

Wi-Fi in Canadian Schools: A Health and Safety Issue

Peer-reviewed scientific studies (50) documenting potentially harmful biological effects of Wi-Fi frequency (2.4-2.45 GHz) at or below Health Canada's Safety Code 6¹ guidelines and recommendations for precautionary measures

By Margaret Friesen M.Sc. on behalf of Canadians for Safe Technology* - 28 November 2015

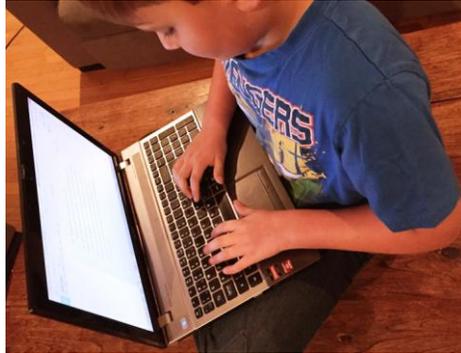


Photo: Canadians for Safe Technology

ABSTRACT

Potentially harmful health consequences of exposure to non-ionizing radiation from Wi-Fi devices being installed widely in Canadian schools is a growing concern for parents, students, school personnel and those responsible for health and safety in the school environment. Most non-federal Canadian bodies e.g. school boards, defer to Safety Code 6 guidelines for safe Wi-Fi exposure. Safety Code 6 is established by Health Canada, and sets the levels (limits) for "safe" human exposure in the radiofrequency/microwave range for "all individuals working at, or visiting federally regulated sites." Safety Code 6 has been called into question, with federal legislators recommending a full review of the scientific literature, public risk reduction and education. Health Canada has never revealed its entire reference list or its "weight of evidence" analysis to justify determination of Safety Code 6 guidelines.

The objective of this work is to identify original research studies in the peer-reviewed scientific literature, which show potentially harmful biological effects of Wi-Fi frequency radiation at levels that are at or below Safety Code 6 guidelines, and to compare that list with the reference list in Health Canada's **Safety Code 6 (2015) Rationale** document. The Rationale document stands as Health Canada's evidence that the updated Safety Code 6 protects the health of all Canadians. Also compared to the identified list, is the list of 16 studies that Health Canada released to a news reporter in October 2010 when Wi-Fi was first deployed in schools and parents reported that their children were becoming ill from newly installed Wi-Fi in their school.

The search identified 50 studies published between 1990 and the end of September 2015. Studies were conducted on human subjects, laboratory animals (including two on insects), and tissue and cell cultures. Fifteen (15) found effects on brain chemistry and oxidative stress. Eleven (11) documented DNA (genetic) damage. Adverse effects were reported on behaviour and learning in ten (10) studies. Also affected were the immune and cardiovascular systems. Nine (9) studies found abnormalities in sperm and testes. None of these are listed in the Rationale document or in the "16 studies" list.

The 50 studies compiled here provide only a portion of the scientific evidence that exposure to Wi-Fi should be considered a high priority health and safety issue, requiring immediate implementation of effective precautionary measures. It is especially important to protect young children, pregnant women and men who want to conceive healthy children. Precautionary measures in schools can be taken immediately by eliminating exposure wherever possible and otherwise implementing a policy to achieve exposures **As Low As Reasonably Achievable (ALARA)**. Until Safety Code 6 is adequately revised, Canadian school boards can and should take the initiative to use the most protective guidelines available globally.

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BACKGROUND

Wi-Fi² is a networking technology used by many electronic devices to communicate without wires (wireless). Devices that use Wi-Fi include tablet computers, laptops, some cell phones, personal computers and wireless accessory devices e.g. mouse, keyboard and printers. Wi-Fi routers are being installed widely in schools to permit convenient access to the Internet and for communication with other electronic wireless devices and networks. Wi-Fi frequency is 2.4-2.45 GHz,³ the same frequency emitted by household microwave ovens.

Exposure to non-ionizing radiation from Wi-Fi routers and associated devices in Canadian schools is a growing concern for parents, students, school personnel and those responsible for health and safety in the school environment because of potentially harmful health consequences.⁴ Some school routers may emit at a much higher power than household Wi-Fi routers, particularly if many devices simultaneously are transmitting data.

Health Canada currently establishes guidelines⁵, Safety Code 6, for "safe" levels (limits) of human exposure to radiofrequency/microwave radiation including Wi-Fi and other wireless devices.⁶ Safety Code 6 applies to "all individuals working at, or visiting, federally regulated sites"; adoption of these guidelines is discretionary for non-federal "interested parties" such as school boards, other levels of government, etc.^{7,8} The City of Toronto is one example of a jurisdiction which has set its own guidelines; it has a Prudent Avoidance Policy with levels 100x more stringent (safer) than Safety Code 6⁹.

Health Canada produced a document called **Safety Code 6 (2015) Rationale**,¹⁰ which outlines its rationale for the latest revision of Safety Code 6. This Rationale document omitted many studies relevant to the full evaluation of the biological effects of radiofrequency/microwave radiation at levels at or below Safety Code 6.¹¹ Except for the reference list in the Rationale document and a list provided to a news reporter in October, 2010 (see below), to date, Health Canada has not provided any other information to the public or to the Government of Canada's Parliamentary Standing Committee on Health¹² as to which studies it has or has not examined, nor how it conducted its "weight of evidence" analysis.

The first public reports of Canadian children becoming ill from newly installed Wi-Fi in their school occurred in the fall of 2010 and were documented in a Global News television program called **WiFi Safety in Schools**.¹³ Health Canada provided the reporter with a list of 16 studies as evidence that there were studies indicating Wi-Fi could not be the cause of the illness reported by the students. The reporter states "not a single [study] looks at whether Wi-Fi in school poses a health risk to students." True. In fact, 15 of the studies are on exposure measurements or on non-living models. The sole study on biological effects on actual people was conducted on the sleep quality of a group of adults and was not specific to Wi-Fi (Appendix 1).

Precautionary measures regarding Wi-Fi exposure should be considered a high priority health and safety issue, especially in schools, because:

- There have been more reports of children in Canada becoming ill from Wi-Fi exposure in their school;¹⁴
- In 2011 the World Health Organization - International Agency for Research on Cancer (WHO-IARC) classified wireless radiation in the radiofrequency/microwave range [radiofrequency electromagnetic fields], which includes Wi-Fi, as a Class 2B, *possible* human carcinogen.^{15,16} Dr. Hardell and his brain cancer research team, whose work was used, in part, to reach this determination, is now calling for a Class 1 *known* human carcinogen classification, based on newer research;^{17,18}
- In 2014 over 40 Canadian doctors and over 50 international scientists called on the federal Minister of Health to revise Safety Code 6 to make it more protective;¹⁹
- In June 2015 the Government of Canada's Parliamentary Standing Committee on Health (HESA), after their hearings on Safety Code 6, recommended: "That the Government of Canada develop an awareness campaign relating to the safe use of wireless technologies, such as cell phones and Wi-Fi, in key environments such as the school and home to ensure that Canadian families and children are reducing risks related to radiofrequency exposure" and " That Health Canada conduct a comprehensive review of

all existing literature relating to radiofrequency fields and carcinogenicity based on international best practices";²⁰

- Following the hearings, the Canadian Medical Association Journal (CMAJ) published an article outlining the omission of studies in Health Canada's latest revision of Safety Code 6 guidelines;²¹
- In May 2015 an international group of over 200 hundred scientists specializing in wireless radiation research submitted appeals to the United Nations and the WHO calling for more protective measures;²²
- Studies indicate that children absorb more radiation than adults;^{23,24}
- There has been a small, but statistically significant increase in incidence of primary malignant brain and central nervous system tumors in children in the United States between 2000-2010;²⁵
- Rates of autism are rising and a plausible link to exposure of wireless radiation has been presented;^{26,27,28}
- A study involving 2,422 Korean children found a significant association between wireless radiation exposure to the head (mobile phone use) and Attention Deficit Hyperactivity Disorder (ADHD), but only in the group with higher blood levels of lead. The authors suggest that the radiation may have increased blood-brain-barrier permeability, and thus access of the lead (a potent neurotoxin) to the brain.
- The Canadian Teachers' Federation has expressed concern for students and their exposure to Wi-Fi;^{29,30}
- The Ontario English Catholic Teachers Association (OECTA) state in **A position regarding the use of Non-ionizing Electromagnetic Radiation, including WiFi, in the workplace:** "Controls for WiFi would best be guided by the ALARA principle (As Low As Reasonably Achievable), as well as by applying the concept of prudent avoidance";³¹ and
- Other countries such as France, Israel and Italy have taken precautionary measures in schools.³² Two examples: France has legislated no Wi-Fi in daycares and the State Parliament of South Tyrol, Italy mandated the replacement of existing wireless networks whenever possible with networks that emit less radiation in schools and preschools in keeping with the Precautionary Principle.³³

OBJECTIVES

1. To compile a list of peer-reviewed original research studies published from 1990 to the end of September 2015, documenting potentially harmful biological effects from exposure to Wi-Fi frequency (2.4 -2.45 GHz) at or below Health Canada's Safety Code 6 guidelines.
2. To compare this list with:
 - The reference list included in the **Safety Code 6 (2015) Rationale** document as Health Canada's evidence that the current Safety Code 6 is protective of Canadians' health and
 - The "16 studies" reference list from Health Canada in 2010 (when Wi-Fi started to be deployed in schools on a large scale) as evidence that Wi-Fi was "safe" in schools.
3. To provide recommendations for precautionary measures that can be taken immediately, and for future consideration, in Canadian schools.

