Research into bio-effects at low levels of exposure

The low-level studies reviewed by the Working Group are summarised in the table below.

In vitro

Author	Exposure	Test System	Theme	Endpoint	Outcome	Impact	Notes
Albee et al. (1997)	835.62 MHz FMCW and 847.74 MHz CDMA	C3H10T1/2 mouse embryo cells	Gene expression	Effects on the transit of quiescent cells into the proliferation cycle, transit of log phase cells into the plateau growth phase	No effect on the expression of c-jun or c-myc proto-oncogenes	No effect	
Cain et al. (1997)	836.55 MHz TDMA-modulated in repeated cycles of 20 min on/20 min off 24h/day for 28 days. SARs of 0.15, 1.5 and 15 mW/Kg.	C3H/10T1/2 cells used in 16 different experiments in terms of the number, density, and area of foci.	Tumor promotion	Alteration of TPA-induced focus formation. Enhancement of tumour promotion.	No alteration of TPA-induced focus formation thus no effect on tumour promotion	No effect	
Cleary et al. (1997)	2450 MHz RIF (SAR greater and less than 25 W/Kg) Isothermal RF. 24 h exposure.	Cytolytic T lymphocytes (CTLL-2)	Cell proliferation	CTLL-2 proliferation	At SAR > 25W/Kg reduction in CTLL-2 proliferation. At lower SARs increase in CTLL-2 proliferation immediately after exposure but reduced 24 h post-exposure	No effect	It is questionable whether this study was truly isothermal

					proliferation		
Donnellan et al. (1997)	835 MHz for 20 min, 3 times per day for 7 days. Power density of 8.1 +/- 3mW/cm^2.	Mast cell line, RBL-2H3	Cell proliferation	DNA synthesis and cell replication, actin replication and cell morphology, granule secretion	After day 4 DNA synthesis and cell replication increased, actin replication and cell morphology altered, enhancement in the amount of beta-hexosaminidase released. No effects on levels of cytoskeletal protein synthesis or of beta-actin mRNA.		
Fesenko et al. (1995)	42.25 GHz for 20-30 m	Solution (100 mmol/l KCl with Ca2+ added)	Calcium efflux	Channel activity	Channels were partially mediated by changes in the solution properties		
French et al. (1997)	835 MHz for 20 min, 3 times per day for 7 days. Power density of either 40+15 mW/cm^2 or 8.1 +/- 3mW/cm^2.	Human astocytoma cell line, U-87 MG	Cell proliferation	DNA synthesis. Cell morphology. Cell proliferation.	At 8.1 mW/cm^2 decrease in the rate of DNA synthesis and cells flattened and spread out. At 40 mW/cm2 no effect on cell proliferation but increase in cell spreading and also the appearance of actin containing blebs at localised sites on the membrane.		
Garaj-Vrhovac (1999)	MW radiation. No further specification	12 human subjects occupationall	Blood lymphocytes	Cell kinetics Genome damage	Increase in the frequency of micronuclei. Disturbances in the		The abstract is very vague

		y exposed			distribution of cells in the first, second and third mitotic division.		
Geletyuk et al. (1995)	42.25 GHz for 20-30 m. Power density of 100 $\mu W/cm^2$.	Single Ca(2+)-activated K+ channels in cultured kidney cells	Calcium efflux	Channel affinity	Cooperativity and binding characteristics of the channel activation by internal Ca2+ altered.		
Goswami et al. (1999)	835.62 MHz (FMCW) and 847.74 MHz (CDMA). Average SAR of 0.6 W/Kg.	C3H10T1/2 murine embryonic fibroblasts	Gene expression	Fos, jun and Myc mRNA levels. DNA binding activity of AP1, AP2 and NF-kappaB.	No effect in the Jun and Myc mRNA levels. No effect in the DNA binding activity of AP1, AP2 and NF-kappaB. 2-fold increase in Fos mRNA levels (for FMCW) and 1.4-fold increase (for CDMA)	No effect	
Harvey et al. (2000)	864.3 MHz (CW) for 20 min, 3 times per day for 7 days. Average SAR of 7 W/Kg.	Human mast cell line, HMC-1. 588 genes were screened.	Gene expression.	Protein kinase C	Activation of Protein kinase C. Effects seen on 3 out of 588 genes.		
Ivaschuck et al. (1997)	836.55 MHz TDMA for 20, 40 or 60 min in a repeating cycle (20 min on/20 min off). SARs of 0.26, 2.6 and 26 $\mu W/g$. Peak power level of 9 mW/cm^2.	PC12 rat phenochromocytoma cells	Gene expression	Expression of genes c-fos and c-jun	At the 3 SARs specified no change in the c-fos. At the peak power level decrease in the c-jun expression (39% aver.) after 20 min exposure.	No effect at low levels. The decrease of c-jun expression at the higher	

