

Written evidence submitted by Dr Sarah Starkey (EYI0062)

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1. Evidence-base for the link between adverse childhood experiences and long-term negative outcomes.

Wireless radiofrequency signals, such as those from mobile phones, tablet computers, Wi-Fi transmitters, or body-worn devices (below the current ICNIRP exposure guidelines, as followed in the UK) can have adverse biological effects which can damage development or have serious long-term negative outcomes. Evidence is provided below from human and animal studies for effects on development during pregnancy, effects on children and young people, on brain development, fertility and increased risk of cancers.

Wireless exposures during pregnancy:

- (Humans) Maternal mobile phone use during pregnancy was associated with a significantly increased risk of miscarriage¹. There was an association between maternal mobile phone call times during pregnancy and subsequent speech problems in children². Mobile phone exposures during pregnancy have been associated with a significantly increased risk of behavioural problems in human children^{3,4,5}, including hyperactivity and inattention (attention deficit hyperactivity disorder, ADHD), conduct problems and peer problems. A link between radiofrequency exposures during pregnancy and behavioural problems in children is supported by similar changes in animals exposed to radiofrequency signals, with associated changes in brain development and cognitive deficits. Behavioural problems and cognitive effects have also been reported for some radiofrequency exposures in childhood and adolescence (see below).
- (Animal studies) Mobile phone exposures during pregnancy led to ADHD-like behaviours, impaired memory and changes in brain development of the offspring in mice⁶. Wireless radiofrequency exposures in pregnancy altered brain development of the offspring, with cell loss in the hippocampus^{7, 8} (an area important for learning and memory), cerebellum⁹ (important for movement), changes in the electrical properties of neurones^{10, 11}, decreased learning and memory retention^{12,11,13} and changes in signalling chemicals (neurotransmitters)¹⁴ in mice and rats.

¹ Mahmoudabadi et al 2015 J Environ Health Sci Engineering 13: 34.

http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4416385/pdf/40201_2015_Article_193.pdf

² Zarei et al 2015 J Biomed Phys Eng. 5: 151-154. <http://www.ncbi.nlm.nih.gov/pubmed/26396971>

³ Divan et al 2012 J Epidemiol Comm Health 66: 524-529. <http://www.ncbi.nlm.nih.gov/pubmed/21138897>

⁴ Divan et al 2008 Epidemiology 19: 523-529. <http://www.ncbi.nlm.nih.gov/pubmed/18467962>

⁵ Birks et al 2017 Environ Int 104: 122-131. <https://www.ncbi.nlm.nih.gov/pubmed/28392066>

⁶ Aldad et al 2012 Nature Scientific Reports 2: 312. <http://www.nature.com/srep/2012/120315/srep00312/full/srep00312.html>

⁷ Odaci et al 2008 Brain Research 1238: 224-229. <http://www.ncbi.nlm.nih.gov/pubmed/18761003>

⁸ Bas et al 2009 Toxicol Ind Health 25: 377-384. <http://www.ncbi.nlm.nih.gov/pubmed/19671630>

⁹ Odaci et al 2016 J Chem Neuroanat. 75(Pt B): 105-110. <http://www.ncbi.nlm.nih.gov/pubmed/26391347>

¹⁰ Haghani et al 2013 Neuroscience 250: 588-598. <http://www.ncbi.nlm.nih.gov/pubmed/23906636>

¹¹ Razavinasab et al 2016 Toxicol Ind Health 32(6): 968-979. <http://www.ncbi.nlm.nih.gov/pubmed/24604340>

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- Wireless radiofrequency signals during pregnancy increased DNA damage in the liver of female offspring (rabbits)¹⁵, DNA damage in the brains of offspring (rabbits)¹⁶, cell death¹⁷ and oxidative stress¹⁸ in the livers of offspring (rats), decreased pregnancy rates, increased foetal deaths and decreased maternal hormone concentrations (rats)^{19,20,21}, increased cell death and damage to heart muscle²², cell death and tubular defects in the kidney^{23, 24, 25} damaged the cochlea in the ear²⁶, decreased testosterone concentrations²⁷ and damaged male reproductive organs²⁸ of rat offspring.
- 2.45 GHz (Wi-Fi frequency) signals during pregnancy increased oxidative stress in the brain, ovaries, liver and kidneys of rat offspring^{29,30,31,32}, altered enzyme concentrations³², damaged rat kidneys³³ and decreased implantation of pregnancy and increased abnormal development in mice (0.02 W/kg)³⁴. Wi-Fi access point exposures (2h/day) during pregnancy reduced the number of offspring by approximately half compared to controls, increased oxidative stress and impaired neurodevelopment of rats³⁵.
- Not all studies have reported adverse effects during pregnancy, for example one reported no decreased motor skills or language skills in children at the age of 3 or 5 associated with maternal mobile phone use during pregnancy³⁶. A Dutch study reported increased, but not significant, behavioural problems in children at the age of 5 associated with maternal mobile phone use during pregnancy³⁷. Some animal studies have reported no changes: no effects of RF signals pre- and post-natally on the survival rates, development, growth, physical and functional development in rats³⁸; no effects of

¹² Zhang et al 2015 J. Radiat Res. 56: 261-268. <http://www.ncbi.nlm.nih.gov/pubmed/25359903>

¹³ İkinçi et al 2013 NeuroQuantology 11: 582-590. <http://www.neuroquantology.com/index.php/journal/article/view/699>

¹⁴ Jing et al 2012 Electromagn Biol Med. 31: 57-66. <http://www.ncbi.nlm.nih.gov/pubmed/22268709>

¹⁵ Güler et al 2012 Int J Radiat Biol. 88: 367-373. <http://www.ncbi.nlm.nih.gov/pubmed/22145622>

¹⁶ Güler et al 2015 J Chem Neuroanat. 75(PtB): 128-133. <http://www.ncbi.nlm.nih.gov/pubmed/26520616>

¹⁷ Topal et al 2015 Turk J Med Sci. 45: 291-297. <http://www.ncbi.nlm.nih.gov/pubmed/26084117>

¹⁸ Cetin et al 2014 J Matern Fetal Neonatal Med. 27: 1915-1921. <http://www.ncbi.nlm.nih.gov/pubmed/24580725>

¹⁹ Ma et al 2014 Zhongguo Zhong Xi Yi Jie He Za Zhi. 34: 475-479. <http://www.ncbi.nlm.nih.gov/pubmed/24812908>

²⁰ Vereshchako et al 2014 Radiats Biol Radioecol 54: 186-192. <http://www.ncbi.nlm.nih.gov/pubmed/25764821>

²¹ Yüksel et al 2016 Endocrine 52(2): 352-362. <http://www.ncbi.nlm.nih.gov/pubmed/26578367>

²² Turedi et al 2015 Electromag Biol Med. 34(4): 390-397. <http://www.ncbi.nlm.nih.gov/pubmed/25166431>

²³ Bedir et al 2015 Ren Fail. 37: 305-309. <http://www.ncbi.nlm.nih.gov/pubmed/25691088>

²⁴ Ulubay et al 2015 Int J Radiat Biol. 91: 35-41. <http://www.ncbi.nlm.nih.gov/pubmed/25084839>

²⁵ Odaci et al 2015 Biotech Histochem. 90: 93-101. <http://www.ncbi.nlm.nih.gov/pubmed/25158858>

²⁶ Seckin et al 2014 J Laryngol Otol. 128: 400-405. <http://www.ncbi.nlm.nih.gov/pubmed/24784924>

²⁷ Sehitoglu et al 2015 Arch Esp Urol. 68: 562-568. <http://www.ncbi.nlm.nih.gov/pubmed/26179793>

²⁸ Odaci et al 2016 Biotech Histochem. 91(1):9-19. <http://www.ncbi.nlm.nih.gov/pubmed/26472053>

²⁹ Sangun et al 2015 Electromagn Biol Med. 34: 63-71. <http://www.ncbi.nlm.nih.gov/pubmed/24460416>

³⁰ Celik et al 2016 J Chem Neuroanat. 75(Pt B): 134-139. <http://www.ncbi.nlm.nih.gov/pubmed/26520617>

³¹ Kuybulu et al 2016 Ren Fail. 38(4): 571-580. <http://www.ncbi.nlm.nih.gov/pubmed/26905323>

