

Public health and the radio frequency radiation emitted by cellphone technology, smart meters and WiFi

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ABSTRACT

This paper argues that the prevailing official narrative in New Zealand concerning the relationship between public health and the radio frequency emissions (RF) from cellphone technology, WiFi and electricity smart meters is scientifically and ethically flawed. The main regulatory document in the area, NZS2772.1:1999, is 20 years out of date and ignores existing laboratory evidence disproving its core assumption that the only biological effect of non-ionising radiation is tissue heating. This and further laboratory evidence for harmful effects of RF continues to be ignored, nominally on the contradictory grounds that (a) cellphone manufacturers say their products now emit less RF than early models, so early lab studies exposed tissue to RF levels higher than those now relevant (b) given the lack of actual data on population exposures either then or now, all laboratory evidence is unconvincing anyway. The official narrative further opines that since there exist both laboratory and epidemiological studies concluding that RF is not biologically harmful, as well as studies concluding that RF is harmful, the appropriate response is to count up the number on each side, declare the “weight of evidence” to be such that “causation is not proven” and, pending unspecified further studies, continue exposing to unmonitored levels of RF the entire population of the country, none of whom has given informed consent to participate in the experiment. This approach is obviously unethical. It is also unacceptable scientifically. First, the algebraic model is flawed: studies that do find a harmful effect of RF are not invalidated by differently constructed studies that fail to find an effect. Secondly, while causation is relatively easy to study in the laboratory, it is difficult if not impossible to prove epidemiologically, given that (1) the very narrative under discussion has ensured that there is now no unexposed control group and (2) interpretation of timeline correlation studies is hampered by changes in the way new cancer registrations have been recorded over the years and the perennial problem of multiple possible causal factors. The present paper concludes that a precautionary approach is justified, and ends with a number of specific suggestions on how to start implementing such an approach.

Properties of the various standard divisions of the electromagnetic spectrum are summarised in Table 1.

Electromagnetic radiation is generally divided into two classes: ionising and non-ionising. Ionising radiation (gamma rays, x-rays and ultraviolet light) has enough energy to knock electrons off molecules, and is a known carcinogen. Non-ionising radiation (visible and infrared light, microwaves and radio waves) carries less energy than needed to knock electrons off molecules, and in the past has been thought to affect biological tissue only by means of heating

it. Hence many of the regulatory standards used around the world permit exposure of the public to non-ionising radiation up to limits based solely on intensities that cause tissue heating. Much of North America and Western Europe, Japan, Australia and New Zealand rely on guidelines put out in 1998 by the International Commission on Non-ionising Radiation Protection (ICNIRP).¹ ICNIRP guidelines allow exposure of the public to radiation at the frequencies emitted by cellphone towers and WiFi transmitters up to a power density of 10 watts per square meter.

Table 1: Divisions of the electromagnetic spectrum.

Region of spectrum	Frequency (Hz)	Frequency (GHz)
Gamma ray	10^{21} – 10^{24}	10^{12} – 10^{15}
X-ray	10^{18} – 10^{20}	10^9 – 10^{11}
Ultraviolet light	10^{15} – 10^{16}	10^6 – 10^7
Visible light	4 – 7×10^{14}	4 – 7×10^5
Infrared light	10^{12} – 10^{14}	10^3 – 10^5
Microwave	10^{10} – 10^{11}	10 – 10^2
Radio wave	10^4 – 10^{11}	10^{-5} – 10^2

The relevant regulatory document in New Zealand is NZS 2772.1:1999, a pdf of which can be purchased from the Standards New Zealand website for \$128.70 + GST. Since New Zealand law can be downloaded for free, this charge underlines the fact that NZS 2772.1:1999 is not a statutory document, merely a set of recommendations. To emphasise the commercial nature of the document, NZS 2772.1:1999 starts with the statement “Standards New Zealand will vigorously defend the copyright in this Standard. Every person who breaches Standards New Zealand’s copyright may be liable to a fine not exceeding \$50,000 or to imprisonment for a term not to exceed three months. If there has been a flagrant breach of copyright, Standards New Zealand may also seek additional damages from the infringing party, in addition to obtaining injunctive relief and an account of profits.” This point being made, NZS 2772.1:1999 goes on with a disclaimer “There is scientific research, including epidemiology, which has suggested associations between some adverse health effects and exposure to RF [radio frequency] fields at levels lower than the basic restrictions specified in this Standard, however causation has not been shown.”

The aim of the present article is to discuss some of the scientific research referred to by this disclaimer, and as a result argue that current public policy in New Zealand is inadequate to protect public health.

Evidence from laboratory studies

Early laboratory studies in this area were largely concerned to investigate the underlying assumption of documents like NZS 2772.1:1999 that heating is the main, if not only, biological effect of non-ionising radiation.

In fact evidence disproving this hypothesis was already plentiful by 1999.

