IARC 2B possible human carcinogen classification

- **Health Protection Agency (HPA)/Public Health England (PHE) failed to mention the International Agency for Research on Cancer (IARC) classification of radiofrequency fields as a possible human carcinogen (2B) in their submission to the Commons Select Committee Enquiry into smart meter roll-out.**
- **HPA/PHE failed to mention the IARC 2B classification in their information about Wi-Fi, smart meters or other wireless technologies other than mobile phones.**

UK Organisations associated with the International EMF Alliance

We would like PHE to include the IARC classification of radiofrequency electromagnetic fields as a Group 2B possibly carcinogenic to humans in all information about wireless devices passed on to schools, organisations and government departments, as well as in their published or communicated information about each technology, i.e. Wi-Fi and smart meters.

Including the 2B classification in information about wireless devices allows people to make informed choices. Organisations have legal responsibilities to provide safe environments and to not harm children, employees or members of the public; being fully informed allows them to fulfil these legal requirements. The Trades Union Congress (TUC) in their 'Occupational Cancer, A Workplace Guide' advises employers that Group 1 and 2 carcinogens should be removed from the workplace or caution used to prevent exposure to them (2008, 2012; http://www.tuc.org.uk/sites/default/files/extras/occupationalcancer.pdf).

Evidence:

In May 2011 the World Health Organization (WHO) International Agency for Research on Cancer (IARC) classified all radiofrequency fields as a possible human carcinogen (Group 2B).
Monograph 102. http://monographs.iarc.fr/ENG/Monographs/vol102/

The decision was based on epidemiology studies, mechanistic data and animal studies, for a range of radiofrequency sources (including radar, wireless phones, 2.4GHz signals and other frequencies).

The IARC monograph makes it clear that the classification is for all radiofrequency radiation and not only for mobile phones: "it should be emphasized that the evaluations in this volume address the general question of whether RF radiation causes cancer in humans or in experimental animals: it does not specifically or exclusively consider mobile phones, but rather the type of radiation emitted by mobile phones and various other sources." (p 33, IARC Monographs, Volume 102, Non-ionizing Radiation, Part 2: Radiofrequency Electromagnetic Fields, 2013).

Evidence for the classification included studies which found tumours, DNA damage and effects on immune cells from 2.45 GHz (Wi-Fi frequency). Some of these are described in Appendix 1.

Epidemiology

An OR (Odds Ratio) > 1.0 indicates that the exposure is associated with increased odds of developing a certain type of cancer. 95% CI (Confidence Interval) with a first number > 1.0 is needed for the increased risk to be considered significant. OR of 2.0 indicates a doubling of the risk, or an increase of 100%.

For comparison, passive smoking which has been banned in workplaces and other public spaces, increases the likelihood of lung cancer by up to 74% (or an OR of up to 1.74; Kim *et al* 2014, Int J Cancer 135:2232). The odds rations for actual tobacco smoking and the risk of lung cancers are similar to those listed below for mobile phones and brain tumours for the same time since first use (IARC Monographs 83 and 100E). For example Kreuzer *et al* (2000) found that men smoking for <20 years gave an OR of 2.4 (95% CI 1.8-3.3) and smoking for >40 years gave an OR of 39.1. Agudo *et al* (2000) found in women who smoked for 20-29 years an OR for lung cancer of 4.5 (3.5-5.7). Rylander *et al* (1996) found that men smoking more than 20 cigarettes a day for 20-29 years had an OR of 2.8 and smoking the same amount for >50 years an OR of 41. A more detailed comparison can be found in Appendix 2. We do not yet have data for use of wireless phones for >40 years, but the risks can be expected to be higher than that currently reported for >10 or >20 years.

The data below indicates similar increased cancer risks for mobile/cordless phone use as for smoking and lung cancer, for the equivalent time since first use.

The 2B classification and evidence of carcinogenicity is extremely important, because in schools and workplaces, where smoking has been banned, children are being given wireless tablet computers and mobile hand-held devices to use on a daily basis. If we wouldn't give them cigarettes to smoke, then the evidence presented here indicates that perhaps we shouldn't be giving them wireless devices to use.

Epidemiology studies considered by IARC included Interphone, a multi-country case-control study, and Hardell case-control studies.

