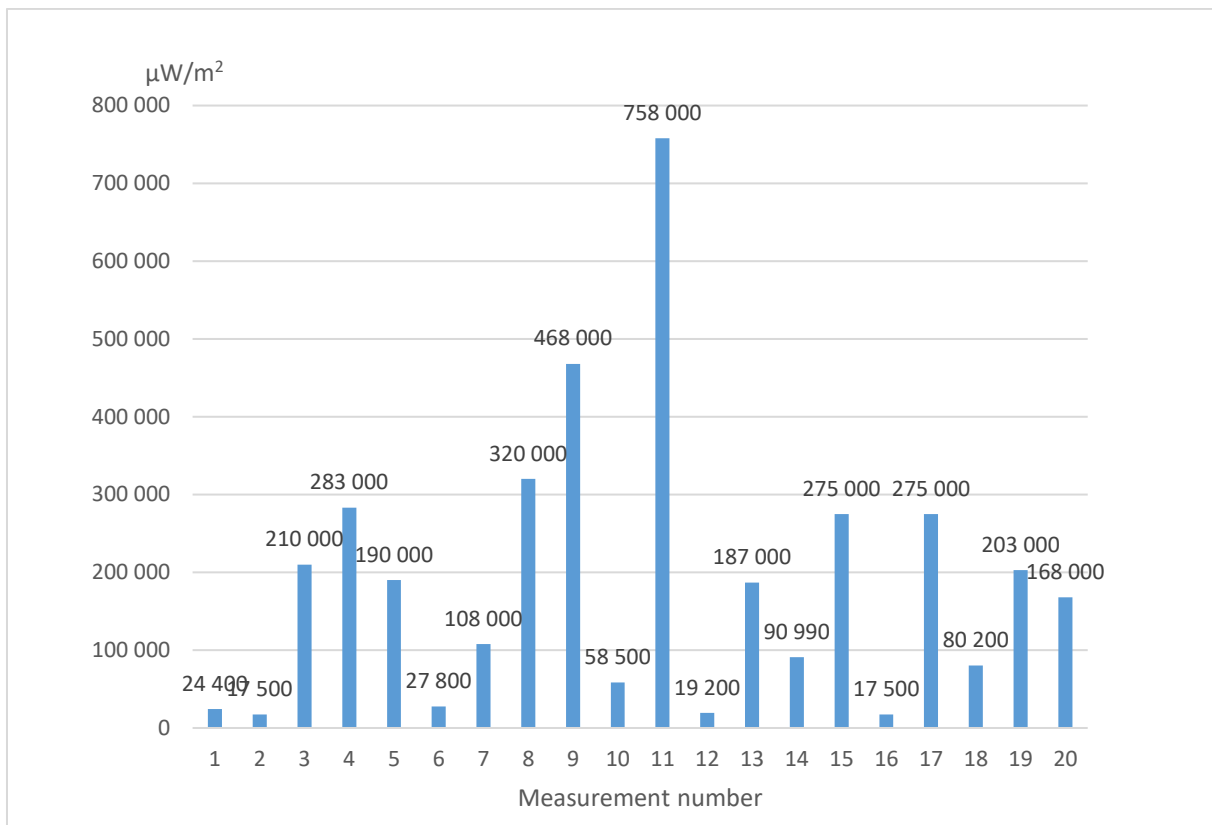
Figure 1: Mast with 5G base stations 200 meters from the school

The report describes a child who experienced severe headaches, fatigue, and dizziness at school following the installation of nearby 5G base stations. It also provides RF radiation measurements from the schoolyard, classroom, and home. The reported measurements indicate higher peak levels at school than at home. The temporal relationship between installation of the 5G base stations and the child's symptoms is of interest as well as comparison with symptoms at home with lower radiation levels.

Case report: A 52 year healthy woman developed severe microwave syndrome shortly after installation of 5G base station close to her apartment (4).

In this case report we present a woman aged 52 years who developed health problems consistent with the microwave syndrome after installation of a 5G base station 60 meters from her apartment. These symptoms consisted of e.g., headache, dizziness, concentration difficulties, fatigue, arrhythmia, skin burning and nose bleeding corresponding to the microwave syndrome.

In her living room at the window 17,500 to 758,000 $\mu\text{W}/\text{m}^2$ peak levels were obtained during 10 measurements, each over 1 minute. At the place of her sofa in her living room peak levels from 36,800 to 222,000 $\mu\text{W}/\text{m}^2$ were measured. It is noteworthy that very high radiation was found at the balcony facing the base station. All ten measurements at that place yielded within 10-15 seconds peak levels $>2,500,000 \mu\text{W}/\text{m}^2$, which is the highest measurable level with the meter used in this study.



Results of 20 measurements in $\mu\text{W}/\text{m}^2$, each during 1 minute, for peak radiation from 5G at the window in the living room.

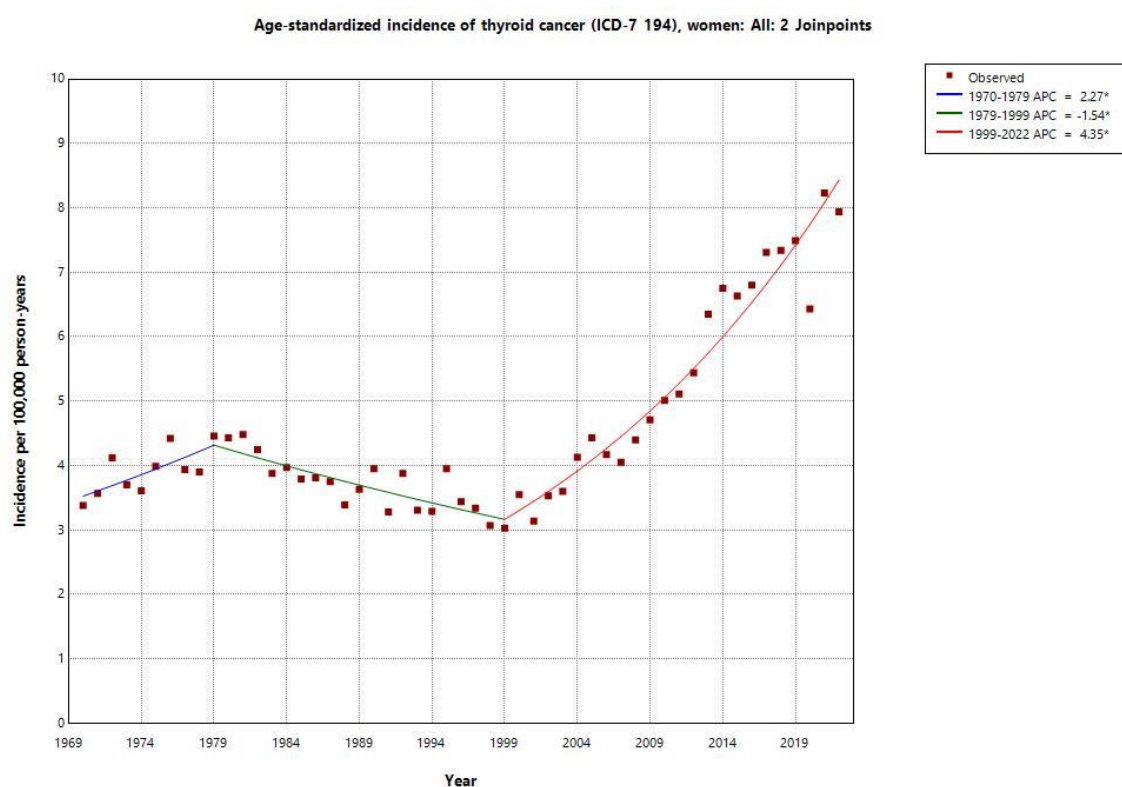


5G base station on the roof of a three floor building located 60 meters from the study apartment. Initial figure after the 5G installation showing the previous base station attached to the chimney

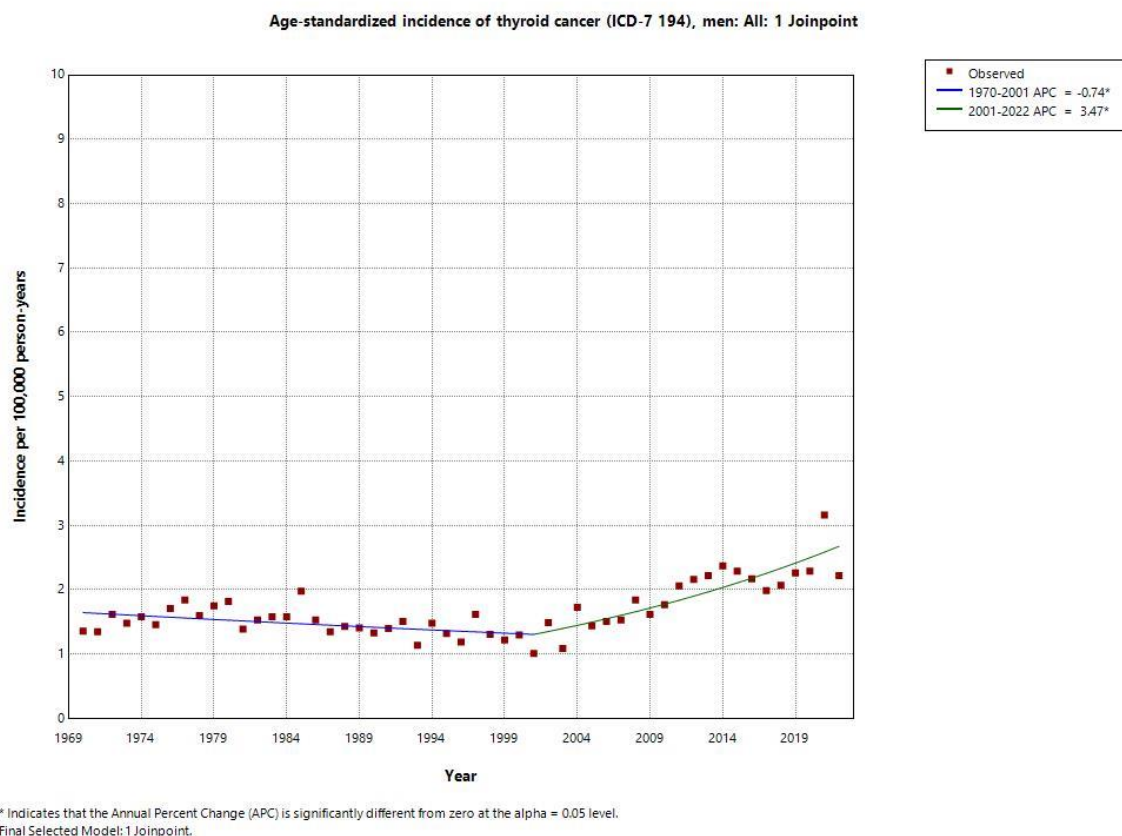
In a recent review on health risks from the wireless technology it was concluded that “A wide range of evidence indicates that there are numerous non-thermal effects from wireless radiation on reproduction, development, and chronic illness” (11). Further, in an Essay it was stated that “Based on the precautionary principle, the author echoes the calls of others for a moratorium on the further roll-out of 5G systems globally, pending more conclusive research on their safety...In short, one should ‘err on the side of caution’. In the case of 5G transmission systems, there is no compelling public health or safety rationale for their rapid deployment” (12).

Thyroid cancer: The increasing incidence of thyroid cancer in Sweden revisited (13).

It described an increasing incidence in recent years both among women with annual percentage change; APC in women +4.35 %; 95% confidence interval; CI +3.88, 4.89% (1999-2022) and in men +3.47%, 95% CI 2.52, +4.84% (2001-2022).