³² Othman et al 2017 Environ Toxicol Pharmacol 52: 239-247. <https://www.ncbi.nlm.nih.gov/pubmed/28458069>

³³ Kuybulu et al 2016 Ren Fail. 38(4): 571-580. <http://www.ncbi.nlm.nih.gov/pubmed/26905323>

³⁴ Shahin et al 2013 Appl Biochem Biotechnol. 169: 1727-1751. <http://www.ncbi.nlm.nih.gov/pubmed/23334843>

³⁵ Othman et al 2017 Environ Toxicol Pharmacol 52: 239-247. <https://www.ncbi.nlm.nih.gov/pubmed/28458069>

³⁶ Papadopoulou et al 2017 BMC Public Health 17:685. <https://bmcpublihealth.biomedcentral.com/articles/10.1186/s12889-017-4672-2>

³⁷ Guxens et al 2013 J Epidemiol Comm Health 67(5): 432-438. <https://www.ncbi.nlm.nih.gov/pubmed/23386674>

Written evidence submitted by Dr Sarah Starkey (EYI0062)

Wi-Fi signals on growth or signs of toxicity in rats³⁹; no effects of Wi-Fi signals pre-and post-natally on a range of antibodies in the offspring in rats⁴⁰.

Childhood and adolescence:

- (Humans, hearing, behaviour) Postnatal mobile phone use by children has been associated with hearing loss in children at the age of 7⁴¹. The behavioural problems associated with prenatal maternal mobile phone use (above) were also seen prenatal and postnatal mobile phone exposures combined, but to a greater extent^{3,4}. 24h radiofrequency exposures of children were measured with body-worn monitors and assessed against their mental health behaviour. There was a significant association between increased behavioural problems and the higher radiofrequency exposures⁴². A Spanish study of 9-11 year old boys found a significant association between higher background radiofrequency exposures in the home (\geq median values) and anxious/depressed behaviours, social problems, rule breaking, aggressive behaviour, internalizing, total behavioural problems, anxiety and conduct problems, obsessive compulsive disorder and ADHD⁴³. The risk of ADHD symptoms in some primary school children was found to be associated with mobile phone exposures when they also had higher levels of lead in their blood⁴⁴.
- (Humans, cognition) The Spanish study⁴³ also found that the higher radiofrequency exposures in the home were significantly associated with poorer verbal expression, comprehension and a lower IQ score. A study of 12-17 year olds in Switzerland⁴⁵ investigated a possible link between wireless exposures and memory performance. Exposures were assessed using body-worn monitors, phone operator records, self-reported use data and parental questionnaires. Cognitive tests were carried out at the beginning of the study and repeated a year later. Figural memory (remembering symbols) was significantly worse for the 25% of children who used wireless devices the most, both for self-reported use and operator records. Children living near a radio transmitter were found to have reduced memory and attention as well as slower reaction times⁴⁶. Mobile or cordless phone use was associated with poorer reaction times in a small number of tests in 8-11 year old children⁴⁷, but had previously been associated with improved reaction times but poorer memory and accuracy⁴⁸. When

³⁸ Shirai et al 2017 J Radiat Res 58(1): 48-58. <https://www.ncbi.nlm.nih.gov/pubmed/27694283>

³⁹ Poulletier de Gannes et al 2012 Birth Defects Res B Dev Reprod Toxicol 95(2): 130-136.

<https://www.ncbi.nlm.nih.gov/pubmed/22311618>

⁴⁰ Ait-Aissa et al 2012 Bioelectromagnetics 33(5): 410-420. <https://www.ncbi.nlm.nih.gov/pubmed/22228576>

⁴¹ Sudan et al 2014 Paediatr Perinat Epidemiol. 27: 247-257. <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3625978/>

⁴² Thomas et al 2010 Eur J Epidemiol. 25: 135-141. <http://www.ncbi.nlm.nih.gov/pubmed/19960235/>

⁴³ Calvente et al 2016 Bioelectromagnetics 37:25-36. <http://www.ncbi.nlm.nih.gov/pubmed/26769168>

⁴⁴ Byun et al 2013 PLoS One 8:e59742. <http://www.ncbi.nlm.nih.gov/pubmed/23555766>

⁴⁵ Schoeni et al 2015 Environment International 85: 343-351. <http://www.ncbi.nlm.nih.gov/pubmed/26474271>

⁴⁶ Kolodynski and Kolodynska 1996 Sci Total Environ. 180: 87-93. <http://www.ncbi.nlm.nih.gov/pubmed/8717320>

⁴⁷ Redmayne et al 2016 Environ Health 15: 26. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4759913/>

⁴⁸ Abramson et al 2009 Bioelectromagnetics 30(8): 678-686. <https://www.ncbi.nlm.nih.gov/pubmed/19644978>

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students had their mobile phones removed in a classroom they performed better in a learning test than when they were allowed to use them, or allowed to keep them but not use them⁴⁹. This was attributed to the phones not distracting students.

- Cognitive effects of acute (short-term) radiofrequency exposures in humans are mixed. Wireless signals decreased accuracy in a working memory test in adolescents⁵⁰, decreased a measure of attention in young men during a working memory test⁵¹, slowed reaction times in spatial memory tests^{52, 53} and decreased performance in an auditory discrimination test⁵⁴. But they have also been found to have no effects or to improve reaction times or attention^{e.g. 55,56,57,58}. For example, reaction times were unaffected by a mobile phone signal in a cognitive task⁵⁶ or reaction times were found to be improved in acoustic tests⁵⁵. A UK study (SCAMP) is currently investigating whether mobile phone use in 11-14 year olds might damage cognition⁵⁹.
- (Humans, brain activity) Mobile phone, Wi-Fi and other radiofrequency signals have been found to alter electrical brain activity^{e.g.51,60,61,62}.
- (Humans, cancer) Young people who first started to use a mobile or cordless phone under the age of 20 had higher risks than adults of developing a tumour^{63, 64}. The CEFALO case-controlled study⁶⁵ looked at brain tumours in children, although the numbers were small and mobile phone use was low at the time of the study. Overall it found no association between mobile phone use and brain tumours. But for 2.8 years of use or more, there was a 115% increased odds of a brain tumour in children (Odds ratio, 2.15, 95% CI 1.07-4.29). A case-control study into possible brain tumours and mobile phone use in children and adolescents is ongoing (MOBI-Kids⁶⁶).
- (Humans, diabetes, antibiotic resistance) It is possible that some increases in type 2 diabetes may be associated with radiofrequency exposures, since higher phone mast antennae signals in schools (children aged 12-17) were associated with an increased risk of type 2 diabetes⁶⁷. Mobile phone and Wi-Fi signals have been found to increase the

⁴⁹ Lee et al 2017 Appl Cognit Psychol 31(3): 360-366. <http://onlinelibrary.wiley.com/doi/10.1002/acp.3323/abstract>

⁵⁰ Leung et al 2011 Clin Neurophysiol. 122: 2203-2216. <http://www.ncbi.nlm.nih.gov/pubmed/21570341>

⁵¹ Papageorgiou et al 2011 Neuroscience 10: 189-202. <http://www.ncbi.nlm.nih.gov/pubmed/21714138>

⁵² Luria et al 2009 Bioelectromagnetics 30: 198-204. <http://www.ncbi.nlm.nih.gov/pubmed/19194860>

⁵³ Eliyahu et al 2006 Bioelectromagnetics 27: 119-126. <http://www.ncbi.nlm.nih.gov/pubmed/16304688>

⁵⁴ Maier et al 2004 Acta Neurol Scand. 110(1): 46-52. <http://www.ncbi.nlm.nih.gov/pubmed/15180806>

⁵⁵ Curcio et al 2004 Neuroreport 15(1): 161-164. <http://www.ncbi.nlm.nih.gov/pubmed/15106850>

⁵⁶ Curcio et al 2012 Clin Neurophysiol. 123(1): 129-136. <http://www.ncbi.nlm.nih.gov/pubmed/21741302>

⁵⁷ Verrender et al 2016 Int J Radiat Biol 92(10): 603-610 <https://www.ncbi.nlm.nih.gov/pubmed/27501119>

⁵⁸ Koivisto et al 2000 Neuroreport 11(8): 1641-1643. <https://www.ncbi.nlm.nih.gov/pubmed/10852216>