Interphone 2010 – Appendix 2 for Glioma, International Journal of Epidemiology 39: 675-694

Time since start of regular use of mobile phone (years)	*Cases*	*Controls*	*OR*	*95% CI*
1-1.9	93	159	1.00	
2-4	460	451	1.68	1.16 - 2.41
5-9	468	491	1.54	1.06 - 2.22
10+	190	150	2.18	1.43 - 3.31
Cumulative call time >1640 hours (temporal lobe)			1.87	1.09 - 3.22

Hardell Studies
e.g. Hardell L. and Carlberg M., 2009. International Journal of Oncology 35: 5-17.
905 malignant brain tumours; 1,254 benign tumours; 2,162 controls.

Ipsilateral astrocytoma, mobile phones, >10 years use	OR 3.3	95% CI 2.0 - 5.4
Ipsilateral astrocytoma, cordless phones	OR 5.0	95% CI 2.3 - 11
astrocytoma first use <20 years age, for mobile phone	OR 5.2	95% CI 2.2 - 12
astrocytoma first use <20 years age for cordless phone	OR 4.4	95% CI 1.9 - 10
ipsilateral acoustic neuroma, mobile phones, >10 years use	OR 3.0	95% CI 1.4 - 6.2
ipsilateral acoustic neuroma, cordless phone	OR 2.3	95% CI 0.6 - 8.8
acoustic neuroma first use <20 years age, for mobile phone	OR 5.0	95% CI 1.5 - 16

Evidence for carcinogenicity has been strengthened by papers published since the 2B classification in May 2011

Epidemiology Studies since Monograph 102:

Hardell L. *et al* 2013 Acoustic neuroma, International Journal of Oncology 43: 1036-1044.
316 participating cases and 3,530 controls

Analogue mobile phone >20 years use	OR 7.7	95% CI 2.8 - 21
2G mobile phone >1 year	OR 1.5	95% CI 1.1 - 2.1
Cordless phone >20 years	OR 6.5	95% CI 1.7 - 26
All Digital >20 years	OR 8.1	95% CI 2.0 - 32
Total wireless phone >20 years	OR 4.4	95% CI 2.2 - 9.0

Hardell L. *et al* 2013 malignant brain tumours, International Journal of Oncology 43: 1833-1845
593 cases and 1368 controls

Analogue mobile phone >25 years use	OR 3.3	95%CI 1.6 - 6.9
2G mobile phone >15-20 years	OR 2.1	95% CI 1.2 - 3.6
Cordless phone 15-20 years	OR 2.1	95%CI 1.2 - 3.8

Carlberg M. and Hardell L. 2014 **Decreased Survival of Glioma Patients** with Astrocytoma Grade IV (Glioblastoma Multiforme) Associated with Long-Term Use of Mobile and Cordless Phones. International Journal of Environmental Research and Public Health 11, 10790-10805.

Brain cancer	*Cases*	*Controls*	*HR (hazard ratio)*	*95%CI*
Glioma, wireless phone, >20 years	83	480	1.7	1.2 - 2.3
Astrocytoma grade IV, >20 years	52	308	2.0 (mobile)	1.4 - 2.9
			3.4 (cordless)	1.04 - 11

Hardell L. and Carlberg M. 2013, Hill criteria, Reviews of Environmental Health 28: 97–106

"Based on the Hill criteria, 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."

Hardell L. and Carlberg M. 2015, Mobile phone and cordless phone use and the risk of glioma – analysis of pooled case-control studies in Sweden, 1997-2003 and 2007-2009. Pathophysiology 22(1): 1-13.

Time since start of regular use	*Cases*	*Controls*	*OR*	*95% CI*
Analogue >1 year	299	558	1.6	1.2 - 2.0
Digital 2G >1 year	884	2014	1.3	1.1 – 1.6
Digital 3G >1 year	58	141	2.0	0.95 – 4.4
Cordless phone > 1 year	752	1724	1.4	1.1 – 1.7
Analogue >5-10 years	56	137	1.1	0.8 - 1.6
Digital 2G >5-10 years	314	659	1.7	1.3 – 2.2
Digital 3G >5-10 years	12	14	4.1	1.3 - 12
Cordless phone >5-10 years	294	655	1.4	1.1 – 1.8
Analogue >15-20 years	59	107	2.4	1.5 – 3.7
Digital 2G >15-20 years	98	170	2.1	1.5 – 3.0
Cordless phone >15-20 years	50	109	1.7	1.1 – 2.5
Analogue >20-25 years	50	81	3.2	1.9 – 5.5
Analogue >25 years	29	33	4.8	2.5 – 9.1
1st use < 20 years old, mobile	69	93	1.8	1.2 - 2.8
1st use <20 years old, cordless phone	46	48	2.3	1.4-3.9