METHODS

PubMed³⁴ and EMF portal³⁵ were searched using the key words/terms Wi-Fi, WiFi, 2.4 GHz, 2.45 GHz and 2450 MHz, from 1990 to the end of September, 2015. The search was limited to this single narrow frequency range. Exposures were determined as being at or below Safety Code 6 levels by examining the abstracts from PubMed, details in EMF portal and, in some cases, the full publication. The exposure level was expressed as the Specific Absorption Rate (SAR). The SAR level set by Health Canada for the head, neck and trunk is 1.6 W/kg.³⁶ Only studies at or below this level were included in this compilation. In several studies actual devices were used which would have been approved as having acceptable SAR levels for human use; these were listed as being at 1.6 W/kg although the actual SAR may have been lower (or higher if the device was defective).

RESULTS

Fifty (50) studies from 1990 to 2015, documenting potentially harmful effects of Wi-Fi exposure at or below Safety Code 6, were identified (Figure 1). Most were published after the WHO/IARC's *possible* human carcinogen classification (May 2011). Studies were on human subjects, laboratory animals, and on tissue and cell cultures; two were on insects. The 50 studies were grouped into seven topics: Brain Biochemistry, Oxidative Stress, DNA (Genetic) Damage, Behaviour & Learning, Immune & Cardiovascular, Sperm & Testes and Other (cell replication, cells of the small intestine, fibroblasts and insect (*Drosophila*) reproduction) (Figure 2).

Titles of all studies, with the full reference, are provided in Appendix 2, as well as an excerpt from the abstract. Key words describing the potentially harmful effect in each study are listed in the "Findings" column and findings are summarized in Figure 3. In cases where potentially harmful effects were elicited in order to study possible therapeutic treatments, only the potential adverse effects are noted (6 studies).

None of the 50 studies are listed in the **Safety Code 6 (2015) Rationale** document or in the "16 studies" list.

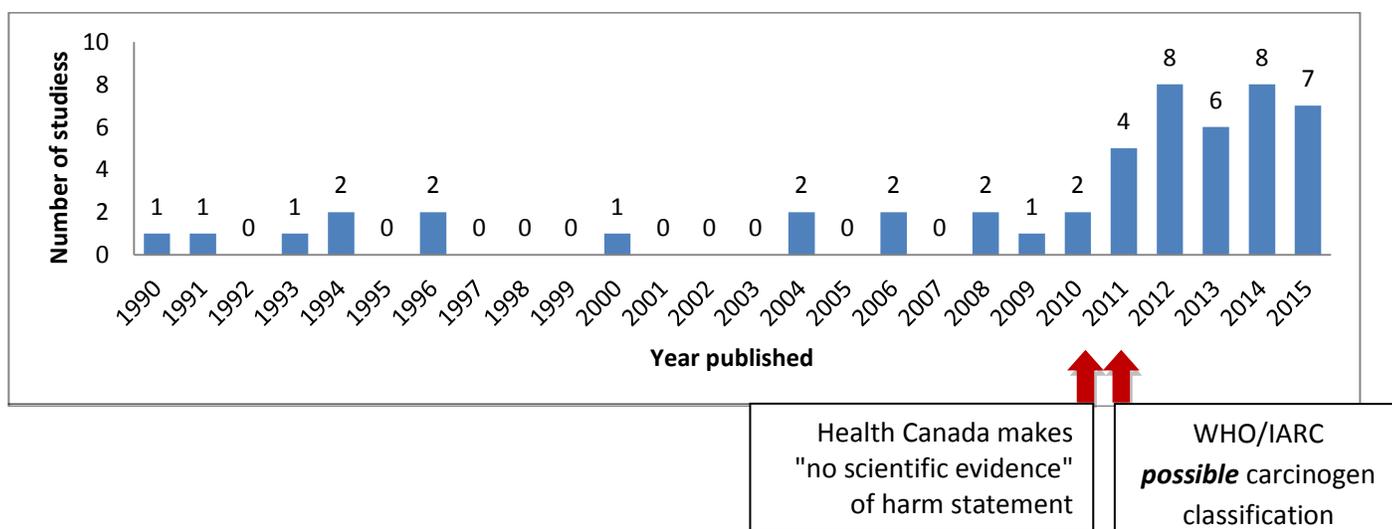


Figure 1. Number of Wi-Fi exposure studies published annually from 1990 to the end of September 2015 showing potentially harmful biological effects of Wi-Fi exposure at levels at or below Safety Code 6. Health Canada's Wi-Fi related statement in the Global News program was made in October, 2010. The World Health Organization-International Agency for Research on Cancer (WHO-IARC) Class 2B *possible* human carcinogen classification for radiofrequency/microwave radiation (radiofrequency electromagnetic fields) was announced in May 2011.

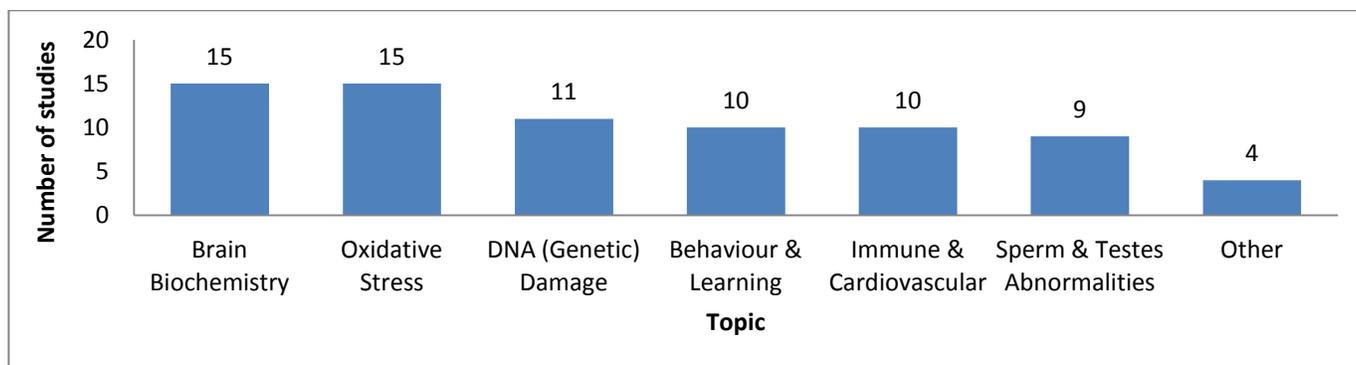


Figure 2. Studies showing potentially harmful effects of Wi-Fi exposure at levels at or below Safety Code 6, grouped according to various topics. One study may have examined more than one topic.