⁵⁹ SCAMP <http://www.telegraph.co.uk/news/health/news/10842271/Wifi-fears-three-year-study-into-health-risks-of-mobiles-to-childrens-brains.html>

⁶⁰ Ghosn et al 2015 J Neurophysiol 113(7): 2753-2759. <https://www.ncbi.nlm.nih.gov/pubmed/25695646>

⁶¹ Vecchio et al 2012 Int J Psychophysiol 84(2): 164-171. <https://www.ncbi.nlm.nih.gov/pubmed/22326594>

⁶² Yang et al 2017 Clin EEG Neurosci 48(3): 168-175. <https://www.ncbi.nlm.nih.gov/pubmed/27118764>

⁶³ Hardell and Carlberg 2009 Int J Oncol. 35: 5-17. <http://www.ncbi.nlm.nih.gov/pubmed/19513546>

⁶⁴ Hardell and Carlberg 2015 Pathophysiology 22: 1-13. <http://www.ncbi.nlm.nih.gov/pubmed/25466607>

⁶⁵ Aydin et al 2011 J Natl Cancer Inst 103(16):1264-1276. <https://academic.oup.com/jnci/article/103/16/1264/898567>

⁶⁶ MOBI-Kids http://cordis.europa.eu/result/rcn/193614_en.html

⁶⁷ Meo et al 2017 Int J Environ Res Public Health 12(11): 14519-14528. <https://www.ncbi.nlm.nih.gov/pubmed/26580639>

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antibiotic resistance of common microorganisms⁶⁸. This is a concern, as antibiotic resistance is a threat to human health.

- (Animal studies, young) Young mice exposed to radiofrequency signals displayed hyperactivity behaviours and demyelination of neurones in the brain⁶⁹. Radiofrequency exposures in adolescent mice increased anxiety-like behaviours and altered neurotransmitter concentrations in the brain, but had no effect on depression-like behaviours⁷⁰. In rats radiofrequency signals increased anxiety-like behaviours, decreased learning and increased neurodegeneration in the hippocampus and cerebral cortex in the brain⁷¹. Other studies found no effect of radiofrequency signals on anxiety-like behaviors or emotional memory⁷², or motor skills or memory⁷³ in young or adolescent rats. A large number of animal studies have demonstrated impaired learning and memory in rats and mice^{6, 74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94, 71}. Some studies have found no effect on learning or memory in rats⁹⁵, or improvements⁹⁶.

Brain development:

- It should not be surprising that radiofrequency exposures have been associated with some behavioural, cognitive or neurodevelopmental problems in humans. Animal studies have shown that wireless signals can produce changes in the brain which are likely to affect brain development. For example, radiofrequency signals can increase the

⁶⁸ Taheri et al 2017 Dose-Response 2017:1-8. <http://journals.sagepub.com/doi/pdf/10.1177/1559325816688527>

⁶⁹ Kim et al 2017 Sci Rep 7: 41129. <https://www.ncbi.nlm.nih.gov/pubmed/28106136>

⁷⁰ Zhang et al 2017 Int J Environ Res Public Health 14(11):1344. <https://www.ncbi.nlm.nih.gov/pubmed/29113072>

⁷¹ Saikhedkar et al 2014 Neurol Res 36(12): 1072-1079. <https://www.ncbi.nlm.nih.gov/pubmed/24861496>

⁷² Petidant et al 2016 Bioelectromagnetics 37(5): 338-350. <https://www.ncbi.nlm.nih.gov/pubmed/27272062>

⁷³ Klose et al 2014 Radiat Res 182(4): 435-447. <https://www.ncbi.nlm.nih.gov/pubmed/25251701>

⁷⁴ Shahin et al 2015 Toxicol Sci. 148(2): 380-399. <http://www.ncbi.nlm.nih.gov/pubmed/26396154>

⁷⁵ Narayanan et al 2015 Metab Brain Dis. 30: 1193-1206. www.ncbi.nlm.nih.gov/pubmed/26033310

⁷⁶ Deshmukh et al 2015 Int J Toxicol. 34: 284-290. <http://www.ncbi.nlm.nih.gov/pubmed/25749756>

⁷⁷ Tang et al 2015 Brain Res. 1601: 92-101. <http://www.ncbi.nlm.nih.gov/pubmed/25598203>

⁷⁸ Zhang et al 2015 J. Radiat Res. 56: 261-268. <http://www.ncbi.nlm.nih.gov/pubmed/25359903>

⁷⁹ Razavinasab et al 2014 Toxicol Ind Health 32(6):968-979. <http://www.ncbi.nlm.nih.gov/pubmed/24604340>

⁸⁰ Maaroufi et al 2014 Behav Brain Res. 258: 80-89. <http://www.ncbi.nlm.nih.gov/pubmed/24144546>

⁸¹ Sharma et al 2014 Int J Radiat Biol. 90: 29-35. <http://www.ncbi.nlm.nih.gov/pubmed/23952535>

⁸² Hao et al 2014 Neurol Sci. 34: 157-164. <http://www.ncbi.nlm.nih.gov/pubmed/22362331>

⁸³ Deshmukh et al 2013 Ind J Biochem Biophys. 50: 114-119. <http://www.ncbi.nlm.nih.gov/pubmed/23720885>

⁸⁴ İkinici et al 2013 NeuroQuantology 11: 582-590. <http://www.neuroquantology.com/index.php/journal/article/view/699>

⁸⁵ Lu et al 2012 Physiol Behav. 106: 631-637. <http://www.ncbi.nlm.nih.gov/pubmed/22564535>

⁸⁶ Megha et al 2012 Ind J Exp Biol. 50: 889-896. <http://www.ncbi.nlm.nih.gov/pubmed/23986973>

⁸⁷ Hao et al 2012 Neural Regen Res. 7: 1488-1492. <http://www.ncbi.nlm.nih.gov/pubmed/25657684>

⁸⁸ Li et al 2012 Neural Regen Res. 7: 1248-1255. <http://www.ncbi.nlm.nih.gov/pubmed/25709623>

⁸⁹ Chaturvedi et al 2011 Prog in Electromag Res. B 29: 23-42. <http://www.jpier.org/PIERB/pierb29/02.11011205.pdf>

⁹⁰ Narayanan et al 2010 Ups J Med Sci. 115: 91-96. <http://www.ncbi.nlm.nih.gov/pubmed/20095879>

⁹¹ Fragopoulou et al 2010 Pathophysiol. 17: 179-187. <http://www.ncbi.nlm.nih.gov/pubmed/19954937>

⁹² Narayanan et al 2009 Clinics (Sao Paulo) 64: 231-234. <http://www.ncbi.nlm.nih.gov/pubmed/19330250>

⁹³ Nittby et al 2008 Bioelectromagnetics 29: 219-232. <http://www.ncbi.nlm.nih.gov/pubmed/18044737>

⁹⁴ Li et al 2008 J. Radiat Res. 49: 163-170. <http://www.ncbi.nlm.nih.gov/pubmed/18198477>

⁹⁵ Dubreuil et al 2002 Beh Brain Res 129(1-2): 203-210. <https://www.ncbi.nlm.nih.gov/pubmed/11809512>

⁹⁶ Kumlin et al 2007 Radiat Res 168(4): 471-479. <https://www.ncbi.nlm.nih.gov/pubmed/17903040>

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number of dead cells in the brain^{7,74,56,94,97,98,99,100,101,102,103,104,105,106}, decrease cell numbers in some brain regions^{7,8,75,98,100,106,107,108}, damage DNA in the brain^{16,109,110,111,112, 113, 114,115,116,117,118,119,120,121}, alter electrical properties of neurones^{6,79,87,122}, change communication between neurones^{6,74,75,79,82,87,88,122,123} and brain regions¹²⁴, change the genes or RNAs which are 'switched on' (expressed)^{125,126,127,128,129,130,131,132}, change concentrations of chemicals which communicate signals in the brain (neurotransmitters)^{132, 133, 134, 135, 136, 137}, alter enzymes^{132,135,138,139,140,34,100, 101}, and in some cases increase the