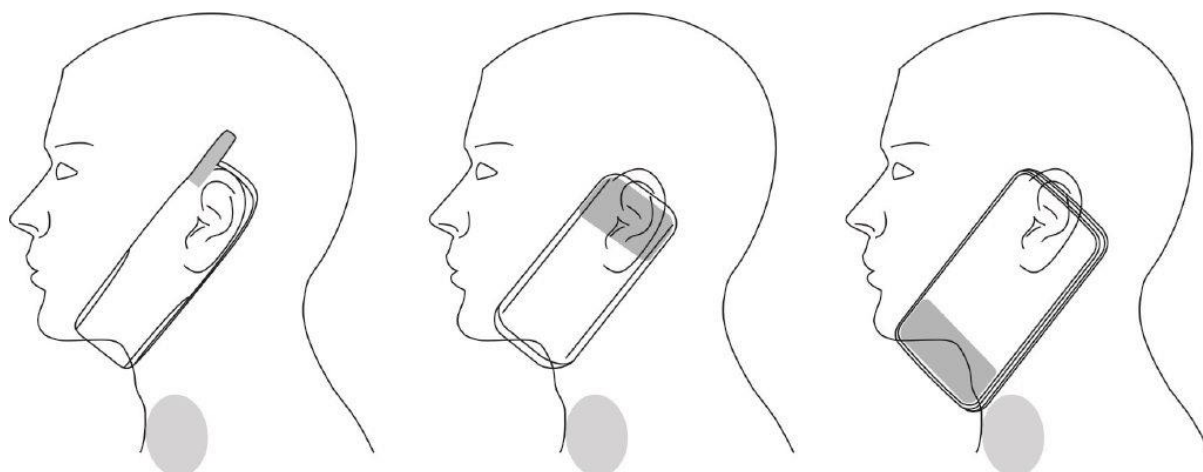


* Indicates that the Annual Percent Change (APC) is significantly different from zero at the alpha = 0.05 level.
Final Selected Model: 2 Joinpoints.

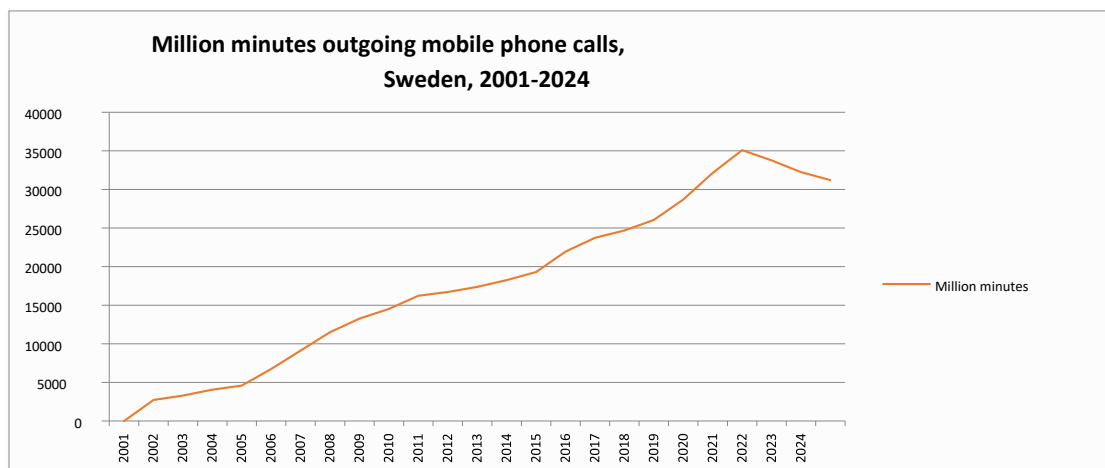


It is to be noted that thyroid cancer is more common in women as seen in the figures. The reported data indicate a sustained increase in thyroid cancer incidence in Sweden among both women and men. Increasing exposure to RF-EMF from mobile phone use has coincided with the increasing incidence, particularly given the anatomical location of the thyroid gland. Register data in Sweden show decreasing exposure from x-ray examination during the last couple of decades which contradicts that x-rays would be associated the increasing incidence. Further, there is no increasing exposure to other potential risk factors besides RF radiation. Use of the handheld mobile phone is increasing and the smartphone gives high RF radiation exposure to the thyroid gland.

This is illustrated by the figures below.

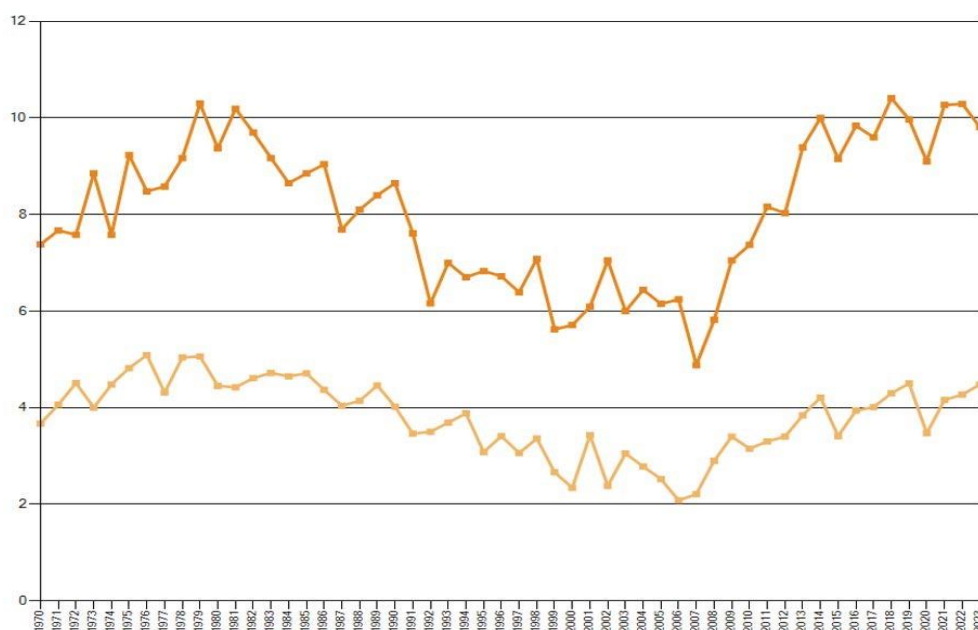


The figure below illustrates the increasing use of mobile phones in Sweden. It shows outgoing mobile phone calls in million minutes in Sweden during 2001-2024. Source: Post och Telestyrelsen, the Swedish Telecommunication Market <https://statistik.pts.se/en/telecom-andbroadband/the-swedish-telecommunication-market/>



Hepatocellular Cancer, Aflatoxin, and Radiofrequency Radiation (14)

The age-standardized incidence of primary liver cancer in Sweden, classified under ICD-7 code 155.0, is shown in the figure below for men and women from 1970 to 2023, based on data from the Swedish Cancer Register. The figure illustrates the long-term decline in incidence beginning in the early 1980s, followed by a reversal of this trend in recent years, starting around 2010, about the same time period that smart phones became very popular.



Age-standardized incidence of primary liver cancer (ICD-7 155.0) in Sweden between 1970-2023 for men (top line) and women (bottom line), all ages, according to the Swedish Cancer Register (Statistikdatabaser - Cancerstatistik - Val).

The declining incidence of liver cancer since early 1980's has been reversed with increasing incidence in women since 2006 and in men since 2007 in Sweden. During the same time exposure to RF radiation has increased. Animal studies have shown a tumor promoting effect, in addition to tumor initiation, from RF radiation.

Increasing Numbers of Children Aged 5-19 Years with Memory Problems in Sweden and Norway (15)

The figures present register-based data on memory-related complaints and cognitive impairment among children and adolescents aged 5–19 years. Figure 1 shows consultations for memory problems, ICPC-2 code P20, per 100,000 inhabitants in Norway from 2006 to 2024. Figure 2 shows the annual number of patients per 100,000 inhabitants in Sweden with R41.8, mild cognitive impairment as the main diagnosis during 2001–2024.

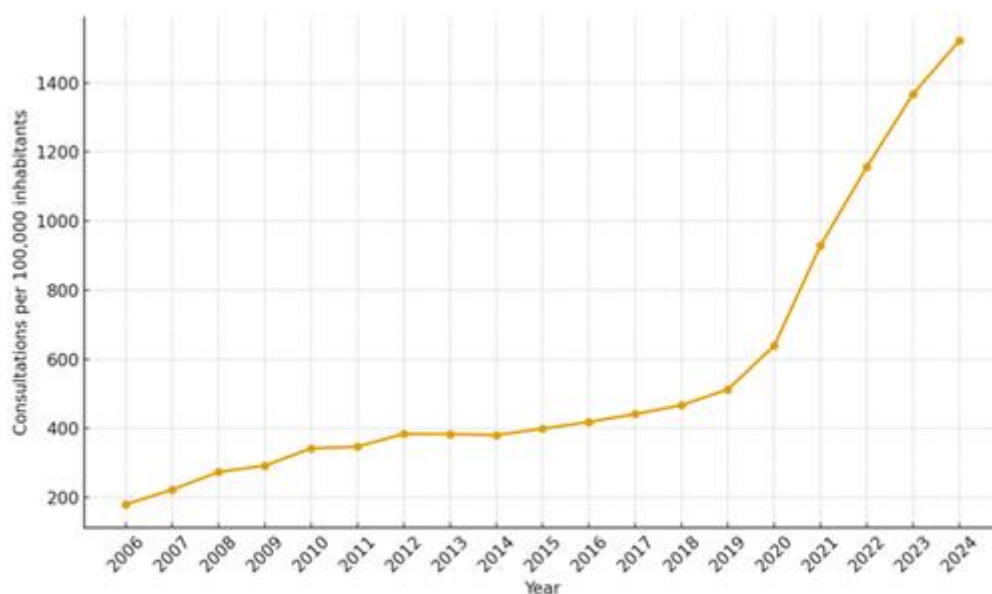


Figure: Consultations for memory problems (ICPC-2 code P20) among children aged 5-19 years per 100,000 inhabitants in Norway during 2006–2024.

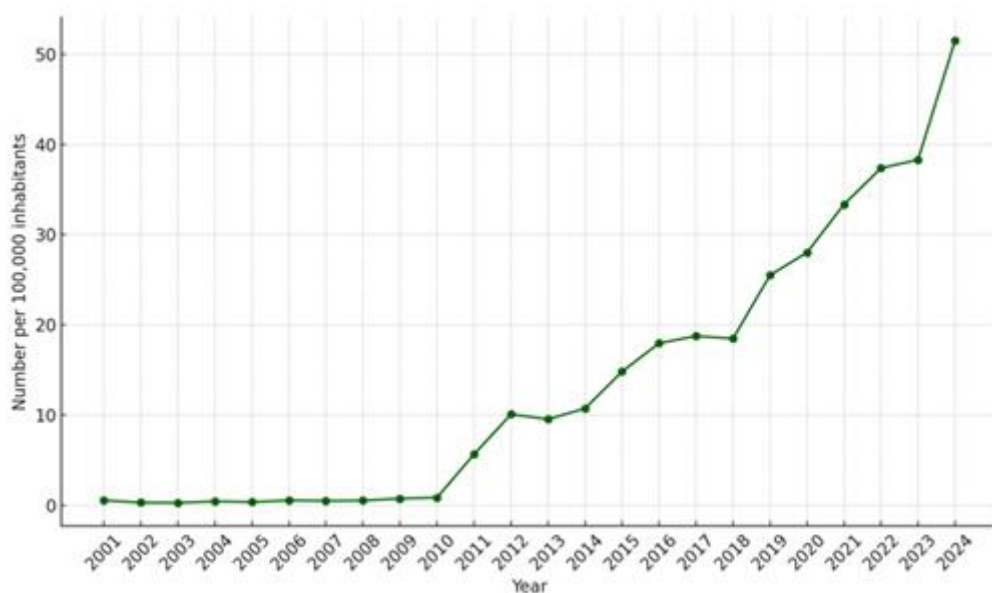


Figure: Number of patients aged 5-19 years per 100,000 inhabitants, each year with R41.8 mild cognitive impairment, subjective, as main diagnosis, in Sweden during 2001-2024.