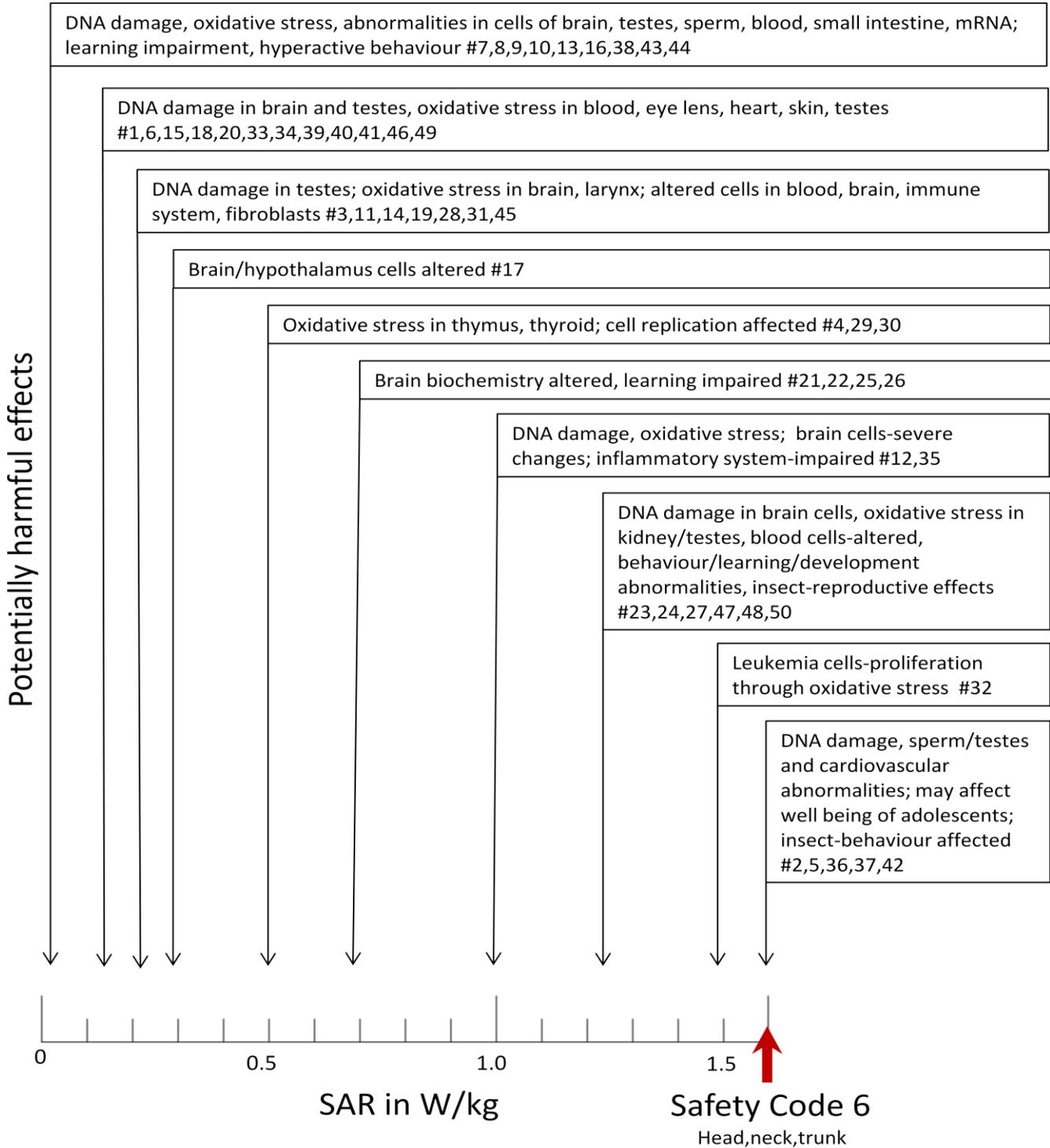


Figure 3. Potentially harmful effects reported for Wi-Fi exposure in 50 studies and the Specific Absorption Rate (SAR) reported for each study at or below the indicated SAR level. Health Canada's Safety Code 6 SAR level is 1.6 W/kg (head, neck and trunk).

DISCUSSION

Potentially harmful effects at Wi-Fi exposure levels at or below Safety Code 6 guidelines are well documented in the 50 studies identified. Effects included DNA (genetic) damage and oxidative stress on body systems e.g. brain, cardiovascular, immune, testes. DNA damage can lead to various adverse reproductive and other health effects - not only cancer. Chronic or excessive oxidative stress can lead to chronic inflammation, which in turn has been associated with illnesses such as cancer, and cardiovascular and neurological diseases (Alzheimer's and Parkinson's).^{37,38} Adverse effects reported in ten studies on behaviour and learning have widespread implications in a school environment, and for our children's future.

This compilation should be considered preliminary; there are undoubtedly more studies that this limited search has not identified. The BioInitiative 2012 and BioInitiative Update³⁹ lists hundreds of peer-reviewed studies reporting similar and other biological effects at exposures below Safety Code 6 levels for other frequencies e.g. 900 MHz and 1800 MHz for cell phones, cordless phones, etc. Use of Wi-Fi in conjunction with multiple other devices, further complicates real-life exposures.

If student and school personnel exposure risks from Wi-Fi radiation are to be minimized, it is clear those responsible for their health and safety must educate themselves, and establish and implement policies and procedures with their own precautionary measures for the school environment.

CONCLUSIONS

This compilation of studies lends further strong scientific evidence that Safety Code 6 guidelines are not adequately protective of Canadians' health.

There is ample evidence that precautionary measures should be taken, especially for young children, pregnant women, and men who want to conceive healthy children. There are also implications for behaviour and learning. Inadequate Safety Code 6 guidelines, combined with rapid and widespread proliferation of Wi-Fi, make it imperative that bodies such as school boards take immediate effective precautionary measures.

RECOMMENDATIONS FOR PRECAUTIONARY MEASURES IN SCHOOLS

1. Eliminate sources of, and exposure to, Wi-Fi frequency radiation wherever possible.
2. When elimination is not possible, implement a policy of **As Low As Reasonably Achievable (ALARA)**.
 - 1) Keep wired technologies, and/or replace Wi-Fi networks and other devices with wired devices.
 - 2) Minimize exposure e.g. follow **Wi-Fi Devices Best Practices** adopted by the Ashland Public School District, Massachusetts, United States⁴⁰ :
 - *Turn off the device when not in use*
 - *Turn Wi-Fi on only when needed*
 - *Always place the mobile⁴¹ device on a solid surface [e.g. keep laptops off laps]*
 - *Viewing distance should be a minimum of 12 inches [30 cm] from the screen*
 - *Specific product information guides are available through the Information Technology (IT) department*
 - *We ask staff members to remind and to instruct students regularly in using best practices in regards to mobile devices.*
3. Provide designated "Wi-Fi free zones" ("white zones") within schools for individuals who are sensitive and/or who want reduced exposure.
4. Investigate and adopt the most protective measures among those used in France, Israel, Italy and elsewhere. Details can be found on the Environmental Health Trust website: <http://ehtrust.org/>
5. Until Safety Code 6 is adequately revised, school boards can and should take the initiative to use the most protective guidelines available globally, such as in Salzburg, Austria.^{42,43}

Appendix 1. The list of 16 studies labelled "List of studies reviewed at Health Canada that are specific to Wi-Fi" that Health Canada provided to the Global Network current affairs program 16:9 The Bigger Picture (aired October, 2010). The links have been added. Added comments are in [square brackets]. Only #10 was a biological effects study conducted on real people.