Coureau G. *et al* 2014. French Cerenat Study Occupational and Environmental Medicine 71(7): 514-522. 231 cases, 446 controls

Brain cancer	*Exposure period*	*OR*	*95% CI*
Glioma	After 1 year	2.89	1.41 - 5.93
	After 2 years	3.03	1.47 - 6.26
	After 5 years	5.30	2.12 - 13.23
Glioma urban use only	All	8.20	1.37 – 49.07
Meningioma	After 1 year	2.57	1.02 - 6.44

CEFALO 2011, risk of brain tumours in children and adolescents (age 7-19) Environmental Health 10:106.

Operator-recorded use for 62 cases and 101 controls, >2.8 years since first subscription, OR 2.15 (95%CI 1.07 - 4.29).

Frei P. *et al* 2011 Use of mobile phones and risk of brain tumours: update of Danish cohort study. BMJ 343:d6387. The Danish cohort study was flawed because corporate mobile phone subscribers were classified as non-users.

Breast Cancers

West J.G. *et al* 2013 Multifocal Breast Cancer in Young Women with Prolonged Contact between Their Breasts and Their Cellular Phones. Case Reports in Medicine ID 354682 [Epub ahead of print].

4 case reports of multi-focal breast tumours clustered directly underlying where the women had regularly kept their mobile phone in their bra for 6-10 years (2 age 21, one 33, other 39). No tumours were found in other regions of the breasts. Three showed metastasis. All were oestrogen and

progesterone positive but Her2 negative, luminal-type carcinomas. All patients had no family history of breast cancer, tested negative for BRCA1 and BRCA2.

Salivary gland tumours

Czerninski *et al* 2011 Increase in parotid (or salivary) gland tumours in Israel over the last 30 years. Epidemiology 22:130. Parotid tumours tripled in Israel, with 1 in 5 under the age 20.

Sadetzki S. *et al* 2008 Cellular Phone Use and Risk of Benign and Malignant Parotid Gland Tumours—A Nationwide Case-Control Study. American Journal of Epidemiology 167(4): 457–467.
402 benign and 58 malignant cases, 1,266 controls

Ipsilateral use, highest cumulative number of calls	OR 1.58 (95% CI 1.11 - 2.24)
Ipsilateral use, highest cumulative call time	OR 1.49 (95% CI 1.05 - 2.13)

"A positive dose-response trend was found. Based on the largest number of benign PGT patients reported to date, our results suggest an association between cellular phone use and PGTs."

Co-carcinogen

Lerchl A. et al 2015. Biochem and Biophys Res Comm 459: 585-590.
Lerchl et al found that 3G signal exposures for 71 weeks can act as a co-carcinogen in mice and statistically significantly increase cancer growth in liver and lungs at very low exposure levels (0.04W/kg). There was also a significant increase in lymphomas. **0.04W/kg is lower than current ICNIRP guideline values and well within the exposures experienced by users of mobile phones and wireless tablet computers.**

Tillmann T. *et al* 2010 Int J Radiat Biol 86(7): 529-541.
The Lerchl study replicated one by Tillmann et al (2010), testing the effects of 3G signals in mice. They found that 4.8 W/m^2 (below current $10W/m^2$ ICNIRP guideline values) enhanced lung tumour rate and increased incidence of lung carcinomas. Tumour multiplicity of the lung carcinomas was increased and the number of metastasising lung tumours was doubled.

Cancer promotion

Nazıroğlu M. *et al* (2012) found that low power 2.45 GHz wireless signals increased the proliferation of human leukaemia cancer cells. Int J Radiat Biol 88(6): 449–456.

Belyaev I.Y. *et al* (2009) reported that 3G signals inhibited the repair of DNA breaks in human lymphocytes. Bioelectromagnetics 30(2): 129-141.