This register based study shows increasing memory problems and/or cognitive impairment in children aged 5-19 years in Norway and Sweden. One etiological factor may be the increasing exposure to microwave RF-EMF radiation that in several human and animal laboratory studies has been associated with impairment of memory and cognitive functions.

These results are supported by animal study by Guan et al (16):

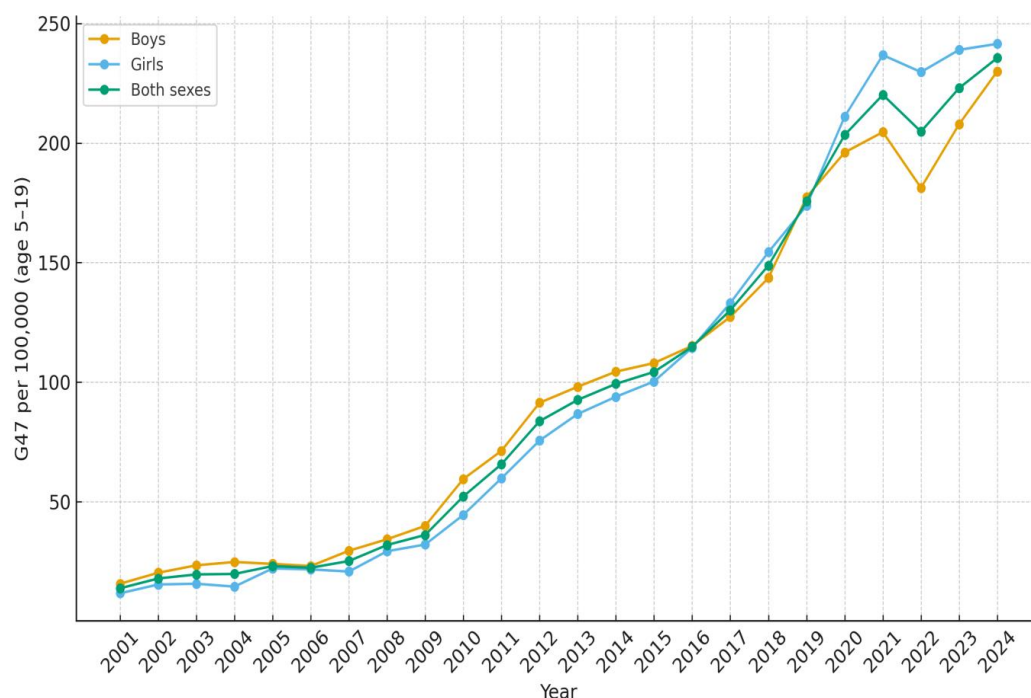
The memory and spatial exploration abilities of rats decreased after radiation. In summary, microwave radiation results in decreased learning and spatial exploration abilities in rats, structural damage to hippocampal neurons, and disruption of hippocampal tissue metabolism.... These findings indicate that microwave radiation causes spatial learning and memory dysfunction in rats and structural damage to hippocampal tissue.

The experimental findings reported by Guan et al. (16) indicate that microwave radiation was associated with learning and memory impairments and changes in hippocampal tissue in rats.

Increasing numbers of persons with sleeping problems in Sweden (17).

We recently reported an increase in the number of people in Sweden registered with sleep problems. The figure shows the annual number of patients aged 5–19 years per 100,000 inhabitants with sleep disorders (ICD-10 code G47) recorded as the main diagnosis in Sweden between 2001 and 2024.

This register based study showed increasing sleeping problems in the population since about 2009, especially in the age groups up to 19 years. The substantial rise in exposure to microwave RF-EMF radiation following the deployment of 4G and 5G infrastructure and the growing use of mobile phones and other RF emitting technologies is of concern. The rapid increase during the last years has temporally coincided with an increase in the public's exposure to RF radiation and increasing use of screens. RF radiation and use of screens may negatively impact sleep. These trends raise concerns about the potential public health implications of increasing sleep difficulties, particularly among children, adolescents, and young adults, for whom adequate sleep is essential for cognitive development, learning, emotional regulation, and general health.



Number of patients aged 5-19 per 100,000 inhabitants diagnosed with sleep disorders (G47) as main diagnosis, each year 2001-2024, Sweden.

Use of mobile and cordless phones and the association with prostate cancer (18).

The pooled analysis gave for mobile phone use OR = 1.8, 95 % CI = 1.01-3.1, increasing in the >10 year latency group to OR = 2.8, 95 % CI = 1.5-5.3. Also, use of the cordless phone gave increased risk, although not statistically significant. Dose-response analysis gave highest risk for >2,000 h use of the mobile phone with OR = 2.4, 95 % CI = 1.2-5.1. The cordless phone yielded highest risk in the group 1001-2000 h with OR = 2.3, 95 % CI = 1.01-5.4. The study reported higher risk estimates among men with more aggressive prostate cancer, assessed using Gleason score, prostate-specific antigen (PSA), and high-risk classification. Higher estimates were also observed among men with a family history of prostate cancer.

The results in this study are supported by data from the UK Biobank Study (19). A statistically significant increased risk was found for prostate cancer with hazard ratio (HR) = 1.19, 95 % CI = 1.13-1.25. Length of mobile phone use gave highest risk for >8 years, HR = 1.33, 95 % CI = 1.17-1.52 with a statistically significant trend ($p < 0.001$). The NTP study gave support of an increased risk for prostate neoplasia, for details see the publication.

Mobile and cordless phone use and brain tumor risk:

The side of the head during use of the wireless phone is of importance due to the distribution of RF-EMF radiation. The following tables give overall results, and also for ipsilateral and contralateral use of the wireless phone (same side and opposite side of the tumor localization). The results from the Hardell research group, the Interphone study, the French study by Coureau et al., and the study by Pettersson et al. illustrate the findings that should be considered in this assessment. The results include the numbers of exposed cases and controls, odds ratios (ORs), and 95% confidence intervals (CIs). An OR above 1 indicates an increased risk. Further information is found in the different publications.

1. Studies by the Hardell research group

Acoustic neuroma – Hardell et al. (20)

Exposure	Overall OR (95% CI)	Ipsilateral OR (95% CI)	Contralateral OR (95% CI)
Mobile phone	1.6 (1.2–2.2)	1.8 (1.3–2.6)	1.5 (0.98–2.2)
Cordless phone	1.5 (1.1–2.1)	1.8 (1.2–2.6)	1.2 (0.7–1.8)

Meningioma - Carlberg and Hardell (21)

Exposure	Overall OR (95% CI)	Ipsilateral OR (95% CI)	Contralateral OR (95% CI)
Mobile phone	1.0 (0.9–1.2)	1.2 (0.9–1.5)	1.0 (0.8–1.3)
Cordless phone	1.1 (0.9–1.3)	1.1 (0.9–1.4)	1.0 (0.8–1.3)

Glioma - Hardell and Carlberg (22)

Exposure	Overall OR (95% CI)	Ipsilateral OR (95% CI)	Contralateral OR (95% CI)
Mobile phone	1.3 (1.1–1.6)	1.8 (1.4–2.2)	1.1 (0.8–1.4)
Cordless phone	1.4 (1.1–1.7)	1.7 (1.3–2.1)	1.2 (0.9–1.6)

The results show highest ORs for ipsilateral use which is of biological relevance.

2. Interphone study

Glioma and meningioma - Interphone (23)

For participants reporting more than 1,640 hours of mobile phone use, the reported estimates were:

Outcome	Overall OR (95% CI)	Ipsilateral OR (95% CI)	Contralateral OR (95% CI)
Glioma	1.40 (1.03–1.89)	1.96 (1.22–3.16)	1.25 (0.64–2.42)
Meningioma	1.15 (0.81–1.62)	1.45 (0.80–2.61)	0.62 (0.31–1.25)

Acoustic neuroma - Interphone (24)

For mobile phone use exceeding 1,640 hours, the following estimates were reported for different latency periods:

Latency	Overall OR (95% CI)	Ipsilateral OR (95% CI)	Contralateral OR (95% CI)
More than 1 year	1.30 (0.87–1.94)	2.33 (1.23–4.40)	0.72 (0.34–1.53)
More than 5 years	2.86 (1.55–5.28)	3.53 (1.59–7.82)	1.69 (0.43–6.69)

Overall ipsilateral use gave highest ORs.

3. Coureau et al. (25)

Coureau et al. examined mobile phone use in relation to glioma and meningioma, including analyses of cumulative use above the 90th percentile, reported as more than 896 hours.

Outcome	Overall OR (95% CI)	Ipsilateral OR (95% CI)	Contralateral OR (95% CI)
Glioma	2.89 (1.41–5.93)	2.11 (0.73–6.08)	0.66 (0.23–1.89)
Meningioma	2.57 (1.02–6.44)	2.29 (0.58–8.97)	1.18 (0.34–4.12)

The overall estimates were statistically significant for both outcomes, but the laterality-specific estimates were imprecise and their confidence intervals included 1.

4. Pettersson et al. (26)

For acoustic neuroma, Pettersson et al. reported the following results for cumulative mobile phone use exceeding 680 hours:

Exposure	Overall OR (95% CI)	Ipsilateral OR (95% CI)	Contralateral OR (95% CI)
Mobile phone	1.46 (0.98–2.17)	1.20 (0.69–2.08)	1.26 (0.70–2.25)

These findings support the scientific relevance of examining tumor laterality as one component of RF-EMF exposure assessment. The following table gives the results of meta-analysis of the results for glioma and acoustic neuroma. Highest ORs were calculated for ipsilateral use, which is of biological relevance.

Odds ratios (OR) with 95% confidence interval (CI) for glioma and acoustic neuroma in case-control studies in the highest category for cumulative (cum) mobile phone use in hours^a

	Glioma				Acoustic neuroma			
	All		Ipsilateral		All		Ipsilateral	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Interphone (23) Cum use ≥ 1,640 hr	1.40	1.03-1.89	1.96	1.22-3.16	1.32	0.88-1.97	2.33	1.23-4.40
Coureau et al, (25) Cum use ≥ 896 hr	2.89	1.41-5.93	2.11	0.73-6.08				
Hardell, Carlberg (20,22) Cum use ≥ 1,640 hr	2.13	1.61-2.82	3.11	2.18-4.44	2.40	1.39-4.16	3.18	1.65-6.12
Meta-analysis longest cum use	1.90	1.31-2.76	2.54	1.83-3.52	1.73	0.96-3.09	2.71	1.72-4.28

^a Note Hardell, Carlberg also assessed use of cordless phones.

Thus, for worst case scenario the preferred side used for the wireless phone is important to assess. However, this method was disregarded by Karipidis et al (27) in the WHO-commissioned review with the following argument:

“The preferred side of the head for mobile phone use is an important exposure determinant but, when assessed retrospectively through selfreport, is affected by substantial misclassification and recall bias...i.e. in certain studies with no overall association, there was an increased risk with ipsilateral use which was compensated by a decreased risk with contralateral use, indicating a bias.