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- ⁹⁷ Zhang et al 2013 *Int J Radiat Biol.* 89: 976-984. <http://www.ncbi.nlm.nih.gov/pubmed/23786497>
- ⁹⁸ Maskey et al 2012 *Neurosci Lett.* 506: 292-296. <http://www.ncbi.nlm.nih.gov/pubmed/22133805>
- ⁹⁹ Köktürk et al 2013 *Exp Ther Med.* 6: 52-56. <http://www.ncbi.nlm.nih.gov/pubmed/23935717>
- ¹⁰⁰ Saikhedkar et al 2014 *Neurol Res.* 36: 1072-1079. <http://www.ncbi.nlm.nih.gov/pubmed/24861496>
- ¹⁰¹ Kesari et al 2014 *Cell Biochem Biophys.* 68: 347-358. <http://www.ncbi.nlm.nih.gov/pubmed/23949848>
- ¹⁰² Motawi et al 2014 *Cell Biochem Biophys.* 70: 845-855. <http://www.ncbi.nlm.nih.gov/pubmed/24801773>
- ¹⁰³ Yilmaz et al 2014 *Eur Rev Med Pharmacol Sci.* 18: 992-1000. <http://www.ncbi.nlm.nih.gov/pubmed/24763879>
- ¹⁰⁴ Salford et al 2000 *Environ Health Perspect.* 111: 881-883. <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1241519/pdf/ehp0111-000881.pdf>
- ¹⁰⁵ Zhu et al 2000 *Prog Electromagn Res.* 82: 287-298. <http://www.jpier.org/PIER/pier82/19.08022813.pdf>
- ¹⁰⁶ Bas et al 2009 *Brain Research* 1265: 178-185. <http://www.ncbi.nlm.nih.gov/pubmed/19230827>
- ¹⁰⁷ Rağbetli et al 2010 *Int J Radiat Biol.* 86: 548-554. <http://www.ncbi.nlm.nih.gov/pubmed/20545571>
- ¹⁰⁸ Sonmez et al 2010 *Brain Res.* 1356: 95-101 <http://www.ncbi.nlm.nih.gov/pubmed/20691167>
- ¹⁰⁹ Megha et al 2015 *Neurotoxicology* 51: 158-165. <http://www.ncbi.nlm.nih.gov/pubmed/26511840>
- ¹¹⁰ Deshmukh et al 2015 *Int J Toxicol.* 34: 284-290 <http://www.ncbi.nlm.nih.gov/pubmed/25749756>
- ¹¹¹ Kesari et al 2014 *Cell Biochem Biophys.* 68: 347-358 <http://www.ncbi.nlm.nih.gov/pubmed/23949848>
- ¹¹² Gürler et al 2014 *Int J Radiat Biol.* 90: 892-896 <http://www.ncbi.nlm.nih.gov/pubmed/24844368>
- ¹¹³ Shahin et al 2013 *Appl Biochem Biotechnol.* 169: 1727-1751 <http://www.ncbi.nlm.nih.gov/pubmed/23334843>
- ¹¹⁴ Deshmukh et al 2013 *Toxicol Int.* 20: 19-24 <http://www.ncbi.nlm.nih.gov/pubmed/23833433>
- ¹¹⁵ Karaca et al 2012 *J Neurooncol.* 106: 53-58 <http://www.ncbi.nlm.nih.gov/pubmed/21732071>
- ¹¹⁶ Chaturvedi et al 2011 *Prog in Electromagn Res.* 29: 23-42 <http://www.jpier.org/PIERB/pierb29/02.11011205.pdf>
- ¹¹⁷ Kesari et al 2010 *Int J Radiat Biol.* 86: 334-342 <http://www.ncbi.nlm.nih.gov/pubmed/20353343>
- ¹¹⁸ Güler et al 2010 *Gen Physiol Biophys.* 29: 59-66 <http://www.ncbi.nlm.nih.gov/pubmed/20371881>
- ¹¹⁹ Kesari and Behari 2009 *Appl Biochem Biotechnol.* 158: 126-139 <http://www.ncbi.nlm.nih.gov/pubmed/19089649>
- ¹²⁰ Paulraj and Behari 2006 *Mutat Res.* 596: 76-80 <http://www.ncbi.nlm.nih.gov/pubmed/16458332>
- ¹²¹ Lai and Singh 1996 *Int J Radiat Biol.* 69: 513-521 <http://www.ncbi.nlm.nih.gov/pubmed/8627134>
- ¹²² Haghani et al 2013 *Neurosci.* 250: 588-598. <http://www.ncbi.nlm.nih.gov/pubmed/23906636>
- ¹²³ Xu et al 2006 *Neurosci Lett.* 398: 253-257. <http://www.ncbi.nlm.nih.gov/pubmed/16443327>
- ¹²⁴ Vecchio et al 2007 *Eur J Neurosci.* 25: 1908- 1913. <http://www.ncbi.nlm.nih.gov/pubmed/17432975>
- ¹²⁵ Dasdag et al 2015 *Int J Radiat Biol.* 91: 555-561. <http://www.ncbi.nlm.nih.gov/pubmed/25775055>
- ¹²⁶ Dasdag et al 2015 *Int J Radiat Biol.* 91: 306-311. <http://www.ncbi.nlm.nih.gov/pubmed/25529971>
- ¹²⁷ Lu et al 2014 *PLoS One* 9: e108318. <http://www.ncbi.nlm.nih.gov/pubmed/25275372>
- ¹²⁸ Jorge-Mora et al 2011 *Neurochem Res.* 36: 2322-2332. <http://www.ncbi.nlm.nih.gov/pubmed/21818659>
- ¹²⁹ Karaca et al 2012 *J Neurooncol.* 106: 53-58. <http://www.ncbi.nlm.nih.gov/pubmed/21732071>
- ¹³⁰ Zhao et al 2007 *Toxicology* 235: 167-175. <http://www.ncbi.nlm.nih.gov/pubmed/17449163>
- ¹³¹ Fragopoulou et al 2012 *Electromagn Biol Med.* 31: 250-274 <http://www.ncbi.nlm.nih.gov/pubmed/22263702>
- ¹³² Megha et al 2015 *Cell Biochem Biophys.* 73(1): 93-100 <http://www.ncbi.nlm.nih.gov/pubmed/25672490>
- ¹³³ Aboul Ezz et al 2013 *Eur Rev Med Pharmacol Sci.* 17: 1782-1788. <http://www.ncbi.nlm.nih.gov/pubmed/23852905>
- ¹³⁴ Noor et al 2011 *Eur Rev Med Pharmacol Sci.* 15: 729-742. <http://www.ncbi.nlm.nih.gov/pubmed/21780540>
- ¹³⁵ Jing et al 2012 *Electromagn Biol Med.* 31: 57-66. <http://www.ncbi.nlm.nih.gov/pubmed/22268709>
- ¹³⁶ Zhao et al 2012 *Biomed Environ Sci.* 25: 182-188. <http://www.ncbi.nlm.nih.gov/pubmed/22998825>
- ¹³⁷ Khadrawy et al 2009 *Romanian J Biophys.* 19: 295-305. <http://www.rjb.ro/articles/260/yakha.pdf>
- ¹³⁸ Paulraj and Behari 2012 *Cell Biochem Biophys.* 63: 97-102. <http://www.ncbi.nlm.nih.gov/pubmed/22426826>
- ¹³⁹ Paulraj and Behari 2012 *Electromagn Biol Med.* 31: 233-242. <http://www.ncbi.nlm.nih.gov/pubmed/22897404>
- ¹⁴⁰ Paulraj and Behari 2006 *Electromagn Biol Med.* 25: 61-70. <http://www.ncbi.nlm.nih.gov/pubmed/16595335>

Written evidence submitted by Dr Sarah Starkey (EYI0062)

permeability of the blood-brain barrier^{77, 141, 142, 143, 144, 145, 146}, which can enable normally excluded toxic molecules to enter the brain. Mobile phone-like signals can decrease the ability of human haemoglobin in the blood to carry oxygen¹⁴⁷, which may compromise brain function or development. Decreased neurite outgrowth of embryonic neural stem cells has been reported in mice. REMBRANDT¹⁴⁸ (Radiofrequency ElectroMagnetic fields exposure and BRAiN Development; 2014-2017) is a project which aims to assess the association between radiofrequency exposures and brain development during childhood and adolescence.