As far back as 1967, a paper in *Nature* reported that microwaves cause lymphoblastoid transformation of lymphocytes *in vitro* at intensities specifically shown not to result in any changes in temperature.² In 1974, well-controlled interventional experiments showed that microwaves caused chromosome damage in both hamster and human cell cultures, again at measurably non-thermal intensities.³ By 1993 at least two major reviews had been published summarising a plethora of further evidence for non-thermal effects of microwave radiation.^{4,5} None of these papers is cited in NZS 2772.1:1999’s summary of existing evidence, which discusses only studies reporting negative or inconclusive findings.

Since 1999, considerable further work has appeared. In 2005, Belyaev reviewed 115 papers showing harmful non-thermal effects of RF on a variety of biological factors.⁶ Five years later, the same author reviewed the complex dependence of many of the reported effects on various physical and biological parameters, none of which is controlled in a number of studies that purportedly fail to replicate the original findings.⁷

Reading this literature is not easy. One difficulty is that different studies use different metrics to quantify the amount of RF delivered: power density in watts (W) per square metre or microwatts (μ W) or milliwatts (mW) per square centimetre; electric field strength in volts per meter; specific absorption rate in watts per kilogram. Another problem is that, because US government funding in the area was reportedly shut down in the late 1970s, a good deal of the work was done in

the former Soviet Union and published in Russian: only a summary of this is available in English.⁸ However, these are relatively trivial problems compared with the more fundamental complexities the work reveals. Essentially, average RF power density is not the best predictor of biological effect. For some parameters, short pulses of RF such as those emitted by electricity smart meters have worse effects than continuous irradiation.^{9,10} Within any given temporal emission pattern dose-response curves are counterintuitive, showing dose windows where biological effects are greater than those caused by either larger or smaller doses.^{11–14} Nittby et al^{15,16} summarise repeated attempts to replicate Frey's 1975 report¹⁷ that 30 min of exposure to either pulsed or continuous 1.2 GHz waves with average power densities a fifth of that permitted by ICNIRP guidelines increased the permeability of the rat blood brain barrier (BBB) to fluorescein. These attempts were apparently unsuccessful, until it was realised that an inverted-U shaped dose response curve held—at which point it became clear that the parameters involved in mobile phone use are particularly effective at damaging the BBB. Given that the BBB is vitally important in protecting brain neurons from environmental influences, this effect may underpin later findings from Kaplan's lab that exposure of rats to RF levels perfectly legal under NZS2772.1 causes death of pyramidal neurons in the CA region of hippocampus.¹⁸ Since a properly functioning hippocampus is essential for memory formation, this suggests that levels of RF exposure currently legal in New Zealand might well contribute to the development of dementia.

Even more worryingly, there seems to be no lower limit on the amount of RF that can cause harm. Exposure of quail eggs to 900 MHz (0.9 GHz) RF at doses as low as 0.0025 watts per square meter (cf NZS2772.1:1999's 10 watts per square meter) causes significant oxidative stress—overproduction of free radicals/reactive oxygen species—and oxidative damage to DNA.¹⁹ Given that oxidative stress is “common for many types of cancer cell that are linked with altered redox regulation of cellular signalling pathways”²⁰ and has also been linked to atherosclerosis, Alzheimer's disease,

arthritis and diabetes, there would seem to be significant reason for concern about allowing the public to be routinely exposed to 4,000 times the level of RF known to cause oxidative stress ($10 \text{ W/m}^2 = 4,000 \text{ times } 0.0025 \text{ Watts/m}^2$)

In summary, there is laboratory evidence that RF at power densities a tiny fraction of those permitted by NZS2772.1:1999 causes (a) overproduction of free radicals (b) opening of the blood brain barrier (c) damage to DNA (d) death of hippocampal neurons and (e) transformation of lymphocytes to immortal cell lines that spontaneously replicate. Obviously all of these provide plausible mechanisms by which RF exposure might cause any number of disease states, including cancer.

Does all this translate to proven carcinogenesis in lab animals? Surprisingly little has been published on that question, perhaps partly because rats live for only about two years at best, which may not be enough time for cancer to develop. One 1997 report showed that genetically lymphoma-prone mice were more likely to develop lymphomas if exposed to pulsed 900 MHz RF.²¹ But later, Adey and colleagues reported that intermittent exposure of rats to 836 MHz RF for two years had either no effect²² or (counterintuitively) a protective effect²³ on the formation of CNS cancers, with exposed rats developing fewer tumours than controls. As with the *in vitro* experiments, precise details of exposure parameters may be important in determining biological effects.

Epidemiological evidence

Epidemiology is a discipline beset by multiple problems. To ask whether some agent causes a particular harm, the most scientifically watertight methodology is to expose a test group of subjects to the putative agent and compare them with a control group who have never been exposed. Ideally both groups should be uniform with regard to all other possible causes of the harm, or at least randomised from a heterogeneous population. However, this approach becomes significantly problematic when the subjects under study are human. Deliberately exposing humans to potential harm is generally considered ethical if the participants give their informed consent to participate in the experiment. But when no informed consent is ever solicited, there

are multiple, non-randomised factors that might contribute to any increased incidence of harm, and (thanks to the increasingly inescapable exposure of everyone to RF from mobile phones and their base stations, smart meters and WiFi) there now exists no unexposed control group, epidemiology is reduced to studying timelines and trying to draw correlative conclusions.