That conception is contradicted by the results in the Hardell group studies, the Interphone study and the Coureau study, as shown above. The Hardell group studies showed no evidence of recall bias in the analyses of laterality of wireless phone (mobile phone and cordless phone) use and tumor localization for acoustic neuroma, meningioma, and glioma. Overall detailed analysis of the published results (20-25) clearly make the claim of “*substantial misclassification and recall bias*” scientifically invalid. Thus, these laterality results should have been included by Karipidis et al (27).

Time trends of brain tumor incidence

The WHO-commissioned review by Karpidis et al (27) concluded that:

“The time-trend simulation studies, evaluated as complementary evidence in line with a triangulation approach for external validity, were consistent in showing that the increased risks observed in some case-control studies were incompatible with the actual incidence rates of glioma/brain cancer observed in several countries and over long periods. Three of these simulation studies consistently reported that RR estimates > 1.5 with a 10+ years induction period were definitely implausible, and could be used to set a “credibility benchmark”.”

“Further, the time-trend simulation studies were very consistent in showing that the increased risks observed in some case-control studies were incompatible with the actual incidence rates of brain cancer observed in several countries and over long periods (up to over 30 years since handheld devices became available).”

“However, three simulation studies consistently reported that relative risk estimates > 1.5 with a 10+ years induction period were definitely implausible...Based on these findings, we carried out the planned sensitivity meta-analyses of glioma risk in relation to long-term mobile phone use (10+ years) excluding studies reporting implausible effect sizes.”

These conclusions are not based on review of all literature on brain tumor incidence. Philips et al (28) reported: *“...a sustained and highly statistically significant ASR rise in glioblastoma multiforme (GBM) across all ages. The ASR for GBM more than doubled from 2.4 to 5.0, with annual case numbers rising from 983 to 2531. Overall, this rise is mostly hidden in the overall data by a reduced incidence of lower grade tumours.... The rise cannot be fully accounted for by promotion of lower-grade tumours, random chance or improvement in diagnostic techniques as it affects specific areas of the brain and only one type of brain tumour.”* This study was excluded in the review by Karipidis et al (27).

Promotion of low-grade tumor to high grade form RF radiation may be one cause in addition to initiation of glioblastoma multiforme. Some support is obtained in the case-control study on glioma by Hardell, Carlberg (22). Increased OR was seen with short latency < 10 years, after that some decline, and increasing OR with latency > 15 years, see Fig 3 (below) from the publication.

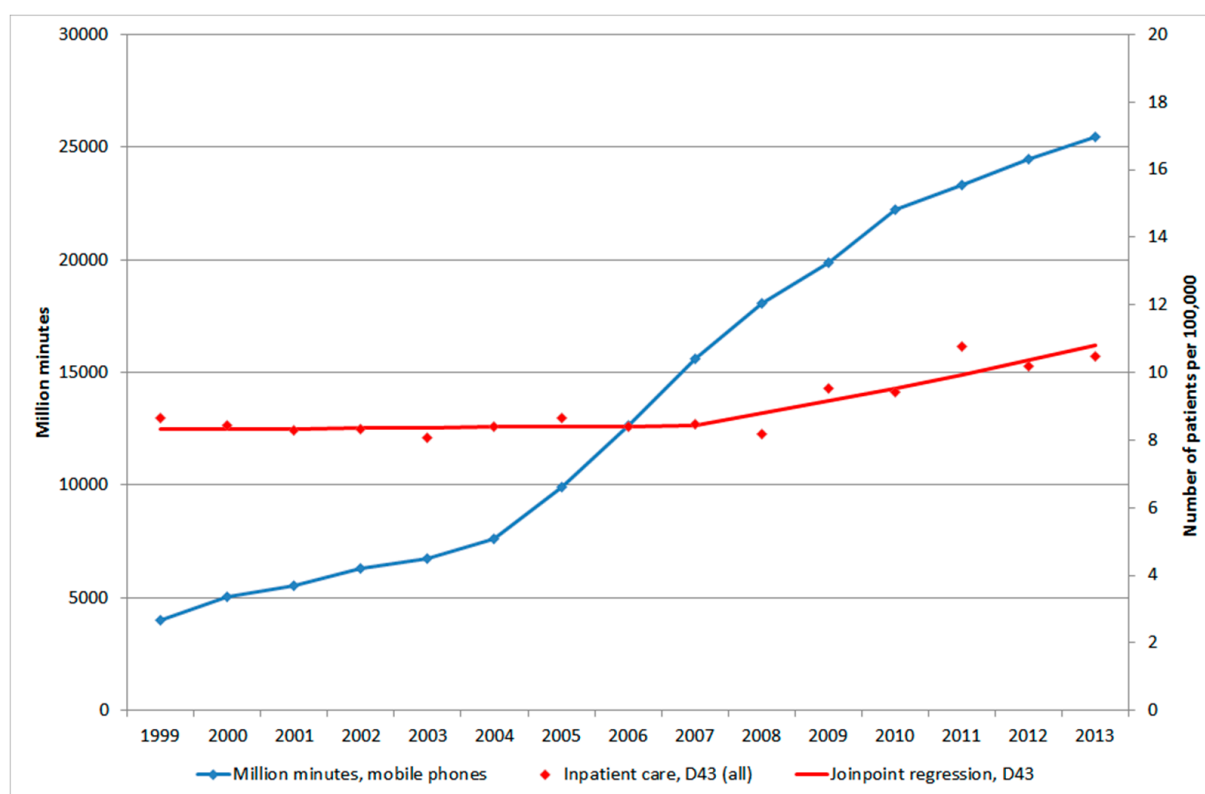
Interesting also the Interphone study (23) yielded increased OR with short latency, 2-9 years, but highest in the 10+ latency group, see Appendix 2.

Other studies excluded by Karipidis et al (27) were Swedish data by Hardell, Carlberg (29,30). Both provided evidence of increasing rates of brain tumors.

Hardell, Carlberg (29) used the Swedish National Inpatient Register (IPR) and Causes of Death Register (CDR) to study the rates of brain tumors comparing with the Cancer Register incidence data for the time period 1998–2013 using joinpoint regression analysis. *“In the IPR we found a joinpoint in 2007 with Annual Percentage Change (APC) $+4.25\%$, 95% CI $+1.98$, $+6.57\%$ during 2007–2013 for tumours of unknown type in the brain or CNS. In the CDR joinpoint regression found one joinpoint in 2008 with APC during 2008–2013 $+22.60\%$, 95% CI $+9.68$, $+37.03\%$. These tumour diagnoses would be based on clinical examination, mainly CT and/or MRI, but without histopathology or cytology. No statistically significant increasing*

incidence was found in the Swedish Cancer Register during these years. We postulate that a large part of brain tumours of unknown type are never reported to the Cancer Register.”

Interestingly data showed increasing number of patients per 100 000 inhabitants with D43 (tumor of unknown type in the brain), see Fig 5 in the article with some lag time from increasing number of out-going mobile phone minutes in millions during 1999-2013 (29).



Number of out-going mobile phone minutes in millions during 1999–2013 and joinpoint regression analysis of number of patients per 100,000 inhabitants according to the Swedish National Inpatient Register for all ages during 1999–2013 diagnosed with D43 = tumour of unknown type in the brain or CNS.

Further analysis was made for the time period 1998-2015 using the Swedish National Inpatient register and the Swedish Cancer Register (30). “Average Annual Percentage Change (AAPC) per 100,000 increased with +2.06%, 95% confidence interval (CI) +1.27, +2.86% in both genders combined. A join point was found in 2007 with Annual Percentage Change (APC) 1998±2007 of +0.16%, 95% CI -0.94, +1.28%, and 2007±2015 of +4.24%, 95% CI +2.87, +5.63%. Highest AAPC was found in the age group 20±39 years. In the Swedish Cancer Register the age standardized incidence rate per 100,000 increased for brain tumors, ICD-code 193.0, during 1998±2015 with AAPC in men +0.49%, 95% CI +0.05, +0.94%, and in women +0.33%, 95% CI -0.29, +0.45%.

Fig 1 from the article shows the results for men.

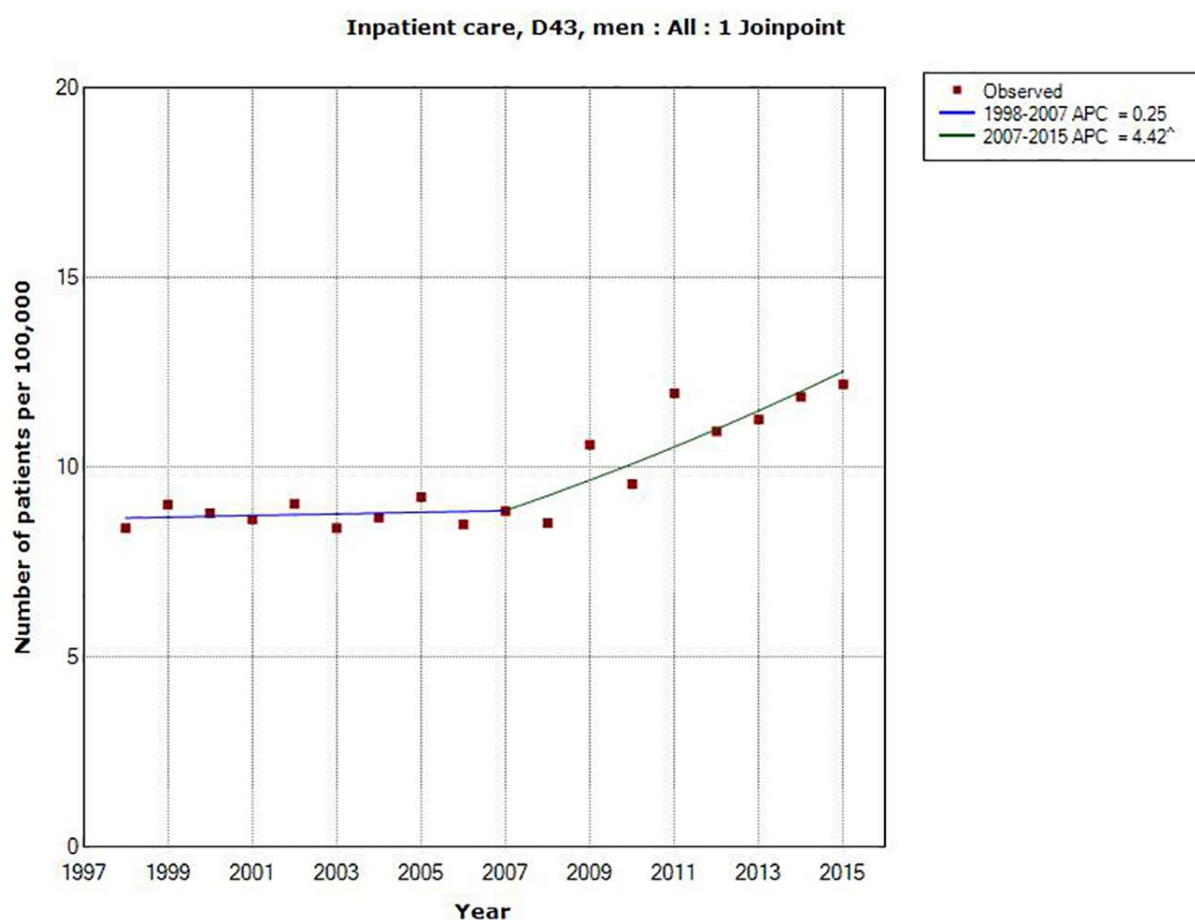


Fig 1. Joinpoint regression analysis of number of patients per 100,000 inhabitants according to the Swedish National Inpatient Register for men, all ages during 1998-2015 diagnosed with D43 = tumor of unknown type in the brain or CNS (30).

(<http://www.socialstyrelsen.se/statistik/statistikdatabas/diagnoserislutenvard>).

