Reported Biological Effects from Radiofrequency Radiation at Low-Intensity Exposure

Power Density	Reported Biological Effects	Reference
0.0006 - 0.0128 μW/cm2	Fatigue, depressive tendency, sleeping disorders, difficulty in concentration, and cardiovascular problems were reported with exposure to GSM 900/1800 MHz cell phone signal in study with exposure to base station levels of RF.	Oberfeld, 2004
0.16 μW/cm2	Motor function, memory and attention of school children affected (Latvia).	Kolodynski, 1996
O.168 - 1.053 μW/cm2	Irreversible infertility in mice after 5 generations of exposure to RFR from an "antenna park".	Magras & Xenos, 1997
O.2 - 8 μW/cm2	Two-fold increase in childhood leukemia / exposure to RFR from TV towers.	Hocking, 1996
0.2 - 8 μW/cm2	Decreased survival of children with childhood leukemia with exposure to RFR from television towers.	Hocking, 2000
0.8 - 10 μW/cm2	Changes in emotional behavior in rats from very low microwave exposure, possibly through increased free-radical production affecting ATP synthesis and activity of monoaminoxidase .	Akoev, 2002
1.0 μW/cm2	Whole body RFR irradiation of male mice caused a significant effect on the immune system.	Fesenko, 1999
1.0 μW/cm2	Irradiation (5 hours) with low-power RFR stimulates the immune potential of macrophages and T cells	Novoselova, 1999
1.3 - 5.7 μW/cm2	Two-fold increase in leukemia in adults from AM RFR exposure.	Dolk, 1997
~2-4 μW/cm2	Direct effect of RFR on acetylcholine-induced ion channels on cell membrane.	D'Inzeo, 1988
4-15 μW/cm2	Visual reaction time in children is slowed / lower memory function in tests; changes in immune functions.	Chiang, 1989
5 μW/cm2	Cell phone (GSM-like 9.4 GHz RF) interferes with gene expression during early gestation; resulting in abberant BMP in newborn.	Pyrpasopoulou 2004

Reported Biological Effects from Radiofrequency Radiation at Low-Intensity Exposure

Power Density	Reported Biological Effects	Reference
5 μW/cm2	Immune function in women adversely affected by radio/tv antenna exposure (significant reduction in NK blood lymphocytes).	Boscolo, 2001
5 - 10 μW/cm2	Impaired nervous system activity	Dumansky, 1974
10 μW/cm2 (0.0027 W/Kg SAR)	Changes in active avoidance conditioned reflex (behavioral change) after 0.5 hour exposure to pulsed RFR.	Navakatikian, 1994
10-20 μW/cm2	Increase in micronuclei (aberrant DNA form) in blood cells of workers chronically exposed to RFR at 1250-1350 MHz.	Garaj-Vrhovac, 1999
10 - 25 μW/cm2	Changes in the hippocampus of the brain.	Belokrinitsky, 1982
10-100 μW/cm2	Increased risk of cancer associated with exposure to RFR in radar operators. Very short latency period; showed dose response to exposure.	Richter, 2000
20 μW/cm2	Increase in serum cortisol (stress hormone) (900 MHz RFR pulsed at 217 Hz).	Mann, 1998
30 μW/cm2 (0.015 W/Kg SAR)	Immune system effects - elevation of PFC count (antibody-producing cells).	Veyret, 1991
50 μW/cm2	An 18% reduction in REM sleep (important to memory and learning functions).	Mann, 1996
60 μW/cm2	Cortex of brain activated by 15 minutes of 902 MHz cell phone exposure.	Lebedeva, 2000
100μW/cm2	Changes in immune system functions	Elekes, 1996
100 μW/cm2 (0.027 W/Kg SAR)	A 24.3% drop in testosterone after 6 hours of continuous-wave RFR exposure.	Navakatikian, 1994
120 μW/cm2	A pathological change in the blood brain barrier (915 MHz).	Salford, 1994
500 μW/cm2 (0.135 W/Kg SAR)	A 24.6% drop in testosterone and 23.2% drop in insulin after 12 hours pulsed RFR exposure.	Navakatikian, 1994