- Radiofrequency exposures of babies and young children have particularly increased over the past 7 years or so, with the introduction of iPads, parents giving children smart phones, body-worn devices aimed at babies or children, introduction of smart TVs, etc. Further increasing wireless exposures with 5G, the internet of things, smart meters, driverless cars etc may result in more neurodevelopmental/neurological problems being identified in children or adults.

Fertility:

- Female fertility (animal studies). Female rats exposed to a mobile phone signal for 15 minutes a day for 15 days had significantly fewer ovarian follicles (these mature to produce oocytes/eggs) than rats which were not exposed¹⁴⁹. Pregnant rats exposed to mobile phone-like signals for two 15 minute sessions a day¹⁵⁰ or for 1 hour per day¹⁵¹, had female offspring with significantly fewer ovarian follicles than the unexposed offspring. Mobile phone signals caused single- and double-stranded DNA breaks in rat ovarian granulosa cells¹⁵². Granulosa cells surround the egg in an ovarian follicle and produce hormones and growth factors.
- Male fertility (humans and animals). There is strong evidence of damage to male reproductive health from wireless signals, including from Wi-Fi¹⁸⁵. Effects include damage to sperm DNA, decreased sperm motility, decreased sperm viability, abnormal sperm morphology (shape), decreased diameter of the seminiferous tubules, damage to seminiferous tubule basal membranes, cell death, changes in male hormone concentrations and increased oxidative stress. If the effects on seminiferous tubules or

¹⁴¹ Tang et al 2015 Brain Res. 1601: 92-101. <http://www.ncbi.nlm.nih.gov/pubmed/25598203>

¹⁴² Sirav and Seyhan 2016 J Chem Neuroanat. 75(PtB): 123-127. <http://www.ncbi.nlm.nih.gov/pubmed/26723545>

¹⁴³ Wang et al 2014 Mol Neurobiol. 52: 478-491. <http://www.ncbi.nlm.nih.gov/pubmed/25195697>

¹⁴⁴ Sirav and Seyhan 2011 Electromagn Biol Med. 30: 253-260. <http://www.ncbi.nlm.nih.gov/pubmed/22047463>

¹⁴⁵ Nittby et al 2009 Pathophysiology 16: 103-112. <http://www.ncbi.nlm.nih.gov/pubmed/19345073>

¹⁴⁶ Eberhardt et al 2008 Electromagn Biol Med. 27: 215-229. <http://www.ncbi.nlm.nih.gov/pubmed/18821198>

¹⁴⁷ Mousavy et al 2009 Int J Biol Macromol. 44: 278-285. <http://www.ncbi.nlm.nih.gov/pubmed/19263507>

¹⁴⁸ REMBRANDT https://www.isglobal.org/en/project/-/asset_publisher/qf6QOKuKkIC3/content/radiofrequency-electromagnetic-fields-exposure-and-brain-development-from-exposure-assessment-to-dose-response-assessment-rembrandt

¹⁴⁹ Bakacak et al 2015 Kaohsiung J Med Sci. 31: 287-292. <http://www.ncbi.nlm.nih.gov/pubmed/26043407>

¹⁵⁰ Gul et al 2009 Arch Gynecol Obstet. 280: 729-733. <http://www.ncbi.nlm.nih.gov/pubmed/19241083>

¹⁵¹ Turedi et al 2016 Int J Radiat Biol 92(6): 329-337. <https://www.ncbi.nlm.nih.gov/pubmed/27007703>

¹⁵² Diem et al 2005 Mutat Res. 583: 178-183. <http://www.ncbi.nlm.nih.gov/pubmed/15869902>

Written evidence submitted by Dr Sarah Starkey (EYI0062)

cell death occurs in children or young people, it may damage their future fertility. Wi-Fi/2.45 GHz signals damaged DNA in human sperm¹⁵³ and rat testes^{154, 155}. In rats, Wi-Fi (average of only 0.0024 W/kg in 1g tissue, compared to iPad maximum exposure of 1.19 W/kg), significantly damaged male reproductive organs: decreased weight of the epididymis and seminal vesicles and the diameter of the seminiferous tubules¹⁵⁶. In other studies Wi-Fi/2.45GHz signals decreased the weight of seminal vesicles¹⁵⁷, increased cell death¹⁵⁷ and degeneration of the seminiferous tubules¹⁵⁸, decreased testosterone¹⁵⁸, increased oxidative stress¹⁵⁹ and decreased human sperm motility (60 cm away from a Wi-Fi-enabled laptop¹⁶⁰).

Cancers:

- The WHO IARC classified radiofrequency signals as a possible human carcinogen in 2011, based on increased risks of gliomas or acoustic neuromas being associated with mobile or cordless phone use in humans, studies in animals and other data, such as damage to DNA¹⁸³. Since 2011, further reports have strengthened the evidence^{161,162}, including for increased risks for gliomas and meningiomas associated with mobile phone use¹⁶³ (with the equivalent of 15 minutes or more mobile phone use per day over 10 years, in adults). The US National Toxicology Programme has found that 2 years of exposure to mobile phone-like signals in rats increased gliomas in the brain, schwannomas in the heart, and damaged DNA¹⁶⁴. Radiofrequency signals can also inhibit the repair of damaged DNA^{165,166}. Possible risks are not just for brain or head tumours; breast cancers have been identified directly underneath where some women carried a mobile phone in their bra¹⁶⁷.
- Children are at increased risk compared to adults (they absorb radiation more easily, have greater cell division and their bodies are still developing¹⁸³), so protecting them from possible carcinogenic effects of wireless signals is important. See cancer evidence in children and young people (above). Many children use wireless devices for far longer than the 15 minutes or more a day that was associated with increased cancer risk in adults. We protect children from tobacco and passive smoking, from purchasing alcohol

¹⁵³ Avendaño et al 2012 *Fertil Steril*. 97: 39-45. <http://www.ncbi.nlm.nih.gov/pubmed/22112647>

¹⁵⁴ Meena et al 2014 *Electromagn Biol Med*. 33: 81-91. <http://www.ncbi.nlm.nih.gov/pubmed/23676079>

¹⁵⁵ Akdag et al 2016 *J Chem Neuroanat*. 75(PtB): 116-122. <http://www.ncbi.nlm.nih.gov/pubmed/26775760>

¹⁵⁶ Dasdag et al 2015 *Electromagn Biol Med*. 34: 37-42. <http://www.ncbi.nlm.nih.gov/pubmed/24460421>

¹⁵⁷ Shokri et al 2015 *Cell J*. 17: 322-331. <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4503846/pdf/Cell-J-17-322.pdf>

¹⁵⁸ Shahin et al 2014 *Free Radic Res*. 48: 511-525. <https://www.ncbi.nlm.nih.gov/pubmed/24490664>

¹⁵⁹ Oksay et al 2014 *Andrologia* 46: 65-72. <http://www.ncbi.nlm.nih.gov/pubmed/23145464>

¹⁶⁰ Oni et al 2011 *Int J Rec Res Appl Sci*. 9: 292-294. http://arpapress.com/Volumes/Vol9Issue2/IJRRAS_9_2_13.pdf

¹⁶¹ Hardell et al 2013 *Int J Oncol*. 43: 1036-1044. <http://www.ncbi.nlm.nih.gov/pubmed/23877578>

¹⁶² Hardell et al 2013b *Int J Oncol*. 43: 1833-1845. <http://www.ncbi.nlm.nih.gov/pubmed/24064953>

¹⁶³ Coureau et al 2014 *Occup Environ Med*. 71: 514-522. <http://www.ncbi.nlm.nih.gov/pubmed/24816517>

¹⁶⁴ US National Toxicology Programme on mobile phones <https://ntp.niehs.nih.gov/results/areas/cellphones/>; <https://www.biorxiv.org/content/early/2016/06/23/055699>

¹⁶⁵ Belyaev et al 2009 *Bioelectromagnetics* 30: 129-141. <http://www.ncbi.nlm.nih.gov/pubmed/18839414>

¹⁶⁶ Markova et al 2010 *Environ Health Perspect*. 118: 394-399. <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2854769/>

¹⁶⁷ West et al 2013 *Case Rep Med*. ID 354682. <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3789302/>

Written evidence submitted by Dr Sarah Starkey (EYI0062)

and in my view we ought to be protecting children from using wireless radiofrequency-emitting devices. Wi-Fi access points and Wi-Fi-enabled devices may also increase the risk of cancer, as Wi-Fi signals can damage DNA and increase oxidative stress.