						level could be due to heating.	
Kwee et al. (1998)	960 MHz GSM or ELF in a TEM cell for 3 different exposure times. 3 different power levels.	Cell cultures of transformed human epithelial amnion cells	Cell proliferation	Cell proliferation	For GSM linear correlation between power level and growth change. For ELF linear correlation between the length of exposure time to obtain maximum effect and field strength		
Litovitz et al. (1997)	60 Hz AM or 50 Hz burst-modulated DAMPS phone system together with band-limited 30-100 Hz noise rms ampl. Of up to 10μT for 8 h	L929 cells	ELF noise on RF	ODC levels	Decrease in ODC enhancement till total inhibition above 2 μT.	No explanation of why this happens given	
Malyapa et al. (1997b)	835.62 MHz (FMCW) and 847.74 (CDMA) in RTLs for up to 24 h. SAR of 0.6 W/Kg.	Mouse C3H10T1/2 fibroblasts and human glioblastoma U87MG cells	DNA	DNA damage	No significant difference between the test group and the controls after exposure to either signal	No effect	
Penafiel et al. (1997)	835 MHz TDMA phone system amplitude modulated at a range of frequencies for 24 h. Also AMPS phone	L929 murine cells	ODC activity (& ELF noise?)	ODC levels	TDMA exposure showed an increase in ODC activity. AMPS exposure had no effect		This is similar to the study by Litovitz

	system exposure. SAR of appr. 2.5 W/kg.						
Phillips et al. (1998)	813.5625 MHz (iDEN) or 836.35 MHz (TDMA)	T-lymphoblastoid cells	DNA	DNA single strand breaks	Increases as well as decreases in DNA damage were observed depending on exposure and signal type		
Romano-Spica et al. (2000)	50 MHz modulated at 16 Hz. 0.2 μT magnetic field strength. 60 V/m electric field strength.	Jurkat T-lymphoblastoid and Leydig TM3 cell lines	Gene expression	Expression of the ets1 mRNA	Overexpression of the ets1 mRNA		
Schirmacher et al. (2000)	1.8 GHz GSM	Co-culture model consisting of astrocytes and porcine brain capillary endothelial cells	Blood-brain barrier (BBB)	Permeability of BBB	Overall permeability of the BBB was significantly higher in exposed samples than in control cultures		The pathophysiological mechanism for these results is unknown.
Velizarov et al. (1999)	960 MHz (GSM) in TEM cell	Cell line Size not specified	Cell proliferation	Cell proliferation	No change in cell proliferation under different temperatures		
Wolke et. Al. (1996)	900, 1300 and 1800 MHz pulse modulated at 217 Hz (14% duty cycle) in a TEM cell. Mean SARs within 1	of isolated ventricular cardiac myocytes of the guinea pig	Calcium homeostasis	Intracellular calcium concentration ($[Ca^{2+}]_I$)	No significant differences in calcium concentration between exposed and sham exposed.		

	order of magn. of 1 mW/kg. Variation between 500 s of exposure/sham exposure.						