Fig 2 shows the results for women.

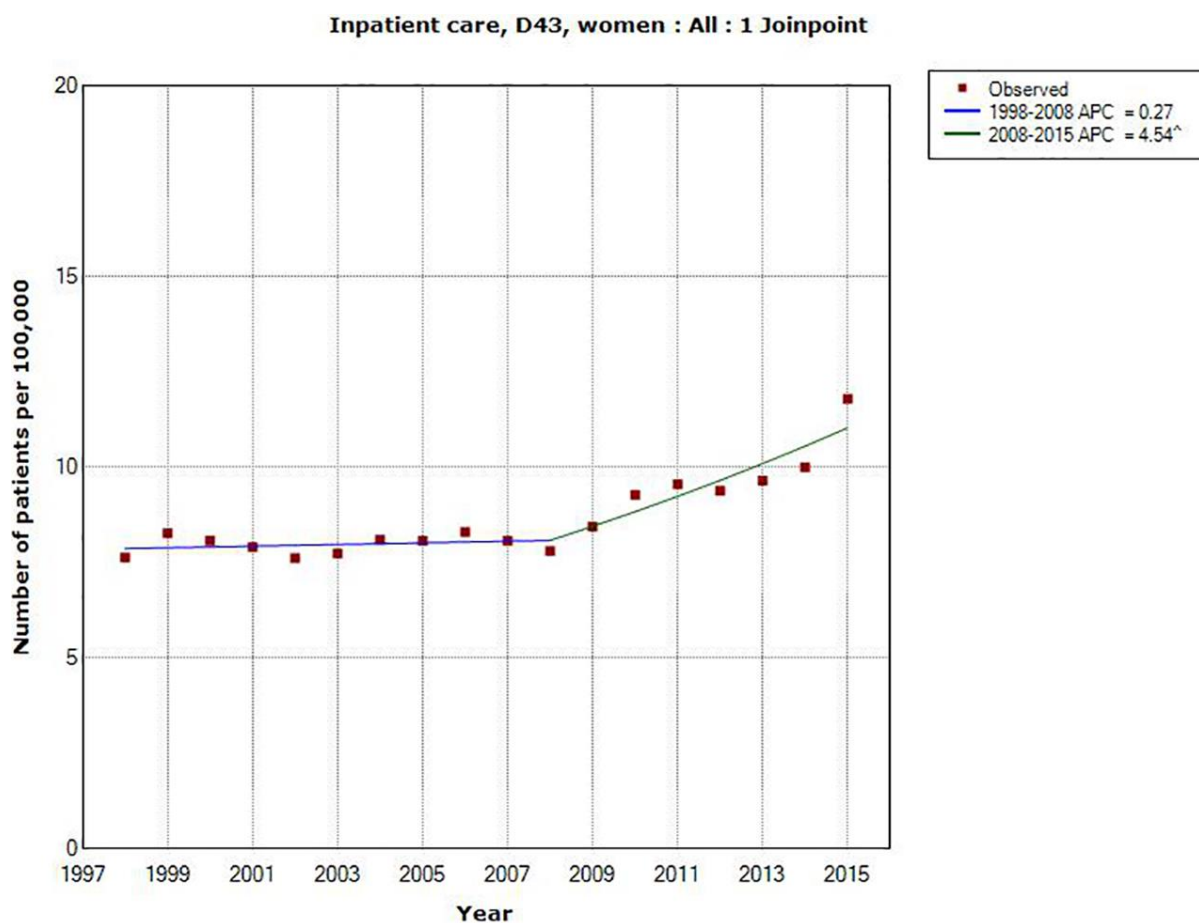
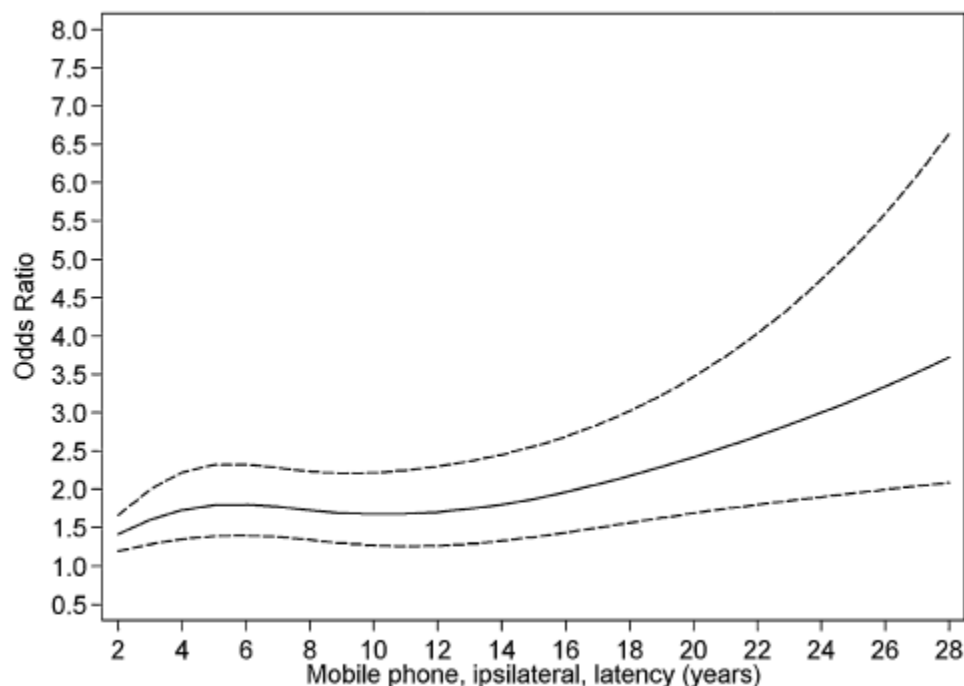


Fig 2. Joinpoint regression analysis of number of patients per 100,000 inhabitants according to the Swedish National Inpatient Register for women, all ages during 1998-2015 diagnosed with D43 = tumor of unknown type in the brain or CNS (30).

(<http://www.socialstyrelsen.se/statistik/statistikdatabas/diagnoserislutenvard>).

Both figures show increasing rates of tumors of unknown type (D43) in the brain or CNS, in men during 2007-2015 and in women during 2008-2015. Both results were statistically significant.



Restricted cubic spline plot of the relationship between latency of ipsilateral mobile phone use and glioma. The solid line indicates the OR estimate and the broken lines represent the 95% CI. Adjustment was made for age at diagnosis, gender, SEI-code, and year for diagnosis. Population based controls were used. (22).

Karipidis et al (27) concluded that “*The time-trend simulation studies,..., were consistent in showing that the increased risks observed in some case-control studies were incompatible with the actual incidence rates of glioma/brain cancer observed in several countries and over long periods.*”

That statement was based on selective inclusion of studies thereby excluding relevant reports published after peer review in scientific journals, including our publications. For a valid conclusion a survey of the whole literature must be made. Furthermore, items such as latency, tumor type, anatomical localization of the tumor and etiologic fraction should be considered. Due to the substantial shortcomings by Karipidis et al (27) the lack of the author’s scientific accuracy is worrying. Several issues need to be considered when interpreting the results of Karipidis et al (27) such as tumor-specific trends, diagnostic and registration practices, induction and latency periods, study selection, and exposure assessment.

Problems with the Karipidis et al. review (27)

The article titled “The effect of exposure to radiofrequency fields on cancer risk in the general and working population: A systematic review of human observational studies – Part I: Most researched outcomes” by Karipidis et al. (27) concluded that there is no increased risk for any of the included cancers (brain tumors, childhood leukaemia or pediatric brain tumors). It was:

“Exposure to RF from mobile phone use likely does not increase the risk of brain cancer.”

“RF from broadcasting antennas or base stations likely does not increase the risk of childhood.”

“Occupational exposure to RF may not increase the risk of brain cancer.”

These results are contradicted by other recent reviews (31) and is likely a result of the bias within the group of authors, where several persons, including the first author, have conflicts of interests.

Mobile Phones and Brain-Tumour Risk: Comparing the Reviews by Karipidis et al. (27) and Moon et al. (32)

Two studies have published contradictory results on the risk of brain tumors associated with use of mobile phones. The first was published by Karipidis et al (27) *The effect of exposure to radiofrequency fields on cancer risk in the general and working population: A systematic review of human observational studies – Part I: Most researched outcomes*. It was commissioned by and partly funded by the World Health Organization, WHO

The authors concluded that: *For near field RF-EMF exposure to the head from mobile phone use, there was moderate certainty evidence that it likely does not increase the risk of glioma, meningioma, acoustic neuroma, pituitary tumours, and salivary gland tumours in adults, or of paediatric brain tumours*. Similar results were reported for use of cordless phones (DECT).

These results are in large contrast to the evaluation by Moon et al (32). The conclusion was that: *Ipsilateral users [of mobile phones] reported a pooled odds ratio (OR) of 1.40 (95% CI 1.21–1.62) compared to non-regular users. Users with years of use over 10 years reported a pooled OR of 1.27 (95% CI 1.08–1.48). When stratified by each type of brain tumor, only meningioma (OR 1.20 (95% CI 1.04–1.39)), glioma (OR 1.45 (95% CI 1.16–1.82)), and malignant brain tumors (OR 1.93 (95% CI 1.55–2.39)) showed an increased OR with statistical significance for ipsilateral users. For users with years of use over 10 years, only glioma (OR 1.32 (95% CI 1.01–1.71)) showed an increased OR with statistical significance. When 11 studies with an OR with cumulative hours of use over 896 h were synthesized, the pooled OR was 1.59 (95% CI 1.25–2.02). When stratified by each type of brain tumor, glioma, meningioma, and acoustic neuroma reported the pooled OR of 1.66 (95% CI 1.13–2.44), 1.29 (95% CI 1.08–1.54), and 1.84 (95% CI 0.78–4.37), respectively. For each individual study that considered cumulative hours of use, the highest OR for glioma, meningioma, and acoustic neuroma was 2.89 (1.41–5.93) (both side use, >896 h), 2.57 (1.02–6.44) (both side use, >896 h), and 3.53 (1.59–7.82) (ipsilateral use, >1640 h), respectively.*

Moon et al (32) made a more thorough analysis including the risk in the most exposed part of the handheld mobile phone (temporal area), cumulative use, and ipsilateral use (same side of the brain as the localization of the tumor). These biologically most relevant issues were not further analyzed by Karipidis et al (27). Furthermore, Karipidis and other authors are members of ICNIRP, a pro industry organization thus giving conflict of interest. These affiliations warrant transparent disclosure and consideration when assessing the review's independence.

Moon et al. reported statistically significant associations for several exposure categories, including ipsilateral use, long-term use, and higher cumulative call time. These findings deserve consideration alongside the broader evidence assessed by Karipidis et al (27).

Here bias and conflicts of interest in the article are described:

Bias and conflicts of interests

ICNIRP has been identified as an organization with ties to the industry, promoting standards that are beneficial to the industry but according to 271 EMF scientists (emfscientist.org) and also according to ICBE-EMF (33) insufficient to protect the public against harmful effects from radiofrequency radiation. ICNIRP limits are only based on acute thermal effects, excluding cancer effects. A result showing increased cancer risks would make ICNIRP limits invalid for human health protection. According to the same authors *“if exposure to RF-EMF increased the risk of cancer, then this would have serious public health consequences and require population-level preventive strategies, including a revision of the threshold-based limitation principle currently applied to non-ionizing radiation in the radiofrequency range (27).”* ICNIRP limits are of considerable economic importance to the telecom industry. Lower limits would render roll out of 5G impossible or difficult according to a major 5G infrastructure provider. A recognition of cancer risks would also cause potential negative outcomes for the telecom industry in court cases on cancer claimed to be caused by mobile phone technology exposure and economic compensation for damage.