DNA damage from mobile phones and Wi-Fi

Supporting evidence for carcinogenicity comes from studies which found that mobile phone and Wi-Fi signals can damage DNA. DNA damage can lead to cancers. Sample of papers listed below:

Atasoy H.I. et al, 2013. Immunohistopathologic demonstration of deleterious effects on growing rat testes of radiofrequency waves emitted from conventional Wi-Fi devices. Journal of Pediatric Urology 9(2): 223-229. http://www.ncbi.nlm.nih.gov/pubmed/22465825

Avendaño C. et al, 2012. Use of laptop computers connected to internet through Wi-Fi decreases human sperm motility and increases sperm DNA fragmentation. Fertility and Sterility 97(1): 39-45. http://www.ncbi.nlm.nih.gov/pubmed/22112647

Margaritis L.H. et al, 2013. Drosophila oogenesis as a bio-marker responding to EMF sources. Electromagn Biol Med. 33(3): 165-189. http://www.ncbi.nlm.nih.gov/pubmed/23915130

Aitken R. J. et al, 2005, Impact of radio frequency electromagnetic radiation on DNA integrity in the male germline, Int J Androl, 28(3), 171-179. https://www.ncbi.nlm.nih.gov/pubmed/15910543

Cam S.T. and Seyhan N. 2012. Single-strand DNA breaks in human hair root cells exposed to mobile phone radiation. International Journal of Radiation Biology 88(5): 420-424. https://www.ncbi.nlm.nih.gov/pubmed/22348707

De Iuliis G. N. et al, 2009. Mobile phone radiation induces reactive oxygen species production and DNA damage in human spermatozoa in vitro, PLoS One 4(7), e6446. https://www.ncbi.nlm.nih.gov/pubmed/19649291

Karaca E. et al, 2011. The genotoxic effect of radiofrequency waves on mouse brain. J. Neurooncol 106(1): 53-58. https://www.ncbi.nlm.nih.gov/pubmed/21732071

Phillips JL et al, 2009. Electromagnetic fields and DNA damage. Pathophysiology 16(2-3): 79-88. https://www.ncbi.nlm.nih.gov/pubmed/19264461

Ruediger H.W., 2009. Genotoxic effects of radiofrequency electromagnetic fields. Pathophysiology 16(2–3): 89–102. https://www.ncbi.nlm.nih.gov/pubmed/19285841

Schwarz C. et al, 2008. Radiofrequency electromagnetic fields (UMTS, 1,950 MHz) induce genotoxic effects in vitro in human fibroblasts but not in lymphocytes. Int Arch Occup Environ Health 81(6): 755-767. https://www.ncbi.nlm.nih.gov/pubmed/18278508

Sekeroglu A.Z. et al, 2013. Evaluation of the cytogenotoxic damage in immature and mature rats exposed to 900 MHz radiofrequency electromagnetic fields. Int J Radiat Biol 89(11): 985-992. https://www.ncbi.nlm.nih.gov/pubmed/23718180

Oxidative stress

Wi-Fi/2.4GHz signals and mobile phone signals can increase oxidative stress. This means that they increase free radical damage in the body caused by increased production of radicals or a decrease in their removal by antioxidants. Oxidative stress can damage DNA, leading to cancer, mutations and cell death. Sample of papers listed below:

Aynali G. et al, 2013. Modulation of wireless (2.45 GHz)-induced oxidative toxicity in laryngotracheal mucosa of rat by melatonin. Eur Arch Otorhinolaryngol 270(5): 1695-1700. http://www.ncbi.nlm.nih.gov/pubmed/23479077

Gumral N. et al, 2009. Effects of selenium and L-carnitine on oxidative stress in blood of rat induced by 2.45-GHz radiation from wireless devices. Biol Trace Elem Res. 132(1-3): 153-163. http://www.ncbi.nlm.nih.gov/pubmed/19396408

Naziroğlu M. and Gumral 2009. Modulator effects of L-carnitine and selenium on wireless devices (2.45 GHz)-induced oxidative stress and electroencephalography records in brain of rat. Int J Radiat Biol. 85(8): 680-689. http://www.ncbi.nlm.nih.gov/pubmed/19637079