- 1. Andersen, J. B., et al. (2010). Power variations of wireless communication systems. *Bioelectromagnetics*, 31(4), 302–310.** <http://www.ncbi.nlm.nih.gov/pubmed/20112260>
- 2. Fang, M., & Malone, D. (2010). Experimental verification of a radiofrequency power model for Wi-Fi technology. *Health Physics*, 98(4), 574–583.** <http://www.ncbi.nlm.nih.gov/pubmed/20220364>
- 3. Findlay, R. P., & Dimbylow, P. J. (2010). SAR in a child voxel phantom from exposure to wireless computer networks (Wi-Fi). *Physics in Medicine and Biology*, 55(15), N405–411.** <http://www.ncbi.nlm.nih.gov/pubmed/20647607>
- 4. Foster, K. R. (2007). Radiofrequency exposure from wireless LANs utilizing Wi-Fi technology. *Health Physics*, 92(3), 280–289.** <http://www.ncbi.nlm.nih.gov/pubmed/17293700>
- 5. Joseph, W., et al. (2010). Comparison of personal radio frequency electromagnetic field exposure in different urban areas across Europe. *Environmental Research*, 110(7), 658–663.** <http://www.ncbi.nlm.nih.gov/pubmed/20638656>
- 6. Joseph, W., (2008). Characterization of personal RF electromagnetic field exposure and actual absorption for the general public. *Health Physics*, 95(3), 317–330.** <http://www.ncbi.nlm.nih.gov/pubmed/18695413>
- 7. Joseph, W., et al. (2010). Estimation of whole-body SAR from electromagnetic fields using personal exposure meters. *Bioelectromagnetics*, 31(4), 286–295.** <http://www.ncbi.nlm.nih.gov/pubmed/20041435>
- 8. Malone, D., & Malone, L. A. (2009). Ambient radiofrequency power: the impact of the number of devices in a Wi-Fi network. *Health Physics*, 96(6), 629–635.** <http://www.ncbi.nlm.nih.gov/pubmed/19430215>
- 9. Martínez-Búrdalo, M., (2009). FDTD assessment of human exposure to electromagnetic fields from WiFi and bluetooth devices in some operating situations. *Bioelectromagnetics*, 30(2), 142–151.** <http://www.ncbi.nlm.nih.gov/pubmed/18937345>
- 10. Mohler, E., Frei, P., Braun-Fahrlander, C., Fröhlich, J., Neubauer, G., Rössli, M., & Qualifex Team. (2010). Effects of everyday radiofrequency electromagnetic-field exposure on sleep quality: a cross-sectional study. *Radiation Research*, 174(3), 347–356.** [study group was on men and women aged 30 to 60 years exposed to various sources, not a study specific to the school environment] <http://www.ncbi.nlm.nih.gov/pubmed/20726726>
- 11. Otto, M., & von Mühlendahl, K. E. (2007). Electromagnetic fields (EMF): do they play a role in children’s environmental health (CEH)? *International Journal of Hygiene and Environmental Health*, 210(5), 635–644.** [supposedly a review of the literature but NONE of the studies identified in this study are referenced. Most, if not all, involve different frequencies] <http://www.ncbi.nlm.nih.gov/pubmed/17765660>
- 12. Parazzini, M., et al.(2010). Assessment of the exposure to WLAN frequencies of a head model with a cochlear implant. *Bioelectromagnetics*, 31(7), 546–555.** <http://www.ncbi.nlm.nih.gov/pubmed/20683910>
- 13. UK Health Protection Agency. (no date). Wi-Fi in schools.** [exposure information, not a biological effects study]
Old link not working: http://www.hpa.org.uk/web/HPAwebFile/HPA_C/1254510618866
Link to archived report (have to copy and paste):
http://webarchive.nationalarchives.gov.uk/20140714084352/http://www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1254510618866
- 14. Verloock, L., et al. (2010). Procedure for assessment of general public exposure from WLAN in offices and in wireless sensor network testbed. *Health Physics*, 98(4), 628–638.** <http://www.ncbi.nlm.nih.gov/pubmed/20220371>
- 15. Viel, J.-F., et al. (2009). Radiofrequency exposure in the French general population: band, time, location and activity variability. *Environment International*, 35(8), 1150–1154.** <http://www.ncbi.nlm.nih.gov/pubmed/19656570>
- 16. Wu, T., Hadjem, A., Wong, M.-F., Gati, A., Picon, O., & Wiart, J. (2010). Whole-body new-born and young rats’ exposure assessment in a reverberating chamber operating at 2.4 GHz. *Physics in Medicine and Biology*, 55(6), 1619–1630.** <http://www.ncbi.nlm.nih.gov/pubmed/20182003>

Appendix 2. Peer-reviewed published studies of biological effects at Wi-Fi frequency of 2.4 (2.45) GHz with evidence of harm at or below Health Canada's Safety Code 6 guidelines. The reference appears in bold, an excerpt from the abstract is quoted verbatim, and a link to the full abstract in PubMed is provided. A brief summary of findings is in the right column.

	References, abstract excerpts, and link to full abstract in PubMed	Findings
1	<p>Atasoy, H. I., et al. (2013). Immunohistopathologic demonstration of deleterious effects on growing rat testes of radiofrequency waves emitted from conventional Wi-Fi devices. <i>Journal of Pediatric Urology</i>, 9(2), 223–229.</p> <p>"These findings raise questions about the safety of radiofrequency exposure from Wi-Fi Internet access devices for growing organisms of reproductive age, with a potential effect on both fertility and the integrity of germ cells."</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/22465825</p> <p>[SAR: 0.091 W/kg]</p>	<p>-Testes: DNA damage</p> <p>- Development: deleterious effects on growing testes</p>
2	<p>Avendaño, C., et al. (2012). Use of laptop computers connected to internet through Wi-Fi decreases human sperm motility and increases sperm DNA fragmentation. <i>Fertility and Sterility</i>, 97(1), 39–45.</p> <p>"Ex vivo exposure of human spermatozoa to a wireless internet-connected laptop decreased motility and induced DNA fragmentation by a nonthermal effect. We speculate that keeping a laptop connected wirelessly to the internet on the lap near the testes may result in decreased male fertility."</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/22112647</p> <p>[Device]</p>	<p>- Sperm: decreased motility</p> <p>- DNA fragmentation</p>
3	<p>Aynali, G., et al. (2013). Modulation of wireless (2.45 GHz)-induced oxidative toxicity in laryngotracheal mucosa of rat by melatonin. <i>European Archives of Oto-Rhino-Laryngology...Head and Neck Surgery</i>, 270(5), 1695–1700.</p> <p>"It is well known that oxidative stress induces larynx cancer ... that electromagnetic radiation (EMR) induces oxidative stress in different cell systems... Wi-Fi-induced oxidative stress in the laryngotracheal mucosa..."</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/23479077</p> <p>[SAR: 0.143 W/kg]</p>	<p>- Larynx: oxidative stress</p>

4	<p>Ballardin, M., (2011). Non-thermal effects of 2.45 GHz microwaves on spindle assembly, mitotic cells and viability of Chinese hamster V-79 cells. <i>Mutation Research</i>, 716(1-2), 1–9.</p> <p>"After an exposure time of 15 min the proportion of aberrant spindles and of apoptotic cells was significantly increased, while the mitotic index decreased as well..."</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/21827772</p> <p>[SAR: 0.04-0.51 W/kg]</p>	- Cell replication: spindle disturbances
5	<p>Cammaerts, M.-C., & Johansson, O. (2014). Ants can be used as bio-indicators to reveal biological effects of electromagnetic waves from some wireless apparatus. <i>Electromagnetic Biology and Medicine</i>, 33(4), 282–288.</p> <p>"...we designed and validated a fast and easy test on ants - these insects being used as a biological model - for revealing the effect of wireless equipments like mobile phones, smartphones, digital enhanced cordless telephone (DECT) phones, WiFi routers and so on."</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/23977878</p> <p>[Device]</p>	Insects: behaviour affected
6	<p>Ceyhan, A. M., et al. (2012). Protective effects of β-glucan against oxidative injury induced by 2.45-GHz electromagnetic radiation in the skin tissue of rats. <i>Archives of Dermatological Research</i>, 304(7), 521–527.</p> <p>"Exposure to 2.45-GHz EMR caused a significant increase in MDA [malondialdehyde] levels and CAT [catalase] activity..."</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/22237725</p> <p>[SAR: 0.064 W/kg]</p>	- Skin: oxidative injury
7	<p>Dasdag, S., et al. (2015). Effects of 2.4 GHz radiofrequency radiation emitted from Wi-Fi equipment on microRNA expression in brain tissue. <i>International Journal of Radiation Biology</i>, 91(7), 555–561.</p> <p>"The results revealed that long-term exposure of 2.4 GHz Wi-Fi radiation can alter expression of some of the miRNAs.[microRNSs].. Long-term exposure of 2.4 GHz RF may lead to adverse effects such as neurodegenerative diseases originated from the alteration of some miRNA expression levels."</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/25775055</p> <p>[SAR: 0.00151 W/kg]</p>	- Brain cells: altered mRNA expression