WHO is known to collaborate with ICNIRP, promoting the ICNIRP attitude that there are no cancer risks from RF-radiation emitted from mobile phones and mobile phone base stations. The collaboration has been very close since the start of the WHO EMF project in 1996 resulting in the WHO conducting a project promoting the ICNIRP guidelines worldwide (WHO Harmonization project). The first chairman of ICNIRP, Michael Repacholi, also became the director of the WHO EMF project in 1996. WHO received funding from telecommunications industry for the EMF Project during many years while the current project manager Emilie van Deventer was working with the project. In 2011 she published a fact sheet on the WHO website shortly after the IARC RF classification as 2B. The fact sheet downplayed the IARC classification about the cancer risks. The WHO International EMF Project, established in 1996, has maintained longstanding scientific collaboration with ICNIRP. As part of this work, WHO initiated an international process to harmonize EMF exposure standards, including the development of a framework intended to facilitate internationally consistent approaches to exposure limits and protection. WHO and ICNIRP have also collaborated on scientific reviews and health-risk assessments (34,35,36).

Several of the authors have conflicts of interests in terms of ties to ICNIRP or other bias.

Ken Karipidis, first author, is a member of ICNIRP. Given ICNIRP's role in developing RF-EMF exposure guidelines, this affiliation is relevant when assessing the independence of a review that evaluates evidence potentially bearing on those guidelines.

Dan Baaken, second author, is scientific secretary of ICNIRP 2024-2028 according to ICNIRP's published information. This professional role should be considered alongside the review's declarations of competing interests.

(<https://www.icnirp.org/en/activities/news/news-article/scientific-secretariat-2024-2028.html>)

Tom Loney has performed research and provided advisory services to the defense, industrial and healthcare sectors. The defense industry is an industry with interests in the outcome of a cancer risk evaluation of RF radiation, thus a potential conflict of interest.

<https://www.mbru.ac.ae/a-z-directory/tom-loney/>

Maria Blettner, was the only one out of 29 experts that voted against classifying RF radiation as 2B carcinogen at the IARC meeting 2011. Two were not present for final evaluation. The majority of all other experts, 26 in total, agreed on the 2B classification. According to accounts of the 2011 International Agency for Research on Cancer (IARC) evaluation, Blettner was the sole expert reported to have voted against classifying RF-EMF as possibly carcinogenic to humans (Group 2B). This position differs from that of the majority of the working group. A difference of scientific opinion is not itself evidence of bias, but the history is relevant when considering the range of scientific perspectives represented in subsequent reviews.

<https://microwavenews.com/short-takes-archive/row-over-review>

Martin Rösli is also a member of ICNIRP and in addition has received funding for research from the telecom industry funded Swiss foundation that serves as an intermediate between telecom industry and researchers (37). Potential conflicts of interest in RF-EMF risk assessments, including relationships with a Swiss research-funding organisation supported by the telecommunications sector are of concern. The nature, extent, and relevance of any such funding should be evaluated using the relevant disclosures and funding records.

He co-authored the Cefalo study that limited cordless phone exposure to the first three years of use without any scientific basis and he has repeatedly downplayed evidence of cancer and other health risks from RF. Critics have questioned aspects of exposure classification and the interpretation of findings in some studies involving wireless technologies.

Susanna Lagorio has repeatedly during over a decade aligned with the ICNIRP attitude. She has collaborated with scientists with known conflicts of interests in terms of funding from industry and membership in ICNIRP. She coauthored a paper with Martin Rösli that was deemed “*the most biased review of this topic that I have [ever] read*” by a reviewer.

<https://microwavenews.com/news-center/repacholi-half-who-emf-project-funding-came-industry>

She also testified on behalf of Radio Vatican regarding cancer risks from the Radio Transmitter claiming there were no cancer risks. Microwave News has reported controversies concerning the WHO EMF Project and industry funding. Lagorio has also been involved in proceedings concerning potential health effects associated with radio transmitters, as documented in Italian parliamentary records.

(<https://www.senato.it/japp/bgt/showdoc/showText?tipodoc=Sindisp&leg=16&id=>

These examples above illustrate that the outcome of the review may have already be pre-determined solely on the basis of the selected group members. Evaluations of health risks from RF radiation should be performed by persons without ties to ICNIRP or industry, in view of the huge economic interests (telecom/defense) that have vested interests in the outcome of such evaluations. Industrial direct or indirect ties may compromise objective and

sound scientific code of conduct, a fact that is documented in several studies on the impact of industry funding of scientific studies. The scope, design and conduct of research may be impacted. Industry sponsored research is documented to be more likely to give results favorable to the industry.

Industry sponsorship and research independence

Research has shown that industry sponsorship can be associated with differences in research agendas and reported findings. Fabbri et al. (38), for example, reviewed evidence on the influence of industry sponsorship on research priorities.

In a field with substantial commercial and regulatory implications, the independence of scientific evaluations is particularly important. Funding relationships may influence which questions are investigated, which exposure measures are prioritized, how outcomes are defined, and how findings are interpreted.

Accordingly, assessments of RF-EMF health risks should include transparent declarations of financial and non-financial interests, clear criteria for study inclusion, reproducible analytical methods, and independent evaluation of the evidence.

In 2002 the Swedish Radiation Protection Authority (SSI) hired two US epidemiologists to review published epidemiological studies on the relationship between the use of cellular telephones and cancer risk. They were Dr. John D. Boice, Jr. and Dr. Joseph K. McLaughlin from the private company International Epidemiology Institute (IEI). In their review [Boice and McLaughlin, 2002], they claimed that no consistent evidence was observed for increased risk of brain cancer, including meningioma, acoustic neurinoma, ocular melanoma, or salivary gland cancer, and mobile phone use (39).

The strength of evidence may be evaluated by using the Hill criteria on casualization. They were initially developed in 1965 at the height of the tobacco and lung cancer controversy. For more details see Hardell, Carlberg (40). The scientific evidence should be evaluated regarding strength, consistency, specificity, temporality, biological gradient, plausibility, coherence, experiment, and analogy. In our evaluation based on these criteria we concluded that glioma and acoustic neuroma should be considered to be caused by RF-EMF emissions from wireless phones and regarded as carcinogenic to humans, classifying it as group 1 according to the IARC classification. The bottom line was that current guidelines for exposure need to be urgently revised (40).

In the review by Belpomme et al (41) it was concluded that *exposure to low frequency and radiofrequency electromagnetic fields at low intensities poses a significant health hazard that has not been adequately addressed by national and international organizations such as the World Health Organization. There is strong evidence that excessive exposure to mobile phone-frequencies over long periods of time increases the risk of brain cancer both in humans and animals. The mechanism(s) responsible include induction of reactive oxygen species, gene expression alteration and DNA damage through both epigenetic and genetic processes* (41)

The Health Council of the Netherlands released on September 2, 2020 their evaluation on 5G and health. Three members were current or former members of ICNIRP that is a conflict of

interest (42). The evaluation was largely based on a World Health Organization draft and report by the Swedish Radiation Safety Authority, both criticized for not being impartial. Further: *The guidelines by the International Commission on Non-Ionizing Radiation Protection were recommended to be used, although they have been considered to be insufficient to protect against health hazards (<http://www.emfscientist.org>). The Health Council Committee recommended not to use the 26 GHz frequency band until health risks have been studied. For lower frequencies, the International Commission on Non-Ionizing Radiation Protection guidelines were recommended. The conclusion that there is no reason to stop the use of lower frequencies for 5G is not justified by current evidence on cancer risks as commented in this article. A moratorium is urgently needed on the implementation of 5G for wireless communication.*

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) published 2020 updated guidelines on radiofrequency (RF) radiation in the frequency range 100 kHz to 300 GHz. Harmful effects on human health and the environment at levels below the guidelines were downplayed although increasing evidence on health risks. Thereby, only thermal (heating) effects were acknowledged disregarding non-thermal effects contrary to scientific evidence. These new ICNIRP guidelines were not lower compared with the previous levels. Several experts in ICNIRP have conflicts of interest with ties to the telecom industry. Disregarding non-thermal effects makes the ICNIRP evaluation less reliable for protection of human health (43).

In 2022 ICBE-EMF published an article with the following conclusion: *In the late-1990s, the FCC and ICNIRP adopted radiofrequency radiation (RFR) exposure limits to protect the public and workers from adverse effects of RFR. These limits were based on results from behavioral studies conducted in the 1980s involving 40–60-minute exposures in 5 monkeys and 8 rats, and then applying arbitrary safety factors to an apparent threshold specific absorption rate (SAR) of 4 W/kg. The limits were also based on two major assumptions: any biological effects were due to excessive tissue heating and no effects would occur below the putative threshold SAR, as well as twelve assumptions that were not specified by either the FCC or ICNIRP. In this paper, we show how the past 25 years of extensive research on RFR demonstrates that the assumptions underlying the FCC's and ICNIRP's exposure limits are invalid and continue to present a public health harm. Adverse effects observed at exposures below the assumed threshold SAR include non-thermal induction of reactive oxygen species, DNA damage, cardiomyopathy, carcinogenicity, sperm damage, and neurological effects, including electromagnetic hypersensitivity. Also, multiple human studies have found statistically significant associations between RFR exposure and increased brain and thyroid cancer risk. Yet, in 2020, and in light of the body of evidence reviewed in this article, the FCC and ICNIRP reaffirmed the same limits that were established in the 1990s. (44)*

This article is another example on how the implementation of the wireless society has progress on its own track, in spite of scientific evidence on adverse health effects, see the summary: *In 2017 an article was published on the unwillingness of the WHO to acknowledge the health effects associated with the use of wireless phones. It was thus stated that the WHO is 'A Hard Nut to Crack'. Since then, there has been no progress, and history seems to be repeating in that the European Union (EU) is following in the blind man's footsteps created by the WHO. Despite increasing evidence of serious negative effects from radiofrequency radiation on human health and the environment, the EU has not acknowledged that there are any risks. Since September 2017, seven appeals by scientists and medical doctors have been sent to the*

EU requesting a halt to the roll-out of the fifth generation of wireless communication (5G). The millimeter waves (MMW) and complex waveforms of 5G contribute massively harmful additions to existing planetary electromagnetic pollution. Fundamental rights and EU primary law make it mandatory for the EU to protect the population, especially children, from all kinds of harmful health effects of wireless technology. However, several experts associated with the WHO and the EU have conflicts of interest due to their ties to industry. The subsequent prioritizing of economic interests is resulting in human and planetary health being compromised. Experts must make an unbiased evaluation with no conflicts of interest. The seven appeals to the EU have included requests for immediate protective action, which have been ignored. On the issue of wireless radiation and the health of citizens, the EU seems to be another hard nut to crack (45)

This was further discussed in a comprehensive review by ICBE-EMF: Due to serious methodological flaws and weaknesses in the conduct of the reviews and MAs on health effects of RF-EMF exposure, the WHO-commissioned SRs cannot be used as proof of safety of cell phones and other wireless communication devices.... The report of harmful effects (e.g., cancer, reproductive toxicity, etc.) at doses below the adverse health effect threshold claimed by ICNIRP demonstrates that current exposure limits to RF-EMF, which were established by applying arbitrary uncertainty factors to their putative adverse threshold dose, lack scientific credibility (46).