Nazıroğlu M. et al, 2012. 2.45-Gz wireless devices induce oxidative stress and proliferation through cytosolic Ca2+ influx in human leukaemia cancer cells. International Journal of Radiation Biology 88(6): 449–456. http://www.ncbi.nlm.nih.gov/pubmed/22489926

Nazıroğlu M. et al, 2012b. Melatonin modulates wireless (2.45 GHz)-induced oxidative injury through TRPM2 and voltage gated Ca(2+) channels in brain and dorsal root ganglion in rat. Physiol Behav. 105(3): 683-92. http://www.ncbi.nlm.nih.gov/pubmed/22019785

Ozorak A. et al, 2013. Wi-Fi (2.45 GHz)- and mobile phone (900 and 1800 MHz)- induced risks on oxidative stress and elements in kidney and testis of rats during pregnancy and the development of offspring. Biol. Trace Elem. Res. 156(103): 221-29. http://www.ncbi.nlm.nih.gov/pubmed/24101576

Oksay T. et al, 2012. Protective effects of melatonin against oxidative injury in rat testis induced by wireless (2.45 GHz) devices. Andrologia 46(1): 65-72.
http://www.ncbi.nlm.nih.gov/pubmed/23145464

Salah MB, 2013. Effects of olive leave extract on metabolic disorders and oxidative stress induced by 2.45 GHz WIFI signals. Environ Toxicol Pharmacol 36(3): 826-834.
https://www.ncbi.nlm.nih.gov/pubmed/23994945

Shahin S. et al, 2013. 2.45 GHz Microwave Irradiation-Induced Oxidative Stress Affects Implantation or Pregnancy in Mice, Mus musculus. Appl Biochem Biotechnol 169: 1727–1751. http://www.ncbi.nlm.nih.gov/pubmed/23334843

Shahin S. et al, 2014. Microwave irradiation adversely affects reproductive function in male mouse, Mus musculus, by inducing oxidative and nitrosative stress. Free Radic Res. 48(5): 511-525. https://www.ncbi.nlm.nih.gov/pubmed/24490664

Tök L. et al, 2014. Effects of melatonin on Wi-Fi-induced oxidative stress in lens of rats. Indian Journal of Opthalmology 62(1): 12-15. http://www.ncbi.nlm.nih.gov/pubmed/24492496

Türker Y. et al, 2011. Selenium and L-carnitine reduce oxidative stress in the heart of rat induced by 2.45-GHz radiation from wireless devices. Biol Trace Elem Res. 143(3): 1640-1650. http://www.ncbi.nlm.nih.gov/pubmed/21360060

We do not have human epidemiology studies on purely Wi-Fi exposures and cancer. But we are seeing significantly increased risks of cancer associated with mobile and cordless phone use in some studies and Wi-Fi-enabled devices can expose the users to similar strength fields close to the body, but often for longer periods of time (see below). Hardell and Carlberg (2014) found that 3G signals, which include internet access, increased the risk of developing a glioma in the brain more than 2G or analogue mobile phone signals. 3G signals also act as a co-carcinogen in mice (Lerchl *et al* 2015; Tillmann *et al* 2010) at exposures which someone using a mobile phone or wireless tablet computer is expected to be exposed to. 3G signals can inhibit the repair of damaged DNA (Belyaev *et al* 2009). That Wi-Fi signals can damage DNA and increase oxidative stress supports the possibility that the radiation could induce cancers. Children are expected to be at increased risk compared to adults, as they absorb radiation more easily and their cells are dividing more, allowing greater opportunity for DNA damage to be expressed. In keeping with this idea, Hardell and Carlberg 2009 found that young

people who first used a mobile phone under the age of 20 had a higher risk of developing a tumour than adults.

The average maximum specific absorption rate (SAR) for a sample of 358 digital mobile phones is 1.02 W/kg in 1g tissue (sarvalues.com; adult); iPad maximum SAR on Wi-Fi is 1.19 W/kg in 1g tissue (iPad Information Guide; adult). Thus, wireless computers positioned close to the body could expose the users to similar levels of radiation as mobile phones next to the body. Exposures from wireless/tablet computers and mobile/cordless phones are all in the personal devices category.