Reported Biological Effects from Radiofrequency Radiation at Low-Intensity Exposure

Power Density	Reported Biological Effects	Reference
500 μW/cm2 (0.135 W/Kg SAR)	Intestinal epithelial cells exposed to 2450 MHz microwave pulsed at 16 Hz showed changes in intercellular calcium.	Somozy, 1993

STANDARDS and BACKGROUND LEVELS

Power Density Standards

~530-600 μW/cm2	Limit for uncontrolled public exposure to 800-900 MHz	ANSI/IEEE
1000 μW/cm2	PCS STANDARD for public exposure (as of September 1,1997)	FCC, 1996
5000 μW/cm2	PCS STANDARD for occupational exposure (as of September 1,1997)	FCC, 1996

Power Density Background Levels

0.05 μW/cm2	Median ambient power density in cities in Sweden (30-2000 MHz)	Hamnerius, 2000
0.003 μW/cm2	Background Level Ambient background RF exposure in US cities and suburbs in the 1990's	Mantiply, 1997
0.1-10 μW/cm2	Ambient RF exposure within 100-200 feet of cell/PCS antenna array	Sage, 2000

Reported Biological Effects from Radiofrequency Radiation at Low-Intensity Exposure

Power Density	Reported Biological Effects	Reference
0.000064 W/Kg - 0.000078 W/Kg	Well-being and cognitive function affected in humans exposed to GSM-UTMS cell phone frequencies; RF levels are similar to those found near cell mast sites.	TNO Physics and Electronics Lab, Netherlands, 2003
0.00015 - 0.0003 W/Kg	Calcium ion movement in isolated frog heart tissue is increased by 18% (0.0003 W/Kg - P<.01) and by 21% (0.00015 W/Kg - P< .05) by weak RF field modulated at 16 Hz.	Schwartz, 1990
0.000021- .0021 W/Kg	Changes in cell cycle and cell proliferation (960 MHz GSM cell phone signal).	Kwee, 1997
0.0016-.0044 W/Kg	Very low power 700 MHz CW affects excitability of hippocampal tissue, consistent with reported behavioral effects of RF.	Tattersall, 2001
0.0095 W/Kg	MW modulated at 7 Hz produces more errors in short-term memory function on complex tasks (can affect cognitive processes such as attention and short-term memory).	Lass, 2002
0.0004-0.008 W/Kg	915 MHz cell phone RFR caused leakage in blood-brain barrier Worst at lowest levels and worse with CW compared to PW with a maximum pathology with 8-50 Hz modulation. Frequency of pathological changes was 35% in rats exposed to pulsed radiation and 50% to continuous wave RFR. Effects observed at a specific absorption (SA) of >1.5 Joules/Kg.	Persson, 1997
0.001 W/Kg	750 MHz continuous-wave (CW) RFR exposure caused an increase in heat shock proteins (stress proteins). Heat shock proteins induced by RFR exposure were equivalent to that which would be induced with 3 degree C. heating of tissue, but no heating occurred during the RFR exposure.	de Pomerai, 2000
0.001 W/Kg	Statistically significant change in intracellular calcium concentration in heart muscle cells exposed to RFR (900 MHz/ 50 Hz modulation)	Wolke, 1996
0.0021 W/Kg	A significant change in cell proliferation not attributable to thermal heating. RFR probably induces non-thermal cell stress involving heat shock proteins (960 MHz GSM cell phone signal).	Velizarov, 1999

Reported Biological Effects from Radiofrequency Radiation at Low-Intensity Exposure