Potential limitations of the Danish mobile phone cohort

The Karipidis et al (27) review included the Danish cohort and a UK cohort. Due to the serious misclassification of exposure in the Danish cohort (47), this cohort study is uninformative about cancer risks from mobile phone use. When included in meta-analyses it will influence the result towards no risk. The Frei et al (47) study, originally funded by Danish telecom operators, reported no increased risks of tumors in the central nervous system. It was based on 420,095 mobile phone private subscribers. This group's incidence of brain tumors was compared with the incidence within the rest of the Danish population (control group). However, the study's exposure classification has been criticised because possession of a private subscription was used as a proxy for mobile phone exposure (49). This approach may have resulted in substantial misclassification of actual use.

The five main errors with the Frei et al (47) study are, see (39):

1. **Restricted definition of the exposed population.** The exposed group consisted of private subscribers whose subscriptions began between 1982 and 1995.
2. **Exclusion of corporate subscribers.** Approximately 200,507 corporate subscribers were excluded from the exposed group. Corporate users may have included people with substantial occupational mobile phone use. Those not classified as private subscribers could consequently have been included in the comparison population.
3. **Classification of later subscribers.** People who obtained subscriptions in 1996 or later were classified as non-users under the study's exposure definition, despite potentially substantial mobile phone use.

4. **Lack of individual exposure information.** The study did not have detailed information on cumulative call time, frequency of use, the side of the head on which the phone was used, or other individual exposure characteristics.
5. **Limited assessment of cordless phone exposure.** Exposure to cordless DECT phones was not adequately captured by the mobile phone subscription classification. This could have resulted in some people with RF-EMF exposure being included in the comparison group.

These limitations are important because exposure misclassification can affect estimated associations. Its findings should be interpreted in the context of these limitations and alongside studies with more detailed individual exposure assessments. In the evaluation attention should be given to:

Long-term exposure and latency: Whether studies adequately assess exposure over periods relevant to the development of cancer.

Cumulative use: Whether total call time and other measures of intensity are analyzed in a way that captures differences between low and heavy users.

Anatomical localization: Whether the location of a tumor relative to the side of the head on which a mobile phone was used is assessed.

Exposure misclassification: Whether the study designs distinguish actual use from subscription status or other indirect measures.

Tumour subtype: Whether analyses consider specific tumor types rather than relying exclusively on broad groupings of brain and central nervous system tumors.

Study quality and sensitivity analyses: Whether the conclusions remain stable when studies with important methodological limitations are excluded.

Conflicts of interest: Whether conflicts of interests are appropriately managed.

These considerations are particularly relevant when a review uses graded statements of certainty, such as “moderate certainty evidence,” to inform public-health policy (27).

5. Exposure standards and risk assessments.

The table shows guidelines on recommended limit exposure levels for the public by different organizations for microwave radiation in $\mu\text{W}/\text{m}^2$.

Year	Power Density ($\mu\text{W}/\text{m}^2$)	Name	Description
1998	10,000,000	ICNIRP	10,000,000 for 2–300 GHz
	9,000,000		9,000,000 for 1800 MHz and
	4,500,000		4,500,000 for 900 MHz

			Whole body exposure averaged over 6 min.
2001	1,000 100 000	Salzburg Resolution	1,000 for the sum total of all pulse modulated high-frequency exposures 100,000 for the total of all high-frequency irradiation. ¹
2001	100	EU Parliament STOA 2001	For chronic exposure from pulsed microwaves. ¹
2002	1	New Salzburg Precautionary Exposure Limit Indoor	P Indoor chronic exposure from GSM base stations. ¹
2012	3-6	Bioinitiative 2012 Recommendation	For chronic exposure to pulsed RF. ¹
2016	0,1-100	Europe EM EMF Guidelines	For extended exposure at least 4 hours a day to frequencies between GSM 900 to WiFi 5.6 GHz depending on sensitivity, night time or daytime exposure. Peak maximum values.
2020	10,000,000 9,000,000 4,500,000	ICNIRP 2020	10,000,000 for >2–300 GHz 9,000,000 for 1800 MHz and 4,500,000 for 900 MHz Whole body exposure averaged over 30 min.
2020	10,000,000 18,200,000 36,600,000 40,000,000 40,000,000 26,600,000 20,000,000	ICNIRP 2020	10,000,000 for 400 MHz 18,200,000 for 800 MHz 36,600,000 for 1,800 MHz 40,000,000 for 2 GHz 40,000,000 for 6 GHz: 26,600,000 for 60 GHz: 20,000,000 for 300 GHz: Local exposure averaged over 6 min.

¹ Average or peak maximum values not specified

ICNIRP's conclusion on cancer risks is: "In summary, no effects of radiofrequency EMFs on the induction or development of cancer have been substantiated." This conclusion is not correct and is contradicted by scientific evidence. The ICNIRP 2020 guidelines allow

exposure at levels known to be harmful. They should be replaced by protective guidelines produced by independent scientists (43).

ICNIRP's guidelines have also been criticized by the International Commission on the Biological Effects of Electromagnetic Fields (44). These guidelines are based on tissue heating that does not account for non-thermal biological effects.

Question 6. What scientific evidence exists about potential adverse health effects caused by current exposure limits?

See above.

Question 7. What scientific methods are currently available for accurately characterizing individual and population-level RF radiation exposure?

Measurement of RF radiation with appropriate RF Meters. See our case studies and measurement studies in Örebro and Stockholm (51-53).

Question 8. What, if any, improvements in exposure assessment methodologies are needed to better evaluate real-world exposure conditions?

Scientific evidence should include:

- Regular review of the research
- Long term effect on humans, flora and fauna
- Children and other susceptible groups
- Studies on health effects from real life exposure to 5G, 6G, WiFi, smart meters etc.
- Outdated guidelines by ICNIRP/FCC should be replaced considering also non-thermal effects
- Special attention to EUROPAEM-EMF guidelines
- Public health risk information

Question 9. What, if any, technical and exposure-related information should be disclosed to consumers, residents, workers, schools, healthcare providers, and local governments?

The information disclosed should include:

- a) The basis for the exposure limits, especially thermal acute effects if today's limits from ICNIRP/FCC are maintained.
- b) Potential health effects reported in several studies, e.g. cancer, symptoms such as sleeping problems, headache, memory- concentration problems, effects on the heart and other organs.
- c) Risk associated with exposure during pregnancy and early childhood.
- d) Risk of developing neurodegenerative diseases or cognitive impairment.
- e) Recommendations on how to reduce exposure, use wired connectivity and Ethernet solutions, keep distance to the RF-EMF emitting source, reduce the time if wireless units are used.

f) Recommendations to keep mobile phone masts and base stations at distance from people's homes, schools, elderly care homes, and hospitals.

g) That individual sensitivity may vary considerably and that some individuals may develop illness at lower levels of RF radiation than others.

Question 10. Should additional data sources or surveillance systems be developed? Please discuss the benefits and challenges of the following data sources and surveillance systems, as relevant

Surveillance systems and research programs should be developed. These systems could help identify emerging health trends, improve exposure assessment, and investigate possible associations. Obviously these should include:

Disease registries; Occupational monitoring; Environmental monitoring; Biomonitoring; Adverse-event reporting; Disease or illness clusters; Other measures: Information and training for healthcare professionals and authorities

Both national and international programs should be implemented. Reliable investigations aiming at early detection and prevention should be performed.

Question 11. Should exposure assessment or risk evaluation differ for sensitive populations such as those noted below? Please explain.

Sensitive persons include children, pregnant women, elderly persons, and those with electromagnetic hypersensitivity should be considered in exposure assessment and risk evaluation. Thereby increased scientific knowledge and differences in vulnerability should be identified aiming at health protection. Where significant uncertainty remains, proportionate precautionary measures should be considered.

Question 12. What scientific evidence exists regarding potential adverse health effects associated with RF radiation exposure at levels below current federal exposure limits?

There is clear scientific evidence of increased cancer risks and other health and biological effects at levels below current exposure levels.

Question 13. According to scientific evidence, how do the technologies below affect cumulative exposure patterns?

Cumulative radiofrequency electromagnetic field (RF-EMF) exposure depends on the number of wireless devices or antennas in use and the distance to the devices or antennas. It is also influenced by transmitting power, antenna direction, network traffic, building characteristics, and exposure time. The expansion of wireless technologies, for instance 5G and smart meters, has increased the number of potential RF-EMF sources in everyday environments. Wired connections should be used in homes, schools, hospitals, elderly care etc. This would reduce RF-EMF emissions.

Question 14. What scientific evidence exists regarding potential adverse environmental effects associated with RF radiation?

See: *Ambient levels of electromagnetic fields (EMF) have risen sharply in the last 80 years, creating a novel energetic exposure that previously did not exist. Most recent decades have seen exponential increases in nearly all environments, including rural/remote areas and lower atmospheric regions.*

<https://pubmed.ncbi.nlm.nih.gov/34047144/https://pubmed.ncbi.nlm.nih.gov/34243228/>

15. What types of scientific evidence should be considered when evaluating RF exposure associated with wireless infrastructure?

See above.

Question 16. What are the highest priority research gaps regarding EMF and RF radiation and public health that the federal health agencies should address?

RF-EMF exposure and long-term cancer risk, reproduction and development, susceptible populations such as children and the elderly, neurological effects, and effects on animals from exposure from mobile phone masts

Question 17. How can federal health agencies improve coordination of EMF and RF radiation research?

See above.

Question 18. Additional Scientific Evidence, Technical Information, and Recommendations for Evaluating Potential Adverse Health Effects Associated with Radiofrequency Electromagnetic Field Exposure

The most important additional recommendation is to establish a transparent, balanced, industry independent, and regularly updated national RF-EMF research and health-surveillance programme.

The FCC limits need to be significantly lower in order to protect against cancer, neurological and other effects on well-being and also take into account particular sensitivity of some groups, such as children, elderly and those with EHS.

Concerns have been raised regarding the influence of ICNIRP-affiliated experts in scientific assessments, see (49,50). Such affiliation might prohibit independent evaluation of scientific evidence on risks (35).

References and supporting evidence

The following publications and reports are submitted as supporting materials for consideration. They include epidemiological studies, case reports, exposure surveys, reviews of regulatory guidelines, and publications raising questions about research methodology and scientific independence.

1. Hardell L, Nilsson M. Summary of Seven Swedish Case Reports on the Microwave Syndrome Associated with 5G Radiofrequency Radiation. *Reviews on Environmental Health*. 2024.