8	<p>Dasdag, S., et al. (2015). Effect of long-term exposure of 2.4 GHz radiofrequency radiation emitted from Wi-Fi equipment on testes functions. <i>Electromagnetic Biology and Medicine</i>, 34(1), 37–42.</p> <p>“In conclusion, we observed that long-term exposure of 2.4 GHz RF emitted from Wi-Fi (2420 μW/kg, 1 g average) affects some of the reproductive parameters of male rats. We suggest Wi-Fi users to avoid long-term exposure of RF emissions from Wi-Fi equipment.”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/24460421</p> <p>[SAR: 0.00242 W/kg]</p>	<p>- Sperm: abnormalities</p> <p>-Testes: abnormalities</p>
9	<p>Deshmukh, P. S., et al. (2013). Detection of Low Level Microwave Radiation Induced Deoxyribonucleic Acid Damage Vis-à-vis Genotoxicity in Brain of Fischer Rats. <i>Toxicology International</i>, 20(1), 19–24.</p> <p>“We demonstrated DNA damaging effects of low level microwave radiation in brain.”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/23833433</p> <p>[SAR: 0.0006672 W/kg]</p>	<p>- Brain cells: DNA damage</p>
10	<p>Deshmukh, P. S., et al. (2015). Cognitive impairment and neurogenotoxic effects in rats exposed to low-intensity microwave radiation. <i>International Journal of Toxicology</i>, 34(3), 284–290.</p> <p>“The results indicated that, chronic low-intensity microwave exposure in the frequency range of 900 to 2450 MHz may cause hazardous effects on the brain.”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/25749756</p> <p>[SAR: 0.0006672 W/kg]</p>	<p>- Brain: DNA damage, oxidative stress</p> <p>- Learning: cognition impairment</p>
11	<p>Elekes, E., et al. (1996). Effect on the immune system of mice exposed chronically to 50 Hz amplitude-modulated 2.45 GHz microwaves. <i>Bioelectromagnetics</i>, 17(3), 246–248.</p> <p>“.. both types of exposure conditions induced moderate elevation of antibody production only in male mice.”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/8809365</p> <p>[SAR: 0.14 W/kg]</p>	<p>- Immune system: altered in males</p>
12	<p>Eser, O., et al. (2013). The effect of electromagnetic radiation on the rat brain: an experimental study. <i>Turkish Neurosurgery</i>, 23(6), 707–715.</p> <p>“... there were severe degenerative changes, shrunken cytoplasm and extensively dark pyknotic nuclei in the EMR [electromagnetically irradiated] groups... EMR causes structural changes in the frontal cortex, brain stem and cerebellum and impairs the oxidative stress and inflammatory cytokine system. This deterioration can cause ... cancer development.”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/24310452</p> <p>[SAR: 1.04 W/kg]</p>	<p>- Brain cells: severe changes, oxidative stress</p> <p>-Inflammatory system: impaired</p>

<p>13</p>	<p>Ghazizadeh, V., & Nazıroğlu, M. (2014). Electromagnetic radiation (Wi-Fi) and epilepsy induce calcium entry and apoptosis through activation of TRPV1 channel in hippocampus and dorsal root ganglion of rats. <i>Metabolic Brain Disease</i>, 29(3), 787–799.</p> <p>“The Wi-Fi exposure induced additional effects on the cytosolic Ca(2+) increase... Wi-Fi in our experimental model is involved in Ca(2+) influx and oxidative stress-induced hippocampal and DRG [Dorsal root ganglion] death...”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/24792079</p> <p>[SAR: 0.00052 W/kg]</p>	<p>- Brain: cell damage</p> <p>-Oxidative stress</p>
<p>14</p>	<p>Grigoriev, Y. G., et al. (2010). Confirmation studies of Soviet research on immunological effects of microwaves: Russian immunology results. <i>Bioelectromagnetics</i>, 31(8), 589–602.</p> <p>“... possible adverse effects of the blood serum from exposed rats on pregnancy and foetal development of intact rats...”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/20857454</p> <p>[SAR: 0.16 W/kg]</p>	<p>- Blood serum: alterations</p>
<p>15</p>	<p>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. <i>Biological Trace Element Research</i>, 132(1-3), 153–163.</p> <p>“In conclusion, 2.45 GHz electromagnetic radiation caused oxidative stress...”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/19396408</p> <p>[SAR: 0.1 W/kg]</p>	<p>- Blood: oxidative stress.</p>
<p>16</p>	<p>Gürler, H. Ş., et al. (2014). Increased DNA oxidation (8-OHdG) and protein oxidation (AOPP) by low level electromagnetic field (2.45 GHz) in rat brain and protective effect of garlic. <i>International Journal of Radiation Biology</i>, 90(10), 892–896.</p> <p>“... low level EMF[electromagnetic fields] at 2.45 GHz MWR increases the DNA damage in both brain tissues and plasma ...”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/24844368</p> <p>[SAR: 0.02 W/kg]</p>	<p>- Brain: DNA damage</p> <p>- Blood plasma: DNA damage</p>
<p>17</p>	<p>Jorge-Mora, T., et al. (2011). The effects of single and repeated exposure to 2.45 GHz radiofrequency fields on c-Fos protein expression in the paraventricular nucleus of rat hypothalamus. <i>Neurochemical Research</i>, 36(12), 2322–2332.</p> <p>“The results suggest that PVN [paraventricular nucleus] is sensitive to 2.45 GHz microwave radiation at non-thermal SAR [specific absorption rate] levels.”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/21818659</p> <p>[SAR: 0.301 W/kg]</p>	<p>- Brain/hypothalamus cells: altered</p>

<p>18</p>	<p>Kesari, K. K., et al. (2010). Mutagenic response of 2.45 GHz radiation exposure on rat brain. <i>International Journal of Radiation Biology</i>, 86(4), 334–343.</p> <p>“The study concludes that the chronic exposure to these radiations may cause significant damage to brain, which may be an indication of possible tumour promotion...”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/20353343</p> <p>[SAR: 0.11 W/kg]</p>	<p>-Brain: DNA damage</p>
<p>19</p>	<p>Kesari, K. K., et al.. (2012). Pathophysiology of microwave radiation: effect on rat brain. <i>Applied Biochemistry and Biotechnology</i>, 166(2), 379–388.</p> <p>“The study concludes that a reduction in melatonin or an increase in caspase-3, creatine kinase, and calcium ion may cause significant damage in brain due to chronic exposure of these radiations. These biomarkers clearly indicate possible health implications of such exposures.”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/22134878</p> <p>[SAR: 0.14 W/kg]</p>	<p>- Brain: cell damage</p>
<p>20</p>	<p>Kumar, S., et al. (2011). The therapeutic effect of a pulsed electromagnetic field on the reproductive patterns of male Wistar rats exposed to a 2.45-GHz microwave field. <i>Clinics (São Paulo, Brazil)</i>, 66(7), 1237–1245.</p> <p>“This finding emphasizes that reactive oxygen species (a potential inducer of cancer) are the primary cause of DNA damage... Electromagnetic fields are recognized as hazards that affect testicular function by generating reactive oxygen species and reduce the bioavailability of androgen to maturing spermatozoa. Thus, microwave exposure adversely affects male fertility...”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/21876981</p> <p>[SAR: 0.014 W/kg]</p>	<p>- Testes: oxidative stress</p>
<p>21</p>	<p>Lai, H., et al. (1990). Corticotropin-releasing factor antagonist blocks microwave-induced decreases in high-affinity choline uptake in the rat brain. <i>Brain Research Bulletin</i>, 25(4), 609–612.</p> <p>“These data suggest that low-level microwave irradiation activates CRF [corticotropin-releasing factor] in the brain, which in turn causes the changes in central HACU [sodium-dependent high-affinity choline uptake.”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/2271963</p> <p>[SAR: 0.6 W/kg]</p>	<p>- Brain biochemistry: alterations</p>

<p>22</p>	<p>Lai, H., et al. (1994). Microwave irradiation affects radial-arm maze performance in the rat. <i>Bioelectromagnetics</i>, 15(2), 95–104.</p> <p>“... rats showed retarded learning while performing in the radial-arm maze to obtain food rewards, indicating a deficit in spatial ‘working memory’ function... These data indicate that both cholinergic and endogenous opioid neurotransmitter systems in the brain are involved in the microwave-induced spatial memory deficit.”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/8024608</p> <p>[SAR: 0.6 W/kg]</p>	<p>- Brain: neurotransmitters affected</p> <p>- Learning: spatial memory deficit</p>
<p>23</p>	<p>Lai, H., & Singh, N. P. (1996). Single- and double-strand DNA breaks in rat brain cells after acute exposure to radiofrequency electromagnetic radiation. <i>International Journal of Radiation Biology</i>, 69(4), 513–521.</p> <p>“An increase in both types of DNA strand breaks was observed after exposure to either the pulsed or continuous-wave radiation... Our data further support the results of earlier in vitro and in vivo studies showing effects of radiofrequency electromagnetic radiation on DNA.”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/8627134</p> <p>[SAR: 1.2 W/kg]</p>	<p>- Brain cells: DNA damage</p>
<p>24</p>	<p>Lai, H. (2004). Interaction of microwaves and a temporally incoherent magnetic field on spatial learning in the rat. <i>Physiology & Behavior</i>, 82(5), 785–789.</p> <p>"Results show that microwave-exposed rats had significant deficit in learning...."</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/15451642</p> <p>[SAR: 1.2 W/kg]</p>	<p>- Behaviour: learning impairment</p>
<p>25</p>	<p>Li M., et al. (2008). Elevation of plasma corticosterone levels and hippocampal glucocorticoid receptor translocation in rats: a potential mechanism for cognition impairment following chronic low-power-density microwave exposure. <i>Journal of Radiation Research</i>, 49(2), 163–170.</p> <p>“... MW[microwave]-exposed rats had significant deficits in spatial learning and memory performance.... MW exposure increased levels of plasma corticosterone, and consequently GC receptor (GR) nuclear translocation and apoptosis in the hippocampus ...”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/18198477</p> <p>[SAR: 0.7 W/kg]</p>	<p>- Learning: cognitive impairment</p> <p>- Brain: neuronal loss</p>