Examples of gaps in the evidence base:

- Animal studies have repeatedly shown that wireless signals can decrease the number of ovarian follicles in female rats (above). But to my knowledge there is no research in humans investigating whether girls who use wireless devices, live/play/work in wireless environments, were exposed to signals *in utero* or carry mobile phones in their trouser pockets, have reduced numbers of ovarian follicles. Will girls who regularly use a wireless-enabled tablet computer positioned on their lap still be able to have children, will they have reduced fertility or will there be no effect? This urgently needs investigating.
- Radiofrequency exposures in animals can lead to cell death in a range of organs (above). There is limited evidence of cell death in human cells^{168,169,170,171,172} but we need to better understand whether radiofrequency signals are inducing cell death in humans. Cell death in the brain may contribute to dementias.
- Animal and human studies have identified increases in behavioural problems in children/offspring/young people, plus cognitive changes (above), but more research is needed to investigate the contribution of radiofrequency signals to the behavioural problems, mental health and brain developmental issues experienced in society today.
- Brain tumours and acoustic neuromas have been associated with mobile or cordless phone use in adults (above). A study of mobile phone use in children is ongoing²⁰¹, but we also need to further investigate whether signals from Wi-Fi transmitters, phone mast antennas, cordless phones, smart meters, driverless cars etc can increase the risk of tumours, damage DNA, decrease DNA repair, increase oxidative stress or increase cancer cell proliferation.
- 15 years or more of mobile phone use was associated with non-significant increased risk of leukaemia in adults¹⁷³. This may reach significance if the number of individuals included in a study or the duration of mobile phone use were increased. Studies could also investigate whether using Wi-Fi-enabled devices, cordless phones or living near smart meters etc might increase the risk of developing leukaemia.
- Some people have reported experiencing headaches¹⁷⁴, dizziness, tachycardia or irregular heart rates¹⁷⁵ etc in wireless environments, but current research into symptoms has limitations and measurements were often subjective. There is a need for

¹⁶⁸ Cig and Naziroglu 2015 Biochim Biophys Acta 1848: 2756-2765. <https://www.ncbi.nlm.nih.gov/pubmed/20940717>

¹⁶⁹ Al-Serori et al 2017 Toxicol In vivo 40: 264-271. <https://www.ncbi.nlm.nih.gov/pubmed/28126644>

¹⁷⁰ Lu et al 2012 Oxid Med Cell Longev 2012: 740280. <https://www.ncbi.nlm.nih.gov/pubmed/22778799>

¹⁷¹ Esmekaya et al 2011 Sci Total Environ 410-411: 59-64. <https://www.ncbi.nlm.nih.gov/pubmed/22014767>

¹⁷² Esmekaya et al 2013 Cell Biochem Biophys 67(3): 1371-1378. <https://www.ncbi.nlm.nih.gov/pubmed/23723005>

¹⁷³ Cooke et al 2010 Br J Cancer 103(11): 1729-1735. <https://www.ncbi.nlm.nih.gov/pubmed/20940717>

¹⁷⁴ Wang et al 2017 Scientific Reports 7:12595. <https://www.nature.com/articles/s41598-017-12802-9>

¹⁷⁵ Havas et al 2010 European J Oncol Vol. 5:273-298. http://www.icems.eu/papers/ramazzini_library5_part2.pdf

Written evidence submitted by Dr Sarah Starkey (EYI0062)

more studies with improved methodologies and non-subjective measurements carried out under double-blind conditions.

In summary:

A limited number of studies in humans, plus substantial evidence from animal studies, point to wireless radiofrequency signals being able to cause physical damage during development (prenatally, postnatally, in childhood and adolescence), as well as in adulthood, which may result in serious negative health, wellbeing or developmental outcomes. That effects are seen in animal studies indicates that the radiofrequency signals themselves can have adverse effects, and it is not just children or young people accessing social media/internet through mobile devices, or time spent looking at screens. Exposures to wireless radiofrequency signals need to be considered when looking at developmental, health, behavioural, wellbeing and mental health issues in children and young people. If children are to be protected from harm, or possible harm, restrictions and regulations need to be introduced.

2. Interventions

There are no early-years (or later-years) interventions in the UK to protect babies, children or young people from adverse effects of radiofrequency signals that I am aware of, other than the following two recommendations. Public Health England (PHE) have advised against the excessive use of mobile phones by children ('excessive' is a subjective and therefore useless term) and the Chief Medical Officers have advised that children under the age of 16 use mobile phones for essential purposes only. But both of these are completely ineffective because almost no one knows about them. They have not stopped parents or schools giving children mobile phones or asking them to use them in lessons. They have also not stopped families or schools giving children tablet computers, which have almost identical maximum radiofrequency exposures as mobile phones (Specific Absorption Rate, SAR; e.g. maximum SAR for the iPhone7 is 1.19 W/kg in 1g tissue¹⁷⁶, iPad Air maximum SAR is 1.19 W/kg in 1 g tissue¹⁷⁷). Some schools demand that pupils bring their own wireless computer to school to use throughout the school day, as well as for homework. Not only are there no interventions to protect foetuses, babies, children or young people, there is currently no choice for children not to be exposed to the signals. Parents currently wanting to protect their children from possible physical harm from radiofrequency signals have no choice, unless they gave up their child's human right to an education at school.

However, the French Government has banned Wi-Fi in nurseries and places of care for children under the age of three and has said that Wi-Fi must be switched off when not being used for educational purposes in all primary/middle schools¹⁷⁸. The Government of Cyprus has made videos to warn pregnant women to reduce their exposures to wireless signals and

¹⁷⁶ iPhone 7 SAR <https://www.apple.com/legal/rfexposure/iphone9,3/en/>

¹⁷⁷ iPad Air SAR <https://www.apple.com/legal/rfexposure/ipad4,1/en/>

¹⁷⁸ France, Assemblée Nationale <http://www.assemblee-nationale.fr/14/ta/ta0468.asp>

Written evidence submitted by Dr Sarah Starkey (EYI0062)

to ask parents and schools to restrict exposures of children^{179,180}. The Cyprus National Committee on Environment and Children's Health (NCECH), Cyprus Medical Association and Austrian Medical Associations have recommended that wireless networks should be prohibited in schools, particularly in preschools, kindergartens and elementary schools, where wired connections should be adopted¹⁸¹. They stated, 'All children and in particular those with existing neurological or behavioural problems as well as those with chronic diseases must be provided with wired (not wireless) learning, living and sleeping environments.'

The UK ignored the call from the Council of Europe in 2011 to prefer wired connections (not Wi-Fi) in schools and to put in place information and awareness-raising campaigns on the risks of potentially harmful long-term biological effects, especially "targeting children, teenagers and young people of reproductive age"¹⁸². The UK has taken no action to protect the public following the classification by the World Health Organization (WHO) International Agency for Research on Cancer (IARC) of all radiofrequency signals as a possible human carcinogen¹⁸³. Indeed, PHE is withholding appropriate specialist advice by having no mention of the IARC classification of radiofrequency signals on its current website. The UK has not yet listened to the concerns of scientists from around the world who are calling for action to better protect the public from radiofrequency radiation¹⁸⁴.

In the UK it is now commonplace for parents, carers, workers in early years settings or schools, to give babies, toddlers, children or young people wireless tablet computers, smart phones or body-worn devices to play with/use and to expose them to signals from Wi-Fi access points, baby monitors or similar radiofrequency-emitting transmitters. Pregnant women use wireless devices, and live, work and travel in wireless environments, exposing the developing foetuses to the radiofrequency signals. New technologies, including 5G, are being developed, promoted (and in some cases supported with tax payers' money) which will dramatically increase the radiofrequency exposures of babies, children and young people. There can be no informed consent from babies, children or young people to the damaging effects of wireless signals, they are dependent upon adults to safeguard them from harm. Interventions are needed to protect children from the harmful effects of wireless radiofrequency signals.

3. Whether local and national government policies for early-years intervention reflect the evidence-base, and challenges involved in disseminating, accessing and using the latest evidence, as well as the opportunities for intervention suggested by the evidence but not currently being implemented.