It is worth noting that the significantly increased risks of tumours reported for the highest users of mobile phones in the Cerenat or Interphone studies were for people who had used a mobile phone for at least 896 or 1640 hours, respectively. This is the equivalent of using a mobile phone for 15-27 minutes or more a day, for 10 years. Today many children in schools, as well as the wider population, use wireless devices for much longer than this each day.

It is of concern that many children and young people regularly use mobile phones/smartphones and wireless/tablet computers, often held against the head, on the lap or up against the abdomen/chest. Some young people sleep with their mobiles under their pillows and some carry their devices close to their body when switched on or in standby. Schools are giving these devices to children to use on a regular basis, as well as exposing them to signals from Wi-Fi access points throughout the school day, for many years. The data presented here supports a possible increase in cancers as a result of exposures to wireless signals. It is important that schools, parents and employers are aware of the cancer risks and realise that they may be placing the people for whom they are responsible at increased risk of developing cancer, or increased risk of dying from cancer should they already have it.

Some scientists and doctors are calling for the 2B to be upgraded to a 2A (probable) or Group 1 classification (definite carcinogen) for radiofrequency radiation

Professor Lennart Hardell, MD, PhD, (Oncologist and member of IARC RF working group) “Based on the Hill criteria, 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. Current guidelines for exposure need to be urgently revised”, 2013.

Professor Anthony B. Miller, BM, (member of IARC working groups; formerly Director of the Epidemiology Unit of the National Cancer Institute of Canada) “radiofrequency fields are a probable human carcinogen (IARC Category 2A)”, 2014.

Dr Annie Sasco, MD, PhD (Director, Epidemiology for Cancer Prevention; worked for 22 years at IARC) and Professor Dariusz Leszczynski, PhD (member of IARC RF working group) both said that they supported a classification of radiofrequency fields as probably carcinogenic to humans (Group 2A), 2012.

International Journal of Oncology, 2015: Lloyd Morgan (Director of Central Brain Tumour Registry, USA), Dr Devra L. Davis, PhD (formerly Center for Environmental Oncology, University of Pittsburgh Cancer Institute, USA), Dr Annie Sasco and Professor Anthony Miller, "We conclude that radiofrequency fields should be classified as a Group 2A 'probable' human carcinogen under the criteria used by the International Agency for Research on Cancer (Lyon, France)". http://www.ncbi.nlm.nih.gov/pubmed/25738972

Dr David Carpenter, MD, (Professor of Environmental Health Sciences, University at Albany, New York) would change the IARC's classification to "likely".

Professor Denis Henshaw, PhD, (Emeritus Professor and Senior Research Fellow, University of Bristol, UK) "Although the risk for brain tumours in the individual is small, even a doubling of risk from prolonged mobile phone use is of public health significance. I think that the IARC classification should be elevated to 2A (probable carcinogen)."

Dr Joel Moskowitz, PhD (Director, Family and Community Health, University of California), "Having reviewed hundreds of studies, I believe it is highly likely that cell phone radiation is carcinogenic. Thus, I believe cell phone radiation should be considered "probably carcinogenic to humans" (Group 2A) in terms of the IARC classification."

Appendix 1

Some papers included in the WHO IARC Monograph 102 on 2.45 GHz:

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2.45 GHz microwaves, far field, 2h/d, 6d/week, mouse, 5mW/cm2 (2-3W/kg)
- mammary gland tumours were detected as a result of exposures. Szmigielski *et al*. (1982).

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2.45 GHz microwaves, far field, 2 h/d, 6 d/week, 5mW/cm2 - significantly increased numbers of mice with skin cancers as a result of exposures. Szmigielski *et al*. (1982).

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DNA microsatellite analysis with synthetic oligonucleotide probes in cells of brain and testis of Swiss albino mice. 1.2W/kg, 1mW/cm2, 2h/d, 120-200 days – significant DNA rearrangement following exposures. Sarkar *et al*. 1994.

(Micronuclei are abnormal small nuclei which form when a chromosome or chromosome fragment is not incorporated into one of the daughter nuclei during cell division; they characterize cells which have a form of DNA damage).

Micronuclei formation in peripheral blood cells of male Wistar rats, 2.45 GHz, 1 and 2 W/kg, 2h/d for up to 30 d - micronuclei found after 8 exposures of 2h. Trosic *et al*. (2002).