In this regard, one question that on the face of it should be relatively easy to answer is whether or not the incidence of brain cancers has increased since the introduction of mobile phones. Here, despite the fact that a 2008 editorial in the journal *Surgical Neurology* cites no fewer than seven published reports detailing an increase in the incidence of nerve sheath and brain tumors, particularly very malignant forms such as glioblastoma multiforme,²⁴ we have repeatedly been assured that the incidence of brain cancer has not increased since the introduction of mobile phones. But quite apart from a concerning refusal even to acknowledge the existence of the many papers that do show increases, a number of confounds render insecure a conclusion from the rest of the literature that the incidence of brain cancers has not increased since introduction of mobile phones.

First, papers in this area need to be read quite closely, because the conclusions in their abstracts sometimes fail to reflect the data reported. For example, Vocht et al²⁵ report data that clearly indicate an increased risk of brain cancers related to mobile phone use. They then raise and demolish in their discussion section all reasonable arguments against the validity of this conclusion (implying that they believe their own data do show an increased risk). Yet in the abstract of the paper they say “These data do not indicate a pressing need to implement a precautionary principle by means of population-wide interventions to reduce RF exposure from mobile phones.” Aydin et al²⁶ also adopt this approach. Further examples are described by Kundi²⁷ and Cherry.²⁸

A second type of confound is pointed out by Hardell and Carlberg.²⁹ The Swedish Cancer Register shows no statistically significant increase in the incidence of brain cancers between 1998 and 2013, which fact has repeatedly been used to dismiss epidemiological evidence of a risk. However,

the Causes of Death Register for the same population shows a highly statistically significant annual percentage change of +22.6% between 2008–2013. This appears to be a localised fault with the Swedish Cancer Register, since Hardell and Carlberg report that the Danish Statens Serum Institut Cancerregisteret reveals an increase in age-standardised incidence of brain tumours of +42.2% among men and +46.1% among women during 2003–2012.

The problem with the Swedish Cancer Register is never clarified, but some general possibilities are suggested by the New Zealand Ministry of Health’s database of new cancer registrations. Here cancers diagnosed at death only started to be registered in 1972, cancers diagnosed in private hospitals were not reliably registered until 1974 and in 1994 the Cancer Registry Act mandated reporting of cancers by diagnostic laboratories, leading to a sharp increase in registration rates. Overlapping with this latter increase, introduction of PSA testing in the early 1990s coincided with a sudden increase in the diagnosis of prostate cancers. In the early 2000s some conditions began to be considered malignant (eg, polycythaemia vera in 2003) while others ceased being considered malignant (eg, superficial transitional cell carcinoma of the bladder in 2005). Since many cellphone users seem to have gradually switched over the last decade from holding their phones against their ears to texting or using speaker mode, exposure of trunk organs is now probably greater than exposure of the brain. But the above administrative changes preclude any clean time-line correlation of total cancer rates with changes in cellphone use.

Returning to published work, what about case-control studies of brain tumours? Khurana et al³⁰ meta-analyse 11 peer-reviewed epidemiologic studies and conclude that using a cellphone for 10 years or more approximately doubles the risk of being diagnosed with a brain tumour on the same side of the head as that preferred for cellphone use. This study specifically includes no participants who are also included in the pooled case-controlled studies of Hardell et al,³¹ which found odds ratios for glioma of 5.9 for analogue cellular phones, 3.7 for digital cellular phones and 2.3 for cordless phones.

In contrast, the largely industry-funded 13 country INTERPHONE study³² reports

overall odds ratios (ORs) that are actually less than 1.0 for gliomas in all centres except Australia, France and New Zealand, where <5% industry funding is declared and odds ratios are not specified in the final report. An OR <1.0 implies either a deficit in methodology or a genuine protective effect of cellphone use. Most commentators have assumed the methodological deficit explanation, although some of the animal data cited in the previous section do suggest the possibility of a genuine protective effect at some exposure parameters. One obvious methodological problem with the INTERPHONE study is that amount of cellphone use was determined simply by asking participants to recall the number of hours a week they had used a cellphone over the last *n* years. Memory is notoriously unreliable, so this methodology could introduce bias in either direction. There is no way of knowing whether such bias contributes to the results, but the highest decile of cumulative time that mobile phones were recalled as being used (>1,640 hours) was associated with significantly increased probability of glioma (OR 1.4; 95% CI 1.03–1.89).

Finally, Kundi and Hutter³³ review a number of studies on the health effects of mobile phone base stations (cell towers) and as a result recommend exposure limits 10,000 times lower than NZS2772.1:1999.

Discussion

So why do regulators still use the 1998 ICNIRP/IEEE exposure limits? One answer is that, while the above emphasises papers that do show harmful effects of weak RF fields, there are also published reports in the literature concluding that RF has no harmful effects. The critical question for public policy is how this dichotomy should be interpreted.

A priori, there are four possible conclusions:

1