¹⁷⁹ Cyprus Government video for pregnant women https://www.youtube.com/watch?v=k_HVMnAXnLw

¹⁸⁰ Cyprus Government video for protecting children <https://www.youtube.com/watch?v=H43IKNjTvRM>

¹⁸¹ Nicosia Declaration 2017 http://www.cyprus-child-environment.org/images/media/assetfile/HMA%20S_EN_17.pdf

¹⁸² Council of Europe 2011 <http://assembly.coe.int/nw/xml/News/News-View-EN.asp?newsid=3462&lang=2>

¹⁸³ IARC Monograph 102 <http://monographs.iarc.fr/ENG/Monographs/vol102/mono102.pdf>

¹⁸⁴ EMF Scientist Appeal <https://www.emfscientist.org/>

Written evidence submitted by Dr Sarah Starkey (EYI0062)

Current local and national government policies do not reflect the evidence-base.

Current national government advice on the safety of radiofrequency signals comes from PHE and is based on an assessment of the evidence by the Advisory Group on Non-Ionising Radiation (AGNIR) in 2012. Local and national government policies and decisions are based on PHE advice. The AGNIR 2012 report has been shown to be inaccurate, with evidence omitted, conclusions which did not reflect the evidence available, incorrect statements and conflicts of interest¹⁸⁵. AGNIR included members from PHE and ICNIRP¹⁸⁵. This means that members of PHE as well as members of ICNIRP, who set the international exposure guidelines, have provided inaccurate, incorrect and misleading scientific information. The ICNIRP guidelines no longer reflect the scientific evidence and are no longer protective of human health. We urgently need biologically-based exposure guidelines to protect the population.

AGNIR was closed down in May 2017¹⁸⁶, but the advice based on factually incorrect information remains on the PHE website and continues to be given by PHE to Members of Parliament (MPs), decision makers and members of the public.

The scientists responsible for the inaccurate AGNIR report who are employed by PHE or the Department of Health (DH) continue in their roles and still advise on the safety of wireless signals. In my view, the evidence points to these employees having broken their employment Code of Conduct¹⁸⁷ and they should be removed from their roles.

We all have a duty to protect children from harm and to speak out when harm is taking place, or where there is the possibility of harm¹⁸⁸. Scientists with a responsibility to advise and protect the public also have a duty to act with integrity. In my view this has not happened with advice from PHE, AGNIR or ICNIRP on the safety of radiofrequency signals.

When PHE provide factually incorrect information about the safety of wireless signals it is extremely difficult for local authorities, schools, decision makers and parents to access evidence-based, accurate information and almost impossible for parents to challenge involuntary exposures of their children and to protect them from harm. So many policy decisions by UK Governments, local authorities, by schools, businesses etc have been made based on the factually incorrect information provided by PHE and AGNIR (regarding the safety of radiofrequency signals). Accurate evidence on the safety of wireless technologies is not currently being used effectively in policy-making. In my view the incorrect conclusions, conclusions omitted and inaccurate statements were not accidental mistakes; evidence was covered-up. Perhaps the misinformation was to protect ICNIRP guidelines (by ICNIRP members in AGNIR), or to protect the current and future proliferation of wireless

¹⁸⁵ Starkey 2017 Rev Environ Health 31(4): 493-503.

<https://www.degruyter.com/downloadpdf/j/reveh.2016.31.issue-4/reveh-2016-0060/reveh-2016-0060.pdf>

¹⁸⁶ AGNIR <https://www.gov.uk/government/groups/advisory-group-on-non-ionising-radiation-agnir>

¹⁸⁷ PHE Code of Conduct

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/528892/Code_of_conduct_for_PHE_staff.pdf

¹⁸⁸ Safeguarding children and young people <https://www.gov.uk/government/publications/safeguarding-children-and-young-people/safeguarding-children-and-young-people>

Written evidence submitted by Dr Sarah Starkey (EYI0062)

technologies, or because once decisions have been made based on misinformation, it is very difficult to admit to the evidence.

Challenges involved in disseminating, accessing and using the latest evidence:

Accurate information about the safety of wireless technologies cannot be disseminated or accessed whilst the scientists responsible in the DH, PHE or its advisory bodies produce, promote and base advice on inaccurate and factually incorrect information. Conflicts of interest associated with membership of ICNIRP need to be addressed. Current advice is not evidence based and the public have been let down by misinformation and a lack of precautionary actions.

The public or decision makers cannot access evidence when PHE withhold it from their website. The current PHE website has no mention of the IARC classification of radiofrequency signals as a possible human carcinogen. It does not mention cordless phones, even though these have been associated with increased risks of cancer^{189,190,183}. Interventions to protect children from wireless technologies are lacking. PHE have stated that there is no reason why schools and others should not use Wi-Fi¹⁹¹, despite a large number of studies describing adverse effects of Wi-Fi/2.45 GHz signals e.g. 21,29,31,34,51,68,109,110,112,114,116,117,120,125,128,140,154,156,157,158,159,160,168,175. Whilst there are also studies which describe no effects of Wi-Fi e.g. 39,40,192,193,194, PHE have not yet admitted that evidence exists for harmful effects from Wi-Fi signals, thus misleading people who rely upon them for information.

Opportunities for interventions:

If we want to safeguard babies, children and young people and protect them from possible physical harm from wireless radiofrequency signals, we need to introduce restrictions. We protect children from tobacco smoke, alcohol consumption and restrict the use of some medicines. We can also take action to protect children from the harmful effects of wireless devices, based on evidence. We could:

- ban babies, children and young people from using mobile/smart/cordless phones, wireless tablet computers, wireless watches and wireless body-worn devices.
- remove Wi-Fi transmitters from pre-schools, nurseries, all schools, children's wards in hospitals and on school transport.
- remove phone mast antennas from or near to places where children spend considerable amounts of time (e.g. nurseries, schools, playgrounds).
- include protecting children from harm from wireless devices in the PHSE curriculum in schools.

¹⁸⁹ Hardell and Carlberg 2015 Pathophysiology 22(1): 1-13. <https://www.ncbi.nlm.nih.gov/pubmed/25466607>

¹⁹⁰ Hardell and Carlberg 2009 Int J Oncol 35(1): 5 – 17. <https://www.ncbi.nlm.nih.gov/pubmed/19513546>

¹⁹¹ PHE Wi-Fi <https://www.gov.uk/government/publications/wireless-networks-wi-fi-radio-waves-and-health>

¹⁹² Sambucci et al 2010 Radiat Res 174(6): 732-740. <https://www.ncbi.nlm.nih.gov/pubmed/21128797>

¹⁹³ Koyana et al 2015 J Radiat Res 56(1): 30-36. <https://www.ncbi.nlm.nih.gov/pubmed/25194051>

¹⁹⁴ Ono et al 2004 Tohoku J Exp Med 202(2): 93-103. <https://www.ncbi.nlm.nih.gov/pubmed/14998303>

Written evidence submitted by Dr Sarah Starkey (EYI0062)

- introduce educational campaigns advising pregnant women to reduce wireless exposures of their unborn child, as occurs in Cyprus (above). Wi-Fi could be removed from antenatal clinics, maternity wards and doctors' surgeries. Pregnant women ought to have a choice to work in non-wireless work environments and to have the option of using wired phones, computers and other equipment at work and in the home. Where there are health and safety risks for pregnant women in the workplace, the employer should take reasonable steps to remove them¹⁹⁵.
 - introduce the requirement for pre-market safety testing of new technologies, as occurs for new medicines. Radiation absorbed by the body (or other technologies introduced into the body) requires safety testing just as much as potential medicines which enter the body.
 - correct decisions which have been made based on inaccurate information from PHE and AGNIR. For example, had schools been accurately advised and warned that evidence of possible serious harm to pupils and employees existed, they would not have introduced Wi-Fi and made pupils use wireless devices; their introduction was not compatible with school child protection policies. Many parents would not have bought a smart phone or tablet computer for their young children had they realised that it may damage their fertility, brain development or increase their risk of cancer.
 - allow all children to have an education without being at risk of harm from radiofrequency signals, from pre-schools and nurseries up to and including Colleges and Universities.
 - help people to be able to make informed decisions for themselves and their dependents by correcting the inaccurate information provided to the public by AGNIR and PHE. The misinformation needs correcting.
- 4. Support and oversight of research into adverse childhood experiences and relevant interventions, including how research priorities are identified and funded, and the extent to which current interventions are reviewed and contribute to the evidence-base.**
- Part of AGNIR's role was to recommend research priorities. Interventions are the responsibility of PHE and the DH. But both AGNIR and PHE provided inaccurate information about the effects of radiofrequency signals and concluded that there were no adverse effects below current ICNIRP guidelines. For years Members of Parliament and Local Authorities have been repeating PHE advice, unaware that it was based on an inaccurate report¹⁸⁵. There was either no oversight of the AGNIR research report or it was ineffective at picking up the inaccurate and misleading reporting. Having processes in place to hold PHE to account and to be able to challenge inaccurate information would help to prevent this happening in the future.
 - Given the widespread use of wireless devices and compulsory exposure of the whole population to radiofrequency signals, there is surprisingly little independent UK funding