Micronuclei formation in PCEs (polychromatic erythrocytes) in bone marrow and peripheral blood of Wistar rats. 2.45 GHz, 1.25W/kg, 2h/d, 7d/week, 30d. Significantly increased micronuclei in PCEs in bone marrow on day 15 and in peripheral blood on day 8. Trosic and Busljeta (2006).

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Micronuclei formation in bone marrow cells of male Wistar rats. 2.45 GHz, 1.35W/kg, 2h/d up to 30 days. Increase in micronuclei in PCEs in bone marrow on day 15. Transient effect on proliferation and maturation of erythropoietic cells. Trosic *et al*. (2004); Busljeta *et al*. (2004)

DNA breaks (single strand breaks (SSB), double strand breaks (DSB)) measured with comet assay in brain cells of male Sprague-Dawley rats. 2.45 GHz, 0.6 and 1.2W/kg, 2h - significant and SAR-dependent increase in DNA strand breaks immediately and at 4 h after exposure. Lai & Singh (1995).

DNA breaks (single strand and double strand breaks) measured with comet assay in brain cells of male Sprague-Dawley rats, 2.45 GHz, 1.2 W/kg, 2 h. Significant increase in strand breaks at 4 h after exposure. Lai & Singh (1996).

DNA breaks (single strand and double strand breaks) measured with comet assay in brain cells of male Sprague-Dawley rats, 2.45 GHz, 1.2W/kg, 2h. Melatonin or N-tertbutyl-α-phenylnitrone (free radical scavengers). Significant increase in DNA strand breaks at 4 h after exposure. Treatment with radical scavengers before and after exposure to RF prevented/reversed induction of strand breaks. Lai & Singh (1997).

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DNA breaks (single strand and double strand breaks) measured with comet assay in brain cells of male Sprague-Dawley rats, 2.45 GHz, 0.6W/kg, 2h - significant increase in strand breaks at 4 h after exposure. Lai & Singh (2005).

DNA breaks (single strand breaks) measured with alkaline comet assay in brain cells of male and female Wistar rats, 2.45 GHz, 1.0 W/kg or 2.01 W/kg, 2 h/d, for 35 d – DNA breakage seen. Paulraj & Behari (2006).

DNA breaks measured with neutral comet assay in brain of Wistar rats, 2.45 GHz, 0.11W/kg, 2h/day, 5d - highly significant decrease in antioxidant enzymes and increase in catalase, Kesari *et al*. (2010).

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BALB/c mice, 2.45 GHz, 0.14 W/kg, 3 h/d for 6 d. Increase in the number of antibody-producing cells in the spleen of male mice, Elekes *et al*. (1996).

Rats, 2.45 GHz, 0.15–0.4 W/kg, 25 months. Transient increase in the number of B and T lymphocytes and their response to the mitogen PHA after exposure for 13 months. Guy *et al*. (1985).

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Rabbit lens epithelial cells, 2.45 GHz, 0.5–20 W/m2 (0.05-2mW/cm2); 2–8 h. Decreased number of cells in S-phase (decreased cellular replication) at exposures > 0.5 W/m2 after 8 h. Yao *et al*. (2004).

Appendix 2

Odds Ratios (OR) from case-control studies for **tobacco smoking and lung cancer** compared to those for **mobile/cordless phone use and head/brain tumours**, for time since first use (Table below). Smoking data is from IARC Monograph 83 (Tables 2.1.1.7 and 2.1.1.5) and wireless phone data for >20 years of use is from Hardell and Carlberg 2015 (Pathophysiology 22:1-13), Hardell et al 2013a (Int J Oncol. 43:1036-1044) and Hardell et al 2013b (Int J Oncol. 43:1833-1845) and is for glioma, acoustic neuroma and malignant brain tumours. ORs are explained on page 2. n indicates the number of studies.