In vivo

Author	Exposure	Test System	Theme	Endpoint	Outcome	Impact	Notes
Adey et al. (1999)	836 MHz (NADC/TDMA) over 2 years for 4 consecutive days, 2h/day. SARs of localised peak brain exposures of a phone user.	236 Fisher-244 rats.	Brain tumour	Tumour initiation or promotion	No increase in tumorgenetic effects. Insignificant decrease in tumour incidence from exposure to the TDMA field.		
Asanami and Shimono (1997)	30°C for 1-6 h. 37°C for 0.5-4 h. 40°C for 1-2 h. Controls were exposed to room temperature	Male ddY mice	Micronuclei formation	Micronucleated polychromatic erythrocyte (MNPCE) frequency	Increase in MNPCEs with a rise in temperature	High body temperatures induce micronuclei formation	
Brown-Woodman et al. (1989)	27.12 MHz near a SW diathermy device for 5 wks	Female rats.	Fertility	Number of matings. Number of conceptions.	Reduced number of matings. Reduced number of conceptions.		
Chaugnaud et al. (1999)	900 MHz (GSM) for 2 h/day over 2 weeks. Power density 55 or 200 $\mu W/cm^2$. SARs of 75 and 270 mW/Kg.	2 m old female Sprague-Dawley rats treated with benzo(a)pyrene	Cancer	Anti-phosphatidylinositol autoantibody levels. Tumour acceleration or delays. Animal survival.	No effect on autoantibody levels. No tumour acceleration or delays. Animal survival was not modified.	No effect.	This study could be related to humans.

Danniells et al. (1998)	Transverse electromagnetic cell (TEM) held in an incubator at 25°C inside a shielded room. MW (CW) exposure at various freq and power levels but most experiments at 750 MHz and 27 dBm.	Transgenic nematodes (Caenorhabditis elegans strain PC72)	Stress responses	Beta-galactosidase (reporter) induction	Significant differences from 25°C controls both at 2 and 16 h, but not at 4 or 8 h. The well arrays most affected were those in the rows closest to the source. Lower power densities tended to induce larger responses.		
De Pomerai et al. (2000)	750 MHz (CW). SAR of 1 mW/Kg. Overnight exposure.	Nematodes	Heat-shock response	Heat-shock proteins	Increase in heat-shock proteins		
Detlavs et al. (1996)	(1) 53.53 GHz no modulation (2) 42.19 GHz no modulation. (3) 42.19 modulated in a 200MHz wide band. Exposed for 5 d 30 m/day.	Wistar rats Subjects with excised full-thickness dermal wounds in the intracapular region.	Reparative-proliferative processes	Glycoprotein macromolecules Hexoses and sialic acid concentrations. Collagen accumulation.	Without modulation the inflammatory exudation diminished. With modulation the inflammation was intensified.		
Elekes et al. (1996)	2.45 GHz (CW) or 50 Hz (AM, square	Male and female	Immune system	Spleen index. Spleen antibody-	CW exposure increased (+37%)		

	wave) over 6 days for 3 h/day	Balb/c mice		producing cells	the number of antibody-producing cells in males. AM exposure increased the spleen index (+15%) and the number of antibody-producing cells in males.		
Fesenko et al. (1999)	8.15-18 GHz (1 Hz within) for 5 h -7 days. Power density of 1 $\mu W/cm^2$.	mice	Cell immunity	TNF production inperitoneal macrophages and splenic T lymphocytes. Proliferation of T cells in response to mitogenic stimulation.	After 24 h exposure increase in TNF production and splenic T lymphocytes. Also increase in proliferation of T cells. After 7 day exposure decrease in TNF production.		SARs not specified in abstract
Frei et al. (1998a)	2450 MHz (CW) in circularly polarised waveguides over 18 months for 20 h/day, 7 days/wk. SAR of 0.3 W/Kg.	C3H/HeJ mice. 100 exposed. 100 sham exposed.	Cancer	Mammary tumour incidence. Latency to tumour incidence. Tumour growth rate. Longevity.	No significant effect in tumour incidence, latency to tumour onset and rate of tumour growth. No significant effect in longevity	Replicated No significant effect	
Frei et al. (1998b)	2450 MHz (CW) in circularly polarised waveguides over	C3H/HeJ mice. 100	Cancer	Mammary tumour incidence. Latency to tumour	No significant effect in tumour incidence, latency	No significant effect	