<p>26</p>	<p>Lu, Y., et al. (2012). Glucose administration attenuates spatial memory deficits induced by chronic low-power-density microwave exposure. <i>Physiology & Behavior</i>, 106(5), 631–637.</p> <p>“MW [microwave] exposure induced spatial learning and memory impairments in rats.”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/22564535</p> <p>[SAR: 0.7 W/kg]</p>	<p>-Learning: spatial and memory impairment</p>
<p>27</p>	<p>Margaritis, L. H., et al. (2014). Drosophila oogenesis as a bio-marker responding to EMF sources. <i>Electromagnetic Biology and Medicine</i>, 33(3), 165–189.</p> <p>“Insect: All EMF [electromagnetic field] sources used created statistically significant effects regarding fecundity and cell death-apoptosis induction, even at very low intensity levels (0.3 V/m blue tooth radiation), well below ... guidelines...”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/23915130</p> <p>[Device: SAR: 1.2 W/kg]</p>	<p>Insect:</p> <p>- Reproductive effects: cell-death-apoptosis induction</p>
<p>28</p>	<p>Meena, R., et al. (2014). Therapeutic approaches of melatonin in microwave radiations-induced oxidative stress-mediated toxicity on male fertility pattern of Wistar rats. <i>Electromagnetic Biology and Medicine</i>, 33(2), 81–91.</p> <p>“...MW [microwave] induced oxidative stress mediated DNA damage in testicular cells.”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/23676079</p> <p>[SAR: 0.14 W/kg]</p>	<p>- Testes: DNA damage</p>
<p>29</p>	<p>Misa Agustino, M. J., et al. (2012). Electromagnetic fields at 2.45 GHz trigger changes in heat shock proteins 90 and 70 without altering apoptotic activity in rat thyroid gland. <i>Biology Open</i>, 1(9), 831–838.</p> <p>“Non-ionizing radiation at 2.45 GHz may modify the expression of genes that codify heat shock proteins (HSP) in the thyroid gland... Ninety minutes after radiation, HSP-90 and HSP-70 had decreased significantly (P<0.01) after applying a SAR of 0.046±1.10 W/Kg... . The results suggest that acute sub-thermal radiation at 2.45 GHz may alter levels of cellular stress in rat thyroid gland...”</p> <p>http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3507243/</p> <p>[SAR: 0.046-0.482 W/kg]</p>	<p>- Thyroid gland: oxidative stress</p>

<p>30</p>	<p>Misa-Agustiño, et al. (2015). EMF radiation at 2450 MHz triggers changes in the morphology and expression of heat shock proteins and glucocorticoid receptors in rat thymus. <i>Life Sciences</i>, 127, 1–11.</p> <p>“Electromagnetic fields (EMFs) can act as inducers or mediators of stress response through the production of heat shock proteins (HSPs) that modulate immune response and thymus functions... Our results indicate that non-ionizing sub-thermal radiation causes changes in the endothelial permeability and vascularization of the thymus, and is a tissue-modulating agent for Hsp90 and GR[glucocorticoid receptors].”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/25731700</p> <p>[SAR: 0.046-0.482 W/kg]</p>	<p>- Thymus: oxidative stress</p>
<p>31</p>	<p>Naziroğlu, M., et al. (2012). 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. <i>Physiology & Behavior</i>, 105(3), 683–692.</p> <p>“Lipid peroxidation (LP), cell viability and cytosolic Ca(2+) values in DRG [dorsal root ganglion] neurons were higher...”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/22019785</p> <p>[SAR: 0.143 W/kg]</p>	<p>- Brain: oxidative injury</p>
<p>32</p>	<p>Naziroğlu, M., et al. (2012). 2.45-Gz wireless devices induce oxidative stress and proliferation through cytosolic Ca²⁺ influx in human leukemia cancer cells. <i>International Journal of Radiation Biology</i>, 88(6), 449–456.</p> <p>“The extent of lipid peroxidation, cytosolic free Ca²⁺ and cell numbers were higher in 2.45 GHz groups... CONCLUSIONS: 2.45 GHz electromagnetic radiation appears to induce proliferative effects through oxidative stress and Ca²⁺ influx...”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/22489926</p> <p>[SAR: 0.1-1.5 W/kg]</p>	<p>- Leukemia cancer cells: induction of proliferation through oxidative stress</p>
<p>33</p>	<p>Oksay, T., et al. (2014). Protective effects of melatonin against oxidative injury in rat testis induced by wireless (2.45 GHz) devices. <i>AND Andrologia</i>, 46(1), 65–72.</p> <p>“In conclusion, wireless (2.45 GHz) EMR caused oxidative damage in testis by increasing the levels of lipid peroxidation and decreasing in vitamin A and E levels.”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/23145464</p> <p>[SAR: 0.1 W/kg]</p>	<p>- Testes: oxidative injury</p>

<p>34</p>	<p>Özorak, 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. <i>Biological Trace Element Research</i>, 156(1-3), 221–229.</p> <p>“In conclusion, Wi-Fi- and mobile phone-induced EMR caused oxidative damage by increasing the extent of lipid peroxidation and the iron level, while decreasing total antioxidant status, copper, and GSH values. Wi-Fi- and mobile phone-induced EMR may cause precocious puberty and oxidative kidney and testis injury in growing rats.”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/24101576</p> <p>[SAR: 0.18- 1.2 W/kg]</p>	<p>- Kidney: oxidative injury</p> <p>-Testes: oxidative injury</p> <p>- Development: may cause precocious puberty</p>
<p>35</p>	<p>Paulraj, R., & Behari, J. (2006). Single strand DNA breaks in rat brain cells exposed to microwave radiation. <i>Mutation Research</i>, 596(1-2), 76–80.</p> <p>“This study shows that the chronic exposure to these radiations cause statistically significant ($p < 0.001$) increase in DNA single strand breaks in brain cells of rat.”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/16458332</p> <p>[SAR: 1.0 W/kg]</p>	<p>- Brain cells: DNA damage</p>
<p>36</p>	<p>Redmayne, M., et al. (2013). The relationship between adolescents’ well-being and their wireless phone use: a cross-sectional study. <i>Environmental Health: A Global Access Science Source</i>, 12(1), 90.</p> <p>“To safeguard young people’s well-being, we suggest limiting their use of cellphones and cordless phones to less than 15 minutes daily...”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/24148357</p> <p>[Device]</p>	<p>- Behaviour: may affect well-being of adolescents</p>
<p>37</p>	<p>Saili, L., et al. (2015). Effects of acute exposure to WIFI signals (2.45 GHz) on heart variability and blood pressure in Albinos rabbit. <i>Environmental Toxicology and Pharmacology</i>, 40(2), 600–605.</p> <p>“WIFI alter catecholamines (dopamine, epinephrine) action on heart variability and blood pressure ...These results suggest for the first time, as far as we know, that exposure to WIFI affect heart rhythm, blood pressure, and catecholamines efficacy on cardiovascular system; indicating that radiofrequency can act directly and/or indirectly on cardiovascular system.”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/26356390</p> <p>[Device]</p>	<p>- Cardiovascular system/heart rhythm/blood pressure: direct and indirect effects</p>