Smoking for 1-29 years		Smoking for 20-29 years		Smoking for 30-39 years		Smoking for 40-49 years		Smoking for >50 years	
n=24	**OR**	n=14	**OR**	n=27	**OR**	n=33	**OR**	n=9	**OR**
	Mean = 2.7		**Mean = 5.7**		**Mean = 8.9**		**Mean = 19.3**		**Mean = 23.3**
Gao et al 1988	2.1	Rylander et al 1996	2.8	Gao et al 1988	7.1	Gao et al 1988	7.2	Rylander et al 1996	41
Gao et al 1988	8.9	Katsouyanni et al 1991	1.3	Gao et al 1988	14.2	Xu et al 1996	6	Pathak et al 1986	91.4
Xu et al 1989	1.5	Osann 1991	11.6	Xu et al 1989	2.7	Xu et al 1996	9.4	Lubin et al 1992	9.6
Xu et al 1989	2.1	Dosemeci et al 1997	4.9	Xu et al 1989	3.4	Wu-Williams et al 1990	5.7	De Stefani et al 1994	2.9
Wu-Williams et al 1990	1.8	Hu et al 1997	2.1	Wu-Williams et al 1990	3.3	Rylander et al 1996	12.6	Sobue et al 1994	4.1
Xu et al 1996	1.5	Hu et al 1997	1.9	Rylander et al 1996	10.9	Xu et al 1989	6	De Stefani et al 1996	10.8
Xu et al 1996	2.1	Dikshit and Kanhere 2000	12	Xu et al 1996	2.7	Xu et al 1989	9.4	Barbone et al 1997	14.5
Pathak et al 1986	12.9	Armadans-Gil et al 1999	11.9	Xu et al 1996	3.4	Boffetta et al 2001	18	Khuder et al 1998	9
Benhamou et al 1989	1	Agudo et al 2000	4.5	Boffetta et al 2001	5.4	Pathak et al 1986	57.3	Armadans-Gil et al 1999	26.8
Katsoutanni et al 1991	1.3	Kubik et al 2001	4	Pathak et al 1986	37.3	Benhamou et al 1987	3.3		
Liu 1992	1	Simonato et al 2001	5	Katsoutanni et al 1991	7.4	Lubin et al 1992	4.4		
Lubin et al 1992	1.3	Simonato et al 2001	4.3	Liu 1992	2.7	Pezzotto et al 1993	6		
Pezzotto et al 1993	1	Boffetta et al 2001	2.8	Lubin et al 1992	2.3	Sobue et al 1994	2.8		
Benhamou et al 1994	1	Bhurgri et al 2002	10.1	Pezzotto et al 1993	3.6	De Stefani et al 1996	10.4		
De Stefani et al 1994	1			Sobue et al 1994	1.5	Barbone et al 1997	11.4		
Sobue et al 1994	1			De Stefani et al 1996	5.2	Muscat et al 1997	23.1		
De Stefani et al 1996	3.4			Yu and Zhao 1996	2.5	Muscat et al 1997	30.1		
Yu and Zhao 1996	1.1			Yu and Zhao 1996	3.8	Rachtan and Sokolowski 1997	58.7		
Yu and Zhao 1996	1.4			Barbone et al 1997	7.9	Matos et al 1998	10.2		

Barbone et al 1997	3.2			Hu et al 1997	2.2	Agudo et al 2000	12.8		
Khuder et al 1998	3.5			Hu et al 1997	1.6	Kreuzer et al 2000	39.1		
Matos et al 1998	5.2			Dikshit and Kanhere 2000	52	Kreuzer et al 2000	7		
Armadans-Gil et al 1999	2.6			Agudo et al 2000	7.6	Simonato et al 2000	16.9		
Rachtan 2002	3			Kubik et al 2001	11.7	Simonato et al 2000	9.3		
				Simonato et al 2001	11	Kubik et al 2001	17.6		
				Simonato et al 2001	7.2	Simonato et al 2001	21.6		
				Bhurgri et al 2002	20.7	Simonato et al 2001	8.6		
						Stellman et al 2001	57.8		
						Bhurgri et al 2002	53.2		
						Petrausaite et al 2002	22.2		
						Rachtan 2002	30		
						Stellman et al 2002	25.1		
						Stellman et al 2002	24.7		

Mobile or cordless phone use >20 years		**Mobile or cordless phone use >30 years**
n=5	**OR**	**No data available yet**
	Mean = 6.1	
Hardell et la 2013a	7.7	
Hardell et al 2013a	8.1	
Hardell et al 2013a	6.5	
Hardell et al 2013b	3.3	
Hardell and Carlberg 2015	4.8	