	78 wks for 20 h/day, 7 days/wk. SAR of 1.0 W/Kg	exposed. 100 sham exposed.		incidence. Tumour growth rate.	to tumour onset and rate of tumour growth.		
Fritze et al. (1997a)	GSM cellular phone at discontinuous transmission mode. SARs of 0.3 W/Kg (GSM), 1.5 W/Kg (GSM) and 7.5 W/Kg (CW). 24 h exposure for 7 days	Rat brain.	Genomic response	Changes in the messenger RNAs of hsp70, the transcription factor genes c-fos and c-jun, the glial structural gene GFAP, protein products of transcription factors, stress proteins, marker proteins of astroglial and microglial activation and cell proliferation	Slight increased expression of c-fos in the cerebellum, neocortex and piriform cortex. No effect on the c-jun and GFAP. After 24 h no effect on FOS and JUN proteins. After 7 days no effect on cell proliferation or expression of astroglial and microglial marker proteins	Some minor effects but no lasting adaptive or reactive changes in the brain	
Fritze et. al. (1997b)	900 MHz GSM for 4 h. SARs of 0.3, 1.5 and 7.5 W/kg	40 rats. 20 exposed and sham-exposed. 20 controls	Blood-brain barrier permeability	Serum albumin extravasations	Increase in serum albumin extravasations only at 7.5 W/kg SAR.	Unlikely pathological changes	
Higashikubo et al. (1999)	835.62 MHz FMCW or 847.74 MHz CDMA over 150 d for 4 h/d, 5	Fischer 344 rats. 3 sham-exposed	Brain tumor	Effect on the proliferation of the 9L brain tumor	For sham-exposed Group 1-median survival of 70 days, 27% survived 150.		

	d/wk. Average SARs of 0.75 +/- 0.25 W/Kg.	groups. Group 1 injected with 2-10 viable cells. Group 2 injected with 11-36 viable cells. Group 3 injected with 37-100 viable cells.			Group 2-median survival of 52 days, 14% survived 150. Group 3-median survival of 45 days, 0% survived 150. Exposed animals showed similar survival parameters		
Imaida et al. (1998a)	929.2 MHz (TDMA) through a ¼-WL monopole antenna over 6 wks for 90 m/day, 5 days/wk. Liver peak SARs of 2.0-1.7 W/Kg. Whole-body peak SARs of 7.2-6.6 W/Kg. Whole-body aver. SARs of 0.80-0.58 W/Kg.	96 male F344 rats injected with diethylnitrosamine. 48 exposed. 48 sham exposed.	Carsinogenesis	Numbers and areas of GST-P positive foci	No significant effect in the numbers and areas of GST-P positive foci	No significant effect	
Imaida et al. (1998b)	1.439 GHz (TDMA) through a	96 male F344 rats	Carsinogenesis	Numbers and areas of GST-P positive	No significant effect in the	No significant	

	¼-WL monopole antenna over 6 wks for 90 m/day, 5 days/wk. Liver peak SARs of 1.91-0.937 W/Kg. Whole-body aver. SARs of 0.680-0.453 W/Kg.	injected with diethylnitrosamine. 48 exposed. 48 sham exposed.		foci	numbers and areas of GST-P positive foci	effect	
Jauchem et. al. (1998)	UWB pulses. 50, 500, 1000 pulses/s at a rise time of 174-218 ps Exposed for 2 m. E field of 87-104 kV/m.	10 anesthetised Sprague-Dawley rats	Cardiovascular system	Heart rate and blood pressure	No effect	No effect	
Jauchem et. al. (1999)	UWB pulses. 1 kHz for 0.5 s at a rise time of 318-337 ps for 2 m (2 s on / 2 sec off). E field 19-21 kV/m.	14 Sprague-Dawley rats	Cardiovascular system	Heart rate and blood pressure	No effect	No effect	
Jensh (1997)	915, 2450 or 6000 MHz CW at power densities of 10, 20 or 35 mW/cm^2.	Pregnant rats	Development and growth	Various morphologic and psychophysiologic parameters	At 915 MHz no effects. At 2450 MHz increased offspring activity level. At 6000 MHz changes in some parameters	Although there were some parameter changes at 6000 MHz cellular and MW	