2. Hardell L, Nilsson M. Case Report: The Microwave Syndrome after Installation of 5G Emphasizes the Need for Protection from Radiofrequency Radiation. *Annals of Case Reports*. 8:1112. doi:10.29011/2574-7754.101112.
 3. Nilsson M, Hardell L. Development of the Microwave Syndrome in Two Men Shortly after Installation of 5G on the Roof above Their Office. *Annals of Clinical and Medical Case Reports*. 2023;8:2378.
 4. Hardell L, Nilsson M. Case report concerning a healthy 52-year-old woman who developed severe microwave syndrome shortly after installation of a 5G base station nearby.
 5. Nilsson M, Hardell L. 5G Radiofrequency Radiation Caused the Microwave Syndrome in a Family Living Close to the Base Stations. *Journal of Cancer Science and Clinical Therapeutics*. 2023;7:127–134.
 6. Nilsson M, Hardell L. A 49-Year-Old Man Developed Severe Microwave Syndrome after Activation of 5G Base Station 20 Meters from His Apartment. *Journal of Community Medicine and Public Health*. Full publication details should be verified against the original article.
 7. Nilsson M, Hardell L. Case Report: Both Parents and Their Three Children Developed Symptoms of the Microwave Syndrome While on Holiday near a 5G Tower. *Annals of Clinical and Medical Case Reports*. 2023;12(1):1–7.
 8. Hardell L, Nilsson M. A Woman Aged 82 Years with Electromagnetic Hypersensitivity since Almost Four Decades Developed the Microwave Syndrome after Installation of 5G Base Stations in Her Living Vicinity — Ethical Principles in Medicine Are Violated. *Journal of Environmental Science and Public Health*. 2024;8:1–8. doi:10.26502/jesph.96120200.
 9. Hardell L, Koppel T. Electromagnetic hypersensitivity close to mobile phone base stations – a case study in Stockholm, Sweden. *Reviews on Environmental Health*. 2023;38(2):219–22
 10. Hardell L, Nilsson M. An Eight-Year-Old Boy Developed Severe Headache in a School Close to a Mast with 5G Base Stations. *Annals of Clinical Case Studies*. 2024. Full publication details should be verified against the original article.
 11. Davis D, Birnbaum L, Ben-Ishai P, Taylor H, Sears M, Eng M, Butler T, Scarato T. Wireless technologies, nonionizing electromagnetic fields and children: Identifying and reducing health risks. *Curr Probl Pediatr Adolesc Health Care* 2023; 53: 101374.
 12. Frank JW. J Electromagnetic fields, 5G and health: what about the precautionary principle? Essay *Epidemiol Community Health* 2021; 75: 562–566.
 13. Hardell L, Nilsson M, Carlberg M. The Increasing Incidence of Thyroid Cancer in Sweden Revisited. *Fortune Journal of Health Sciences*. 2025;8:716–722
 14. Hardell L. Hepatocellular cancer, aflatoxin, and radiofrequency radiation. *Fortune Journal of Health Sciences*. 8 (2025): 1057-1060.
 15. Nilsson M, Hardell L. Increasing Numbers of Children Aged 5–19 Years with Memory Problems in Sweden and Norway. *Archives of Clinical and Biomedical Research*. 2025;9:431–439.
 16. Guan S, Xin Y, Ren K, et al. Mechanism of Microwave Radiation-Induced Learning and Memory Impairment Based on Hippocampal Metabolomics. *Brain Sci*. 2024, 14, 441. <https://doi.org/10.3390/brainsci14050441>
 17. Nilsson M, Hardell L. Increasing Numbers of Persons with Sleeping Problems in Sweden. *Diseases*. 2026;14(1):25.
 18. Hardell L, Carlberg M. Use of Mobile and Cordless Phones and the Association with Prostate Cancer. *Fortune Journal of Health Sciences*, 8 (2025): 267-273.
-

19. Zhang Y, Zhang Y, Ye Z, Yang S, Liu M, Wu Q, Zhou C, He P, Gan X, Qin X. Mobile Phone Use and Risks of Overall and 25 Site-Specific Cancers: A Prospective Study from the UK Biobank Study. *Cancer Epidemiol Biomarkers Prev.* 2024 Jan 9;33(1):88-95. doi: 10.1158/1055-9965.EPI-23-0766. PMID: 37870426

20. Hardell L, Carlberg M, Soderqvist F, Hansson MK. Pooled analysis of case-control studies on acoustic neuroma diagnosed 1997-2003 and 2007-2009 and use of mobile and cordless phones. *Int J Oncol.* 2013;43:1036–44.
21. Carlberg M, Hardell L. Pooled analysis of Swedish case-control studies during 1997-2003 and 2007-2009 on meningioma risk associated with the use of mobile and cordless phones. *Oncol Rep.* 2015;33(6):3093-3098.
22. Hardell L, Carlberg M. Mobile phone and cordless phone use and the risk for glioma – Analysis of pooled case-control studies in Sweden, 1997-2003 and 2007-2009. *Pathophysiology.* 2015;22(1):1-13.
23. Interphone Study Group. Brain tumour risk in relation to mobile telephone use: results of the INTERPHONE international case-control study. *Int J Epidemiol.* 2010;39: 675-694.
24. Interphone Study Group. Acoustic neuroma risk in relation to mobile telephone use: results of the INTERPHONE international case-control study. *Cancer Epidemiol.* 2011;35: 453-464.
25. Coureau G, Bouvier G, Lebailly P, Fabbro-Peray P, Gruber A, Leffondre K, et al. Mobile phone use and brain tumours in the CERNAT case-control study. *Occup Environ Med.* 2014;71: 514-522.
26. Pettersson D, Mathiesen T, Prochazka M, Bergenheim T, Florentzson R, Harder H, et al. Long-term mobile phone use and acoustic neuroma risk. *Epidemiology* 2014;25: 233-241.
27. Karipidis K, et al. *The effect of exposure to radiofrequency fields on cancer risk in the general and working population: A systematic review of human observational studies – Part I: Most researched outcomes.* Environment International. 2024. <https://www.sciencedirect.com/science/article/pii/S0160412024005695>
28. Philips A, Henshaw DL, Lamburn G, O’Carroll MJ. Brain Tumours: Rise in Glioblastoma Multiforme Incidence in England 1995-2015 Suggests an Adverse Environmental or Lifestyle Factor. *J. Environ. Public Health* 2018, 7910754.
29. Hardell L, Carlberg M. Increasing rates of brain tumours in the Swedish national inpatient register and the causes of death register. *Int J Environ Res Public Health.* 2015;12(4):3793-37813.
30. Hardell L, Carlberg M. Mobile phones, cordless phones and rates of brain tumors in different age groups in the Swedish National Inpatient Register and the Swedish Cancer Register during 1998-2015. *PLoS One.* 2017 Oct 4;12(10):e0185461. Choi YJ, Moskowitz JM, Myung SK, Lee YR, Hong YC. Cellular phone use and risk of tumors: Systematic review and meta-analysis. *International Journal of Environmental Research and Public Health* 2020;17(21):8079. <https://doi.org/10.3390/ijerph17218079>
31. Choi YJ, Moskowitz JM, Myung SK, Lee YR, Hong YC. Cellular phone use and risk of tumors: Systematic review and meta-analysis. *International Journal of Environmental Research and Public Health* 2020;17(21):8079. <https://doi.org/10.3390/ijerph17218079>
32. Moon J, Kwon J, Mun Y. Relationship between radiofrequency-electromagnetic radiation from cellular phones and brain tumor: meta-analyses using various proxies for RF-EMR exposure-outcome assessment. *Environ Health.* 2024 Oct 10;23(1):82. doi: 10.1186/s12940-024-01117-8. Erratum in: *Environ Health.* 2024 Nov

- 12;23(1):97. doi: 10.1186/s12940-024-01138-3. PMID: 39390576; PMCID: PMC11465689.
33. ICBE-EMF. Scientific critique of radiofrequency exposure guidelines. 2022. https://icbe-emf.org/wp-content/uploads/2022/10/ICBE-EMF-paper-12940_2022_900_OnlinePDF_Patched-1.pdf
 34. International Commission on Non-Ionizing Radiation Protection (ICNIRP). 2020b. Guidelines for limiting exposure to electromagnetic fields (100 kHz to 300 GHz). *Health Phys.* 118:483-524.
 35. Hardell L, Nilsson M. A Critical Analysis of the World Health Organization (WHO) Systematic Review 2024 on Radiofrequency Radiation Exposure and Cancer Risks. *Journal of Cancer Science and Clinical Therapeutics.* 2025;9:9–26.
 36. Repacholi MH. (2000). *WHO's efforts to protect public health from electromagnetic fields.* Brazilian Journal of Medical and Biological Research, 2000;33(1), 11–16.
 37. Hardell L, Carlberg M. Health risks from radiofrequency radiation, including 5G, should be assessed by experts with no conflicts of interest. *Oncology Letters.* 2020;20:15. <https://www.spandidos-publications.com/10.3892/ol.2020.11876>
 38. Fabbri A, Lai A, Grundy Q, Bero LA. The influence of industry sponsorship on the research agenda: A scoping review. *Am J Public Health.* 2018;108:e9–e16
 39. Hardell L, Walker M, Walhjalt B, Friedman LS, Richter ED. Secret ties to industry and conflicting interests in cancer research. *Am J Ind Med* 2007; 50: 227-233. DOI 10.1002/ajim.2037
-
40. Hardell L, Carlberg M. Using the Hill viewpoints from 1965 for evaluating strengths of evidence of the risk for brain tumors associated with use of mobile and cordless phones. *Rev Environ Health* 2013;28(2-3):97-106.
 41. Belpomme D, Hardell L, Belyaev I, Burgio E, Carpenter DO. Thermal and non-thermal health effects of low intensity non-ionizing radiation: An international perspective. *Environmental Pollution*, 2018;242(Part A), 643–658. <https://doi.org/10.1016/j.envpol.2018.07.019>
-
42. Hardell L. Health Council of the Netherlands and evaluation of the fifth generation, 5G, for wireless communication and cancer risks. *World J Clin Oncol* 2021; 12(6): 393-403 [PMID: [34189065](#) DOI: [10.5306/wjco.v12.i6.393](#)]
 43. Hardell L, Nilsson M, Koppel T, Carlberg M. Aspects on the International Commission on Non-Ionizing Radiation Protection (ICNIRP) 2020 Guidelines on Radiofrequency Radiation. *Journal of Cancer Science and Clinical Therapeutics* 2021;5:250-285.
-
44. International Commission on the Biological Effects of Electromagnetic Fields (ICBE-EMF). Scientific evidence invalidates health assumptions underlying the FCC and ICNIRP exposure limit determinations for radiofrequency radiation: implications for 5G. *Environ Health* 2022;21;92. <https://doi.org/10.1186/s12940-022-00900-9>
 45. Nyberg R, McCredde J, Hardell L. The European Union assessments of radiofrequency radiation health risks – another hard nut to crack (Review). *Rev Environ Health* 2023 <https://doi.org/10.1515/reveh-2023-0046>
-
46. Melnick RL, Moskowitz JM, Héroux P, Mallery-Blythe E, McCredde JE, Herbert M, Hardell L, Philips A, Belpoggi F, Frank JW, Scarato T, Kelley E, and On Behalf of the International Commission on the Biological Effects of Electromagnetic Fields (ICBE-EMF).
 47. Frei P, Poulsen AH, Johansen C, Olsen JH, Steding-Jessen M, Schüz J. Use of mobile phones and risk of brain tumours: update of Danish cohort study. *BMJ.* 2011;343:d6387. <https://www.bmj.com/content/343/bmj.d6387>
-

48. Frei P, Poulsen AH, Johansen C, Olsen JH, Steding-Jessen M, Schüz J. Use of mobile phones and risk of brain tumours: update of Danish cohort study. *BMJ*. 2011;343:d6387. <https://www.bmj.com/content/343/bmj.d6387>

49. Hardell L, Nilsson M, Koppel T, Carlberg M. Aspects on the International Commission on Non-Ionizing Radiation Protection (ICNIRP) 2020 guidelines on radiofrequency radiation. *J Cancer Sci Clin Ther* 2021;5:250-283.
50. Buchner K, Rivasi, M. *The international commission on non-ionizing radiation protection: Conflicts of interest, corporate capture and the push for 5G*. European Parliament Greens/EFA Group. https://www.stralskyddsstiftelsen.se/wp-content/uploads/2020/07/icnirp-report-june_2020_buchner_rivasi.pdf
51. Hardell L, Nilsson M. Very High Radiofrequency (RF) Radiation at Skeppsbron in the Old Town in Stockholm, Sweden. *Annals of Clinical and Medical Case Reports*. 2023;10(23):1–7
52. Hardell L, Nilsson M. High Radiofrequency Radiation in the Surroundings of 10 Schools in Örebro. *Fortune Journal of Health Sciences*. 2025;8:306–310.
53. Hardell L, Nilsson M. Swedish Public Railway Transportation Environments May Be Associated With High Exposure to Radiofrequency Electromagnetic Field (RF-EMF) Radiation. *Cureus* 2026;18(10): e117957. doi:10.7759/cureus.117957