<p>38</p>	<p>Sarkar, S., et al. (1994). Effect of low power microwave on the mouse genome: a direct DNA analysis. <i>Mutation Research</i>, 320(1-2), 141–147.</p> <p>“... band patterns in exposed animals were found to be distinctly altered in the range of 7-8 kb which was also substantiated by densitometric analysis... the results obtained at the present dose are of significance. This dose, which has been set as the safe limit for general public exposure ... may imply a need for (re)evaluation of the mutagenic potential of microwaves at the prescribed safe limit for the personnel and people who are being exposed.”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/7506381?dopt=Abstract</p> <p>[SAR: 0.00118 W/kg]</p>	<p>Brain and testes: DNA damage</p>
<p>39</p>	<p>Shahin, S., et al. (2015). 2.45 GHz Microwave Radiation Impairs Learning and Spatial Memory via Oxidative/Nitrosative Stress Induced p53 Dependent/Independent Hippocampal Apoptosis: Molecular Basis and Underlying Mechanism. <i>Toxicological Sciences: An Official Journal of the Society of Toxicology</i>. doi:10.1093/toxsci/kfv205</p> <p>"...short-term as well as long-term 2.45 GHz MW radiation exposure increases the oxidative/nitrosative stress leading to enhanced apoptosis... These findings led us to conclude that exposure to continuous-wave MW radiation leads to oxidative/nitrosative stress... associated with spatial memory loss."</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/26396154</p> <p>[SAR: 0.0146 W/kg]</p>	<p>Brain cells: Oxidative stress</p> <p>Learning: spatial memory loss</p>
<p>40</p>	<p>Shahin, S., et al. (2014). 2.45-GHz microwave irradiation adversely affects reproductive function in male mouse, <i>Mus musculus</i> by inducing oxidative and nitrosative stress. <i>Free Radical Research</i>, 48(5), 511–525.</p> <p>“MW [microwave] irradiation induced a significant decrease in sperm count and sperm viability along with the decrease in seminiferous tubule diameter and degeneration of seminiferous tubules... these adverse reproductive effects suggest that chronic exposure to nonionizing MW radiation may lead to infertility via free radical species-mediated pathway.”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/24490664</p> <p>[SAR: 0.018 W/kg]</p>	<p>- Sperm: abnormalities</p> <p>- Oxidative stress</p>
<p>41</p>	<p>Shahin, S., et al. (2013). 2.45 GHz microwave irradiation-induced oxidative stress affects implantation or pregnancy in mice, <i>Mus musculus</i>. <i>Applied Biochemistry and Biotechnology</i>, 169(5), 1727–1751.</p> <p>“We observed that implantation sites were affected significantly in MW-irradiated mice as compared to control. Further, in addition to a significant increase in ROS, hemoglobin (p<0.001), RBC and WBC counts (p<0.001), N/L ratio (p<0.01), DNA damage (p<0.001) in brain cells, and plasma estradiol concentration (p<0.05), a significant decrease was observed in NO level (p<0.05) and antioxidant enzyme activities”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/23334843</p> <p>[SAR: 0.023 W/kg]</p>	<p>- Blood: abnormalities</p> <p>- DNA damage</p> <p>- Oxidative stress</p>

<p>42</p>	<p>Shokri, S., et al. (2015). Effects of Wi-Fi (2.45 GHz) Exposure on Apoptosis, Sperm Parameters and Testicular Histomorphometry in Rats: A Time Course Study. <i>Cell Journal (Yakhteh)</i>, 17(2), 322–331.</p> <p>“Both 1-hour and 7-hour groups showed a decrease in sperm parameters in a time dependent pattern. In parallel, the number of apoptosis-positive cells and caspase-3 activity increased in the seminiferous tubules of exposed rats. The seminal vesicle weight reduced significantly in both 1-hour or 7-hour groups... there should be a major concern regarding the time dependent exposure...in the vicinity of our living places.”</p> <p>http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4503846/</p> <p>[Device]</p>	<p>- Sperm: abnormalities</p> <p>- Testes: abnormalities</p>
<p>43</p>	<p>Sinha RK. (2008). Chronic non-thermal exposure of modulated 2450 MHz microwave radiation alters thyroid hormones and behavior of male rats. <i>International Journal of Radiation Biology</i>, 84(6), 505–13.</p> <p>“Following chronic microwave exposure, rats were found hyperactive and aggressive... Changes in behavioral parameters are also correlated with the trend of changes...in hormonal blood levels of T3[3,5,3'-triiodothyronine] and T4 [thyroxine]... CONCLUSION: Low energy microwave irradiation may be harmful as it is sufficient to alter the levels of thyroid hormones as well as the emotional reactivity of the irradiated compared to control animals.”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/18470749</p> <p>[SAR: 0.0000036 W/kg]</p>	<p>- Thyroid: altered hormones</p> <p>- Behaviour: hyperactive and aggressive</p>
<p>44</p>	<p>Somosy, Z., et al. (1993). Effects of modulated and continuous microwave irradiation on pyroantimonate precipitable calcium content in junctional complex of mouse small intestine. <i>Scanning Microscopy</i>, 7(4), 1255–1261.</p> <p>“... a rapid distribution of pyroantimonate precipitable calcium content...We conclude the low frequency modulated microwave irradiation can modify the calcium distribution without heat effects.”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/8023092</p> <p>[SAR: 0.00164 W/kg]</p>	<p>- Small intestine cells: biochemical changes</p>
<p>45</p>	<p>Somosy, Z., et al. (1991). Effects of modulated and continuous microwave irradiation on the morphology and cell surface negative charge of 3T3 fibroblasts. <i>Scanning Microscopy</i>, 5(4), 1145–1155.</p> <p>“The low frequency modulated microwave irradiation yielded more morphological cell changes... Modulated waves of 0.024 mW/g [W/kg] dose increased the ruffling activity of the cells, and caused ultrastructural alteration in the cytoplasm.”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/1822036</p> <p>[SAR: 0.024 W/kg]</p>	<p>- Fibroblast cells: altered</p>

46	<p>Tök, L., et al. (2014). Effects of melatonin on Wi-Fi-induced oxidative stress in lens of rats. <i>Indian Journal of Ophthalmology</i>, 62(1), 12–15.</p> <p>“... There are poor oxidative toxic effects of one hour of Wi-Fi exposure on the lens...”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/24492496</p> <p>[SAR: 0.1 W/kg]</p>	- Lens of the eye: oxidative stress
47	<p>Trosic, I., & Busljeta, I. (2006). Erythropoietic dynamic equilibrium in rats maintained after microwave irradiation. <i>Experimental and Toxicologic Pathology: Official Journal of the Gesellschaft Für Toxikologische Pathologie</i>, 57(3), 247–251.</p> <p>“Such findings are considered to be indicators of radiation effects on BM [bone marrow] erythropoiesis consequently reflected in the PB[peripheral blood]”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/16410191</p> <p>[SAR: 1.25 W/kg]</p>	- Blood cells: altered
48	<p>Trosic, I., et al. (2004). Investigation of the genotoxic effect of microwave irradiation in rat bone marrow cells: in vivo exposure. <i>Mutagenesis</i>, 19(5), 361–364.</p> <p>“The frequency of micronucleated PCEs [polychromatic erythrocytes] was also significantly increased... the findings revealed a transient effect on proliferation and maturation of erythropoietic cells in the rat bone marrow and the sporadic appearance of micronucleated immature bone marrow red cells.”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/15388808</p> <p>[SAR: 1.25 W/kg]</p>	- Blood cells: altered
49	<p>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. <i>Biological Trace Element Research</i>, 143(3), 1640–1650.</p> <p>“In conclusion, 2.45-GHz electromagnetic radiation caused oxidative stress in the heart of rats.”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/21360060</p> <p>[SAR: 0.1 W/kg]</p>	-Heart: oxidative stress
50	<p>Wang, B., & Lai, H. (2000). Acute exposure to pulsed 2450-MHz microwaves affects water-maze performance of rats. <i>Bioelectromagnetics</i>, 21(1), 52–56.</p> <p>“These results show that acute exposure to pulsed microwaves caused a deficit in spatial ‘reference’ memory in the rat.”</p> <p>http://www.ncbi.nlm.nih.gov/pubmed/10615092</p> <p>[SAR: 1.2 W/kg]</p>	- Behaviour: spatial memory affected