						freq. Tested showed no significant effects.	
Juutilainen et al. *in press*							
Lai and Singh (1997)	2450 MHz (pulsed) for 2 h (2 μs pulses, 500 pps). Power density of 2 mW/cm2. SAR of 1.2 W/Kg.	Rat brain cells	DNA	DNA strand breaks	Free radicals were involved in RFR-induced DNA damage. Melatonin and spin-trap compound blocked these effects.		
Lai et al. (1997)	2450 MHz (pulsed) for 2 h (2 μs pulses, 500 pps). Power density of 2 mW/cm2. SAR of 1.2 W/Kg.	Rat brain cells	DNA	DNA strand breaks	Endogenous opioids played a mediating role in RFR-induced DNA damage. Naltrexone partially blocked these effects.		
Lu et al. (1999)	0.5 or 1 kHz UWB (pulsed, 180 or 200 ps rise time, 1.00 or 1.03 ns pulse width) in a GTEM cell for 6 m.	Male Wistar-Kyoto rats	Cardiovascular system	Heart rate. Systolic, mean and diastolic pressures.	Decrease in arterial blood pressure (hypotension). No effect on heart rate.		

	93 or 85 kV/m. SARs of 70 or 121 mW/kg. Sham exposure.						
Magras and Xenos (1997)	Experiments conducted around an “antenna park”. Power densities 168-1053 nW/cm^2.	12 pairs of mice originally. 118 newborns after mating of pairs.	Reproduction and development	Fertility. Prenatal development.	Decrease in the number of newborns per dam leading to irreversible infertility. Prenatal development improved.	Unreplicated	No control group was included.
Malyapa et al. (1997a)	2450 MHz (CW) in RTLs for 2 h. SARs of 0.7 and 1.9 W/Kg.	Cultured mammalian cells	DNA	DNA damage	No significant difference between the test group and the controls after exposure	No effect	
Malyapa et al. (1998)	2450 MHz (CW) in for 2 h in a cylindrical waveguide system. SAR of 1.2 W/Kg.	Rat brain	DNA	DNA damage	No DNA damage observed	No effect	
Morrissey et al. (1999)	1.6 GHz (CW or pulsed at 11 Hz with a duty cycle of 4:1 and a pulse duration of 9.2 ms Iridium) for 1 h.	Mouce brain.	Gene expression	Expression of c-fos	No effect on c-fos at normal levels. At levels 6 times the peak dose (30 times whole body average) elevation of c-fos detected	No effect at non-thermal levels	
Novoselova et al. (1999)	8.15-18 GHz (1 Hz within) for 5 h.	Peritoneal macropha	Immune system	Tumour necrosis factor (TNF).	Increase in TNF production.		

	Power density of 1 $\mu W/cm^2$.	ges and splenic T cells of mice		Immune response. Effects on MWs after antioxidant treatment.	Activation of cellular immunity 3 days after exposure Antioxidant treatment enhanced MW effects.		
Persson et al. (1997)	915 MHz CW and pulsed (at 217 Hz with 0.57 ms pulse width and at 50 Hz with 6.6 ms pulse width) in a TEM line for 2-960 m. Power of 0.001-10 W.	1002 Fischer-344 rats of both sexes. 630 exposed. 372 controls.	Blood-brain barrier	Frequency of pathological rats	The frequency of pathological rats was greater after CW exposure than pulsed-radiation exposure		
Stark et al. (1997)	3-30 MHz over 10 days (3 days switched off). Exposed group 0.5 km away with a field strength 1.59 mA/m. Unexposed group 4 km away with a field strength 0.076 mA/m.	10 cows. 5 exposed. 5 controls.	Melatonin	Salivary melatonin concentrations	No overall significant effect. 2-7 fold increase of melatonin concentration on the first night of re-exposure after the transmitter was switched off for three days.		
Toler et al. (1997)	435 MHz horizontally polarised (pulsed, 1μs pulse width,1 kHz pulse rate) for	400 female C3H/HeJ mice. 200	Cancer	Mammary tumors. Tumor growth, latency and onset. Longevity.	No effect on the incidence of mammary tumors. No effect on the incidence of tumor	No effects	