¹⁹⁵ Pregnant employees' rights <https://www.gov.uk/working-when-pregnant-your-rights>

Written evidence submitted by Dr Sarah Starkey (EYI0062)

of research into possible health effects. The Mobile Telecommunications and Health Research Programme (MTHR) plus its follow-on, the Research Initiative on Health and Mobile Telecommunications (RIHMT), have commissioned research funded by the UK Health Departments, Medical Research Council, Health and Safety Executives, Vodafone, Arqiva, Carphone Warehouse, BT, 3UK, Everything Everywhere EE (Orange and T-Mobile) and Telefonica Europe Plc (O2)¹⁹⁶. The problem with research being partially funded and selected by the wireless industry is that studies may be limited to certain questions and designs and there is the possibility of funding bias in the reporting of the results. Interestingly, most MTHR-funded research concluded that there were no effects of radiofrequency signals, with the exception of using a phone whilst driving¹⁹⁷. RIHMT is currently funding a study into possible cognitive effects of mobile phone use in adolescents (SCAMP¹⁹⁸; ages 11-14).

- This is a field where there is a lot of control. ICNIRP, a private group who set the international radiofrequency exposure guidelines, control the international WHO EMF (Electromagnetic fields) project¹⁹⁹. ICNIRP members were part of AGNIR, including the AGNIR Chair¹⁸⁵, and are part of PHE and the DH¹⁸⁵. An ICNIRP member is now responsible for keeping COMARE²⁰⁰ up-to-date in this field (COMARE are now responsible for assessing the safety of radiofrequency signals in the UK). PHE/DH and the wireless industry appear to control almost all of the research selection and funding in this field in the UK^{196,197}. Even when funding is from the EU, as is the case for the MOBI-Kids²⁰¹ study (risk of brain cancer from exposure to radiofrequency fields in childhood and adolescence) and the GERoNiMO²⁰² study (risks of cancer, neurodegenerative diseases, behaviour, reproductive outcomes and aging), the UK involvement is PHE. Ideally, scientists would be free to investigate possible harmful effects without being selected/overseen by industry and the Government, and would be free to publish all results even when they found harmful effects. Some scientists working in this field have lost their funding when they published adverse effects²⁰³. Losing your funding because you publish inconvenient results is not science, it is excessive control and manipulation. We need high quality independent science and for scientists to be protected when they publish inconvenient results.

¹⁹⁶ RIHMT <http://media.dh.gov.uk/network/221/files/2012/11/Research-Initiative-on-Health-and-Mobile-Telecommunications-%E2%80%93-ITT.pdf>

¹⁹⁷ MTHR

http://webarchive.nationalarchives.gov.uk/20110316163851/http://www.mthr.org.uk/research_projects/funded_projects.htm

¹⁹⁸ SCAMP <https://www.scampstudy.org/>

¹⁹⁹ <https://www.degruyter.com/downloadpdf/j/reveh.2016.31.issue-4/reveh-2016-0060/reveh-2016-0060.pdf>; <https://www.spandidos-publications.com/10.3892/ijo.2017.4046>; https://www.emfacts.com/download/who_conflict.pdf

²⁰⁰ COMARE https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/612316/COMARE_work_programme_-_April_2017_March_2018.pdf

²⁰¹ MOBI-Kids Study http://cordis.europa.eu/result/rcn/193614_en.html

²⁰² GERoNiMO Study 2014-2018 https://www.isglobal.org/en/project/-/asset_publisher/6f6QOKuKkIC3/content/geronimo-generalized-emf-research-using-novel-methods-an-integrated-approach-from-research-to-risk-assessment-and-support-to-risk-management

²⁰³ <https://www.gq.com/story/warning-cell-phone-radiation>; <https://www.emfacts.com/2005/03/35/>

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- The good practice of checking the effects of new technologies as part of product design, or before they are made available to the public, or introduced into research environments, has far too often been lacking. For example, wireless EEG monitors emit radiofrequency radiation. Radiofrequency signals can themselves alter brain EEG signals. The radiofrequency signals from wireless heart rate monitors may be inducing tachycardia or irregular heart rates in some people¹⁷⁵. Laboratories and animal houses within the UK have Wi-Fi, which may be altering the measurements being made in experimental studies. The rush to market or to install technologies may lead to poorly designed products, flawed science and risks to public health.

5. Mechanisms for bringing together the collection, communication, application and review of evidence to ensure interventions are evidence-based.

- We need an independent (of industry, Government, ICNIRP and AGNIR) and honest expert body to regularly assess the evidence. For inconvenient evidence, as in this case, it is especially important to have experts with integrity and no conflicts of interest. Up to now the body collecting the evidence has been AGNIR. But AGNIR has provided inaccurate and incorrect information and was closed in May¹⁸⁶. The role has now fallen to COMARE (the Committee on Medical Aspects of Radiation in the Environment), under the guidance of a former AGNIR member (COMARE Secretariat). However, many COMARE members specialise in ionising radiation; the Secretariat has provided inaccurate information in the past and is part of ICNIRP (a Conflict of Interest). I would recommend that a new group is formed. The International Agency for Research on Cancer (IARC) bring together scientists who have published studies relevant to the field being discussed, to assess the evidence. Bringing together a wide range of scientists who have published papers on the effects of radiofrequency radiation might help to keep assessments evidence based and accurate, provided that scientists who have reported adverse effects are well represented in the group and are not excluded. It might help to include an expert in child safeguarding and an expert in research integrity, to ensure that safeguarding children is considered and that conclusions and recommendations reflect the evidence.
- Current advice from the Chief Medical Officers about mobile phone use for under 16s has been ignored. It would be helpful if advisers making recommendations stand up for their own advice and publicise it widely. Advice on public health is there to keep people safe and well and not to protect the Government by having warnings in small print somewhere, but with no one knowing about it.
- It is vital to have mechanisms in place whereby inaccurate and incorrect Government information and advice can be challenged, corrected or retracted. Mechanisms exist for correcting scientific research published in journals and the same scientific rigour and challenge ought to exist for Government information. There currently appears to be no effective mechanism for challenging and correcting inaccurate or incorrect information provided by Government. Challenge and discussion are part of the scientific process.

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Unless this is put in place, there remains the risk that Government reports and advice may not be evidence based, but may contain the information the Government or lobbyists wish to hear. Decisions, policies and regulations would then be based on inaccurate information.

- There needs to be a body responsible for communicating to the public, medical practitioners and decision makers the evidence for adverse effects of wireless technologies and recommending protective measures. At the moment this is PHE. But PHE have failed to provide accurate information or to protect children or the public (point 3). I would recommend that people who provide factually incorrect information (which could damage public health) within PHE/DH are removed from their role. Conflicts of Interest need to be addressed, including where members of ICNIRP are assessing the safety of exposures below the ICNIRP guidelines. It is possible that a new independent expert scientific body (above) could recommend protective measures, as long as the group is not being controlled by the wireless industry. Introducing a process to hold PHE to account for their advice and recommendations might help to keep information evidence based. This may also be used to check whether recommendations are being followed. However, any group or panel can be corrupted if there are conflicts of interest and people do not act with honesty or integrity. For this issue in particular we need a culture of honesty and caring about public health. Challenge and scrutiny are vital.

Harming children is wrong, even when it is economically advantageous or taking action is difficult.

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