SAR	Reported Biological Effects	Reference
0.0021 W/Kg	Heat shock protein HSP 70 (stress response) is activated by very low power microwave exposure in human epithelial amnion cells.	Kwee, 2001
0.0024 W/Kg to 0.024 W/Kg	Digital cell phone RFR at very low intensities causes DNA effects in human cells. DNA effects are direct DNA damage and the rate at which DNA is repaired.	Phillips, 1998
0.0027 W/Kg	Changes in active avoidance conditioned reflex (behavioral change) after 0.5 hour exposure to pulsed RFR.	Navakatikian, 1994
0.0035 W/Kg	900 MHz cell phone signal induced DNA breaks and early activation of p53 gene. Short exposure (2-12 hours) lead cells to acquire a greater survival chance - linked to tumor aggressiveness.	Marinelli, 2004
.005 to .05 W/Kg	Increase in calcium efflux	Dutta, 1989
0.0059 W/Kg	Cell phone RFR induces glioma (brain cancer) cells to significantly increase thymidine uptake, which may be indication of increased cell division.	Stagg, 1997
0.015 W/Kg	Immune system effects - elevation of PFC count (antibody-producing cells)	Veyret, 1991
0.02 W/Kg	Single 2-hour exposure to GSM cell phone RF results in serious neuron damage and death in cortex, hippocampus and basal ganglia of brain as measured 50 days later, where blood brain barrier is still leaking albumin (P <.002) following one exposure.	Salford, 2003
0.026 W/Kg	Activity of c-jun (oncogene) was altered in cells after only 20 minutes exposure to cell phone signal (TDMA); an average 38% decrease was reported.	Ivaschuk, 1997
0.28 - 1.33 W/Kg	Significant increase in headache with increasing use of hand-held cell phone use (maximum tested was 60 minutes per day)	Chia, 2000
0.0317 W/Kg	Decrease in eating and drinking	Ray, 1990

Reported Biological Effects from Radiofrequency Radiation at Low-Intensity Exposure

SAR	Reported Biological Effects	Reference
0.037 W/Kg	Hyperactivity caused by nitric oxide synthase inhibitor is countered by exposure to ultra-wide band pulses (600/sec) for 30 min.	Seaman, 1999
0.05 W/Kg	Significant increase in firing rate of neurons (350%) with pulsed 900 mHz but not unmodulated cell phone frequency exposure in avian brain cells.	Beason, 2002
0.121 W/Kg	Cardiovascular system/significant decrease in arterial blood pressure (hypotension) after exposure to ultra-wide band pulses.	Lu, 1999
0.13 - 1.4 W/Kg	Lymphoma cancer rate is 2 times normal with two 1/2 hour exposures per day of cell phone RFR for 18 months (pulsed digital mobile phone signal 900 MHz).	Repacholi, 1997
0.14 W/Kg	Elevation of immune response at 100 μW/cm2.	Elekes, 1996
0.141 W/Kg	Structural changes in testes/smaller diameter of seminiferous tubules in rats exposed to RFR from cell phone on speech transmission (but not stand-by mode) with 3 one-minute exposures per hour for two hours per day for one month.	Dasdag, 1999
0.15-0.4 W/Kg	Statistically significant increase in malignant tumors at 480 μW/cm2 in rats chronically exposed to RFR.	Chou, 1992
0.26 W/Kg	Harmful effects to the eye/certain drugs can sensitize the eye to RFR.	Kues, 1992
0.3-0.44 W/Kg	Cellular phone use results in changes to cognitive thinking/ mental tasks related to memory retrieval.	Krause, 2000
0.3-0.44 W/Kg	Attention function of brain/responses are speeded up.	Preece, 1999 Koivisto, 2000a,b

Reported Biological Effects from Radiofrequency Radiation at Low-Intensity Exposure