	21 months, 22 h/day, 7 days/wk. Power density 1 mW/cm^2. SAR of 0.32 W/kg	exposed. 200 sham exposed.			growth, latency and onset. No effect on longevity.		
Tsurita et. al. (2000)	1439 MHz TDMA over 2 to 4 weeks for 1 h/d. SARs of 2 W/kg in the brain and 0.25 W/kg average over the whole body.	24 Sprague-Dawley rats divided into 3 groups. Exposed group arrayed in a circle near a central antenna. Unexposed group placed in the array. Control group	Permeability of the blood-brain barrier. Morphological changes of the brain. Body-mass fluctuations.	Serum albumin levels. Assessment of Burkinje cells and the cellular concentration in the granular layer. Average body mass.	No observable changes	No effect	
Vijayalaxmi et al. (1997)	2450 MHz (CW) in circularly polarised wave guides over 18 m for 20 h/day, 7 days/wk. SAR of 1 W/kg	120 C3H/HeJ mice. 62 exposed. 58 sham exposed.	Cancer	Presence of micronuclei in polychromatic erythrocytes (PCEs) in peripheral blood and bone marrow	No significant difference in the incidence of micronuclei	No effect	

Vollrath et al. (1997)	900 MHz CW and pulsed at 217 Hz. For 15 m to 6 h. Power densities of 0.1-0.6 mW/cm^2. SARs of 0.06-0.36 W/kg in rats and 0.04 W/kg in hampsters.	Male and female Spraugue_ Dawley rats and Djugarian hamsters.	Melatonin	Melatonin synthesis of the pineal gland	No effects	No effects	
Vorobyov et al. (1997)	945 MHz (AM at 4 Hz) for 10 m (1 m ON/1 m OFF). Field strength of 0.1-0.2 mW/cm	8 adult male rats	Nervous system	Averaged electroencephalogram (EEG) spectra	No difference in the spectra	No effect	

Human Experiments

Author	Exposure	Group Size	Theme	Endpoint	Outcome	Impact	Notes
Borbely et al. (1999)	900 MHz GSM ë/4 antennas (3). 1W/kg max, intermittent (15min on/15 min off) during sleep. Linearly polarised	24 young right handed males	Sleep	Sleep stages, waking time, EEG power during various stages	Waking after sleep onset reduced from 18 to 12 min, EEG power in non-REM sleep increased esp. at 11 Hz	Unreplicated. Health implication hard to evaluate, but changes well within normal variation.	
Braune et al. (1998a)	900 MHz GSM phone. 'operated by remote control'. Fixed order sham then exposed (35min each)	7 males, 3 females	Blood pressure	Systolic/ diastolic blood pressure, heart rate. Protocol: rest; standing; Valsalva manoeuvre in time *following* exposure/sham	BP sign higher at rest and on standing after rest, for exposed compared to sham. Heart rate values reduced in all manoeuvres. Autonomic function tests unaffected.	Unreplicated. Health implication hard to evaluate, but changes well within normal variation.	
Braune et al. (1998b) Correspondence to Braune et al. (1998a)							
de Seze et al. (1998)	900 Mhz GSM (217 Hz pulses, 1/8 duty cycle, 2 W peak power) over a month for	20 healthy male volunteers aged from 19 to 40y	Hormone levels	Serum adrenocortecotropin, thyrotropin, growth hormone,	No difference in concentrations after exposure	No effect	

	2 h/day, 5 days/wk.			prolactin, luteinizing hormone, and follicle stimulating hormone concentrations			
de Seze et al. (1999)	(a) 900 MHz GSM (b) 1800 MHz DCS. Both 2hr/day, 5 day/wk for 4 wk @ max power	19 young males in each group, but 1 excluded from (a)	Melatonin	Total melatonin output (area under curve), time and magnitude of peak melatonin	No significant changes in any of the endpoints compared to pre-exposure night, either during or 2 weeks after exposure.	No effect	
Eulitz et al. (1998)	Pulsed high frequency electromagnetic field		Brain activity	Brain electrical response	Alteration of the brain's electrical response to acoustic stimuli		
Freude et al. (1998)	Cellular phone frequencies	Male subjects	Brain activity	Prepatory slow brain potentials (SP)	Decrease of SPs at central and temporo-parieto-occipital brain region	Replicated	
Freude et al. (2000)	Cellular phone frequencies	Male subjects	Brain activity	Bereitschaftspotential (BP). Contingent negative variation (CNV)	No effects on either BP or CNV		
Hladky et al. (1999)	Mobile phone Motorola GSM	20 volunteers	Central nervous	Visual evoked potentials.	No effect on visual evoked	Talking on a mobile phone	