ENDNOTES

- ¹ Limits of Human Exposure to Radiofrequency Electromagnetic Energy in the Frequency Range from 3 kHz to 300 GHz. Safety Code 6. http://www.hc-sc.gc.ca/ewh-semt/pubs/radiation/radio_guide-lignes_direct/index-eng.php
- ² Wi-Fi is often used instead of the term "wireless local area network" (WLAN).
- ³ 5 GHz, used for radio broadcasts and also referred to as Wi-Fi, is not covered in this report.
- ⁴ Canadians for Safe Technology web page: <http://c4st.org/news/category/wifi-in-schools/>
- ⁵ Health Canada: "Guidelines are departmental documents that are used to interpret legislation and/or regulation. Although they may be derived from legislation and are often used to advise how one might comply with a regulation, guidelines do not have the force of law." <http://www.hc-sc.gc.ca/ahc-asc/legislation/index-eng.php> [accessed 15 November 2015]
- ⁶ Includes, but not limited to, video-game consoles, cell (mobile) phones, smart phones, "smart" utility (electricity, water, gas) meters, cell antennae/towers, wireless baby monitors, cordless phones.
- ⁷ Safety Code 6. Preface page 1. http://www.hc-sc.gc.ca/ewh-semt/pubs/radiation/radio_guide-lignes_direct/index-eng.php
- ⁸ Health Canada, Understanding Safety Code 6: "While Health Canada recommends limits for safe human exposure, Health Canada does not regulate the general public's exposure to electromagnetic RF [radiofrequency] fields. However, many provinces and territories apply the exposure limits in Safety Code 6 for general exposure. Wireless devices and their associated infrastructure (such as cell towers) are regulated by Industry Canada, and are required to comply with Safety Code 6." http://www.hc-sc.gc.ca/ewh-semt/pubs/radiation/radio_guide-lignes_direct/safety_code_6-code_securite_6-eng.php [accessed 15 November 2015]
- ⁹ The Prudent Avoidance Policy was passed in 2008. <http://app.toronto.ca/tmmis/viewAgendaItemHistory.do?item=2007.HL10.3> <http://www.toronto.ca/legdocs/mmis/2007/hl/bgrd/backgroundfile-8919.pdf>
- ¹⁰ Updated March 2015. Available upon special request from Health Canada or from Margaret Friesen at safer.wireless@gmail.com
- ¹¹ See "Research ignored by Health Canada". This report also identifies the many studies omitted by the Royal Society of Canada's expert panel in their report on this issue. <http://c4st.org/website-pages/pages/health-canada-submissions.html>
- ¹² Government of Canada, Parliamentary Standing Committee on Health (HESA)- Day 1: Meeting 54 - 24 March 2015: <http://www.parl.gc.ca/HousePublications/Publication.aspx?DocId=7892123&Language=E&Mode=1>
- ¹³ WiFi Safety in Schools - 16:9. The Bigger Picture (about 14 minutes): October 2010 <http://www.youtube.com/watch?v=KN7VetsCR2I>
- ¹⁴ Janis Hoffmann - Parents for Safe Schools (personal communication). E-mail: parentsforsafeschools@gmail.com
- ¹⁵ Baan, R., et al. (2011). Carcinogenicity of radiofrequency electromagnetic fields. *Lancet Oncol.*, 12(7), 624–626. http://www.iarc.fr/en/media-centre/pr/2011/pdfs/pr208_E.pdf
- ¹⁶ WHO/IARC Press Release: http://www.iarc.fr/en/media-centre/pr/2011/pdfs/pr208_E.pdf
- ¹⁷ Hardell, L., et al. (2013). Use of mobile phones and cordless phones is associated with increased risk for glioma and acoustic neuroma. *Pathophysiology: The Official Journal of the International Society for Pathophysiology / ISP*, 20(2), 85–110.
- ¹⁸ Coureau, G., et al. (2014). Mobile phone use and brain tumours in the CERENAT case-control study. *Occupational and Environmental Medicine*, 71(7), 514–522.
- ¹⁹ Canadians for Safe Technology (C4ST) web page: <http://www.c4st.org/HCSubmissions>
- ²⁰ Government of Canada, Parliamentary Standing Committee on Health (HESA) Report (2015): Radiofrequency Electromagnetic Radiation and the Health of Canadians. <http://www.parl.gc.ca/housepublications/publication.aspx?DocId=8041315>
- ²¹ Canadian Medical Association Journal (CMAJ). Scientists decry Canada's outdated Wi-Fi safety rules. *CMAJ June 16, 2015 vol. 187 (9)* First published May 11, 2015, doi:10.1503/cmaj.109-5061. Available at: <http://www.cmaj.ca/content/187/9/639.full>

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- ²² <https://emfscientist.org/>
- ²³ Gandhi, O. P., et al. (1996). Electromagnetic absorption in the human head and neck for mobile telephones at 835 and 1900 MHz. *IEEE Trans Microw Theory Tech*, 44(10), 1884–96.
- ²⁴ Gandhi, O. P., et al. (2012). Exposure limits: the underestimation of absorbed cell phone radiation, especially in children. *Electromagnetic Biology and Medicine*, 31(1), 34–51. <http://www.ncbi.nlm.nih.gov/pubmed/21999884>
- ²⁵ Gittleman, H. R., et al. (2015). Trends in central nervous system tumor incidence relative to other common cancers in adults, adolescents, and children in the United States, 2000 to 2010. *Cancer*, 121(1), 102–112.
- ²⁶ Herbert, M. R., & Sage, C. (2013a). Autism and EMF? Plausibility of a pathophysiological link - Part I. *Pathophysiology: The Official Journal of the International Society for Pathophysiology / ISP*, 20(3), 191–209.
- ²⁷ Herbert, M. R., & Sage, C. (2013b). Autism and EMF? Plausibility of a pathophysiological link. Part II. *Pathophysiology: The Official Journal of the International Society for Pathophysiology / ISP*, 20(3), 211–234.
- ²⁸ Government of Canada, Parliamentary Standing Committee on Health (HESA)- Day 3: Meeting 58 -28 April 2015: Dr. Martha Herbert, Assistant Professor, Harvard Medical School, Massachusetts Hospital, as an individual. <http://www.parl.gc.ca/HousePublications/Publication.aspx?DocId=7945116&Language=E&Mode=1>
- ²⁹ Canadian Teacher Magazine. CTF [Canadian Teachers' Federation] sounds the alarm on Wi-Fi (page 46). http://www.canadianteachermagazine.com/issues/2015/CTM_JanFeb15/index.html
- ³⁰ Canadian Teachers' Federation- The Use of Wi-Fi in Schools - Briefing document. <http://www.ctf-fce.ca/en/Pages/Issues/Wi-Fi-Briefing-Document.aspx>
- ³¹ <http://www.oecta.on.ca/wps/portal/>! <http://www.safeschool.ca/uploads/WiFiPositionpaper2.pdf>
- ³² Environmental Health Trust website: <http://ehtrust.org/>
- ³³ <http://kompetenzinitiative.net/KIT/KIT/progress-in-south-tyrol-applying-the-precautionary-principle/>
- ³⁴ US National Library of Medicine National Institutes of Health website: <http://www.ncbi.nlm.nih.gov/pubmed>
- ³⁵ EMF Portal website: <http://www.emf-portal.de/suche.php?l=e>
- ³⁶ Safety Code 6. The SAR Basic Restrictions (the peak spatially-averaged SAR for the head, neck and trunk, averaged over any 1 g of tissue and averaged over any 6 minute reference period) (page 5). http://www.hc-sc.gc.ca/ewh-emt/alt_formats/pdf/consult/_2014/safety_code_6-code_securite_6/final-finale-eng.pdf;
- ³⁷ Reuter et al. (2010). Oxidative stress, inflammation and cancer: How are they linked? *Free Radic Biol. Med.* 49 (11):1603-1616.
- ³⁸ Dasdag, S., & Akdag, M. Z. (2015). The link between radiofrequencies emitted from wireless technologies and oxidative stress. *Journal of Chemical Neuroanatomy*. doi:10.1016/j.jchemneu.2015.09.001;
- ³⁹ BioInitiative Report "A rationale for biologically-based exposure standards for low-intensity electromagnetic radiation" and updates. <http://www.bioinitiative.org/>
- ⁴⁰ First US Public School District Limits Wi-Fi Radiation Exposure to Students and Staff. <http://www.digitaljournal.com/pr/2688700#ixzz3n6Omi2DM>
- ⁴¹ Not all Wi-Fi enabled devices are mobile.
- ⁴² Redmayne, M. (2015). International policy and advisory response regarding children's exposure to radio frequency electromagnetic fields (RF-EMF). *Electromagnetic Biology and Medicine*, 1–9.
- ⁴³ International Guidance Levels: <http://www.powerwatch.org.uk/science/intguidance.asp>