SAR	Reported Biological Effects	Reference
0.3-0.46 W/Kg	Cell phone RFR doubles pathological blood-brain barrier permeability at two days (P = .002) and triples permeability at four days (P=.001). (1.8 GHZ GSM cell phone signal in an in vitro blood brain barrier model).	Schirmacher, 2000
0.5 W/Kg	900 mHz pulsed RF affects firing rate of neurons (Lymnea stagnalis) but continuous wave had no effect.	Bolshakov, 1992
0.58 - 0.75 W/Kg	Decrease in brain tumors after chronic exposure to RFR (836 MHz TDMA digital cell phone signal).	Adey, 1999
0.87 W/Kg	Altered human mental performance after exposure to GSM phone radiation (900 MHz - 1 hour) with increased speed of processing but decreased capacity to deal effectively with information; overall slowing of decision-making.	Hamblin, 2004
0.87 W/Kg	Change in human brainwaves;decrease in EEG potential .01-3.7 μV; statistically significant change in alpha (8-13 Hz) and in beta (13-22 Hz) band brainwaves	D'Costa, 2003
1 W/Kg	GSM mobile phone use modulates brain oscillations and sleep EEG.	Huber, 2002
1.0 W/Kg (max)	Cell phone RFR during waking hours affects brain wave activity (EEG patterns) during subsequent sleep.	Achermann, 2000
1.0 W/Kg (max)	Cell phone use causes nitric oxide (NO) nasal vasodilation (swelling inside nasal passage) on side of head phone used.	Paredi, 2001
1.0 W/Kg (max)	Four-fold increase in eye cancer (uveal melanoma) in cell phone users.	Stang, 2001
1.0 W/Kg (max)	Increase in headache, fatigue and warmth behind the ear in cell phone users.	Sandstrom, 2001
1.0 W/Kg (max)	Significant increase in concentration difficulties using 1800 MHz cell phone compared to 900 MHz cell phone frequency.	Santini, 2001

Reported Biological Effects from Radiofrequency Radiation at Low-Intensity Exposure

SAR	Reported Biological Effects	Reference
1.0 W/Kg (max)	Sleep patterns and EEG are changed with 900 MHz cell phone exposure during sleep.	Borbely, 1999
1.4 W/Kg	GSM cell phone exposure elevated heat shock protein HSP 70 by 360% (stress response), and phosphorylation of ELK-1 by 390%.	Weisbrot, 2003
1.48 W/Kg	A significant decrease in protein kinase C activity at 112 MHz at 2 hours/day for 35 days; hippocampus appears to be site of EMF-biointeraction consistent with other reports that RF negatively affects learning and memory functions.	Paulraj, 2004
1 - 2 W/Kg	Significant elevation in micronucleus frequency in peripheral blood erythrocytes at 2450 MHz (8 treatments of 2 hours each).	Trosic, 2002
0.6 and 1.2 W/Kg	Increase in DNA single and double strand breaks from RFR exposure (2450 MHz).	Lai & Singh, 1996
1.5 W/Kg	GSM cell phone exposure affected gene expression levels in tumor suppressor p53-deficient embryonic stem cells; and significantly increased Hsp70 heat shock protein production.	Czyz, 2004
2 W/Kg	GSM cell phone exposure of 1 hour activated heat shock protein HSP 27 (stress response) and P38 MAPK (mutagen-activated protein kinase) that authors postulate facilitates brain cancer and causes increase in blood-brain barrier permeability.	Leszczynski, 2002
2 W/Kg	900 MHz cell phone exposure caused brain cell oxidative damage by increasing levels of NO, MDA, XO and ADA in brain; caused statistically significant increase in "dark neurons" or damaged brain cells in cortex, hippocampus and basal ganglia with 1-hour exposure for 7 consecutive days.	Ilhan, 2004
2.6 W/Kg	900 MHz cell phone exposure for one hour significantly altered protein expression levels in 38 proteins following irradiation. Cell phone exposure activates the P38 MAP kinase stress signalling pathway and leads to changes in cell size and shape (shrinking and rounding-up) and to activation of Hsp 27, a heat-shock protein.	Leszczynski, 2004

Reported Biological Effects from Radiofrequency Radiation at Low-Intensity Exposure

SAR	Reported Biological Effects	Reference
2 - 3 W/Kg	Accelerated development in skin and breast tumors by RFR.	Szmigielski, 1982

STANDARDS and BACKGROUND LEVELS

SAR		
0.08 W/Kg	IEEE standard uncontrolled environment (whole body)	IEEE
0.4 W/Kg	IEEE standard controlled environment (whole body)	IEEE
1.6 W/Kg	FCC(IEEE) SAR limit over 1 gram of tissue in a partial body exposure situation (for example, cell phone to ear)	FCC, 1996