	8700 frequencies for 5-6 m.		system (CNS)	Memory and attention. Response and decision speed	potentials. No effect on memory and attention. The response and decision speed were significantly worse.	while driving can be a great risk	
Kellenyi et al. (1999)	GSM phone signal		Brain activity	Auditory brainstream response	Increase in auditory brainstream response. 20 dB hearing deficiency in 2-10 kHz range.		
Koivisto et al. (2000)	902 MHz GSM, 1 hr approx	24 males, 24 females	Cognitive testing	Battery of 12 reaction time tasks, involving shape & object recognition, decision making & vigilance	Of 15 comparisons, vigilance task highly sign. improved. Still sign. with Bonferroni correction	Main finding unreplicated. Health implication hard to evaluate, but changes well within normal variation.	
Krause et al. (2000)	902 MHz	16 normal subjects	Brain activity	EEG power	Increased EEG power in the 8-10 Hz band only. ERD/ERS responses altered in all the		

					bands as a function of time and memory task.		
Mann & Roschke (1996)	Pulsed EMR at digital cellular phone frequencies	Healthy humans	Sleep	REM sleep. EEG signal	Reduced duration and percentage of REM sleep. EEG signal qualitative alterations. Increase in EEG power		
Mann et. al. (1998)	Pulsed EMR at digital cellular phone frequencies	Healthy humans	Heart rate	Heart rate during sleep	Heart rate not affected	No effect	
Mann et. al. (1998)	900 MHz pulsed at 217 Hz. Average power density of 0.02 mW/cm^2.	Healthy humans	Neuroendocrine system	Nocturnal hormone profiles of growth hormone, cortisol, luteinizing hormone and melatonin	No significant alterations	No effect	
Preece et al. (1999)	915 MHz ë/4 antenna; 1 W continuous to simulate analog, 12.5% duty cycle (0.125 W	36 total: both groups: 9 males, 9 females; first group	Cognitive testing	Battery of 10 computer-delivered cognitive tests, measuring 15 endpoints	Of the 15 comparisons, choice reaction time is sign. (even with Bonferroni	Main finding unreplicated. Health implication hard to evaluate, but changes well within normal	

	average) to simulate digital.	larger age range		involving reaction times & accuracy	correction). Improvement for analog, but not digital. Post-hoc analysis of reaction times combined show similar changes.	variation.	
Szmigielski et al. (1998)	0.738-1.503 MHz for 24 h.. 2 levels of exposure. Low intensities (20-180 V/m). High intensities (200-550 V/m).	61 healthy workers (aged 30-50 y) exposed. 38 exposed to low intensities. 23 exposed to high intensities. 42 controls (aged 28-49 y).	Blood pressure & heart rate	Parameters of diurnal rhythms(acrophase, amplitude and mean) of blood pressure and heart rate	Exposed workers showed a significant lowering of the amplitudes of rhythms of blood pressure and heart rate and a shift of the acrophase to an earlier time. More pronounced effects at high intensities.	Clinical significance not established	
Urban et. al. (1998)	GSM frequencies	20 healthy volunteers	Central nervous system	Visual evoked potentials (VEP)	No effect	No effect	
Wagner et al. (1998)	900 MHz circularly polarised	24 healthy males	Sleep	EEG rhythms	Normal rhythms	No effect	

	(pulsed at 217 Hz, pulse width 577 μs) over a whole night. Power flux density 0.2 W/m^2.						

Epidemiological Studies

Author	Exposure	Test System	Theme	Endpoint	Outcome	Impact	Notes
Hannson et al. (1998)	GSM and NMT cellular phone systems	Mobile phone users	Any symptoms	Any symptoms	GSM users reported warmth sensation on, behind and around the ear less frequently than NMT users		
Hardell et al. (1999)	GSM and NMT cellular phone systems	233 people with brain tumors (aged 20-80 y). 466 controls (for every subject 2 controls matching the sex, age and study region).	Brain tumor	Risk of brain tumor	Non-significantly increased risk for tumor in the temporal or occipital lobe on the same side as a cellular phone. The increased risk was for the NMT system only		
Hardell et al. (2000)	Fluoroscopy. Radiotherapy. Medical X-rays. Exposure in the chemical industry and in laboratories. Celular phones	634 men and women aged 20-80 years. 209 cases. 425 controls.	Brain tumor	Brain tumor	Increased risk of brain tumor		

Hocking (1998)	Mobile phone frequencies	Respondents to a notice of interest	Symptoms	Burning sensation. Intra-cranial effects. Local symptoms.	40 cases of feeling a burning sensation in the temporal, occipital or auricular areas. Several cases reported intra-cranial effects. 3 cases reported local symptoms from wearing the phones on their belts.		
Kolmodin-Hedman et al. (1988)	RFR from plastic welding machines	113 men and women occupationally exposed. 23 women controls. 305 pregnant female workers during 1974-1984.	Health problems	Coordination and muscular function of the hands. Eye symptoms. Two-point discrimination (2-PD). Malformation or prenatal mortality.	Numbness in hands prevalent, esp. in women. Irritative eye symptoms reported by 23% m and 40% f. 9 out of 27 people tested had modest conjunctivitis. Significantly impaired 2-PD in women compared to controls. No significant effects on pregnancy outcomes.		
Lagorio et al. (1997)	RF generated by dielectric heat	481 women workers	Mortality	Malignant neoplasms.	Malignant neoplasms	Possible confounding	

	sealers			Leukemia. Accidents.	slightly elevated. Increased risks of leukemia and accidents.	effects of exposure to solvents and vinyl chloride monomer make these results unclear.	
Reeves (2000)	RFR exceeding the permitted exposure limits	34 patients	Physiological and laboratory parameters	Warmth sensation. Abnormal tissue destruction. Neurological or opthalmologic findings.	Warmth sensation associated with power density. Abnormal tissue destruction negatively correlated with power density. No neurological or opthalmologic findings.	No athermal effects	

Thermal levels of RF with Chemical agents

Author	Exposure	Test System	Theme	Endpoint	Outcome	Impact	Notes
Nelson et al (1997a)	10 MHz	Rats	Promotion effects	Toxicity and teratogenicity of 2-methoxyethanol	Enhanced toxicity in rats		
Nelson et al (1997b)	10 MHz	Rats	hypothermia	Toxicity and teratogenicity of 2-methoxyethanol	Enhanced teratogenicity in rats		
Nelson et al (1998)	10 MHZ	Sprague-Dawley rats	Environmental temperature effects on the toxicity of RF and 2ME	Toxicity and teratogenicity of 2-methoxyethanol	Environmental temperature affects the SAR needed to maintain a specific colonic temp. but does not affect the interactive toxicity of RF and 2ME		
Nelson et al (1999)	10 MHZ	Rats	Synergistic interactions between salicylic acid and RF or 2ME	Toxicity and teratogenicity of 2-methoxyethanol	No effect on RF. Limited evidence of antagonism with 2ME.		

Dosimetry

Author	Exposure	Test System	Theme	Endpoint	Outcome	Impact	Notes
Chou et. al. (1999)	837 or 1957 MHz by a 3 × 1 cm loop antenna. At 837 MHz mean brain SAR of 23 W/kg At 1957 MHz mean brain SAR of 22.6 W/kg.	Sprague Dawley rats	Exposure system	Produced SARs	Two-tenths of a watt input power produced 10 W/kg maximum SAR and an estimated 4.8 W/kg average brain SAR in a 300g medium size rat.		
Guy et al. (1999)	837 MHz plane wave. 2450 MHz in a TEM cell. 3000 MHz in a stripline.	Solutions containing suspended or plated cells in vessels	Exposure methods	SAR uniformity	The best SAR uniformity for suspended cells was found for a rectangular slab in a stripline. The best SAR uniformity for plated cells was found for a Petri dish in a TEM cell.		
Rowley et al. (1998)	RF exposure in a 1.1m × 1.1m × 1.1m cubic resonant facility	Biological materials	Dosimetry	Use of resonant cavities for RF exposure of biological materials	This type of system unsuitable due to a number of inherent deficiencies		

Reviews

Author	Exposure	Test System	Theme	Endpoint	Outcome	Impact	Notes
Jauchem (1998)	RF	Humans	Health effects	Various		No effect	
Verschaeve and Maes (1998)	Mobile phone frequencies		Cancer	Genetic, carcinogenic and teratogenic effects	The great majority of the papers reviewed showed no effect.		This paper reviews the current research into genotoxic effects at mobile phone frequencies

(*Ken Karipidis, 6 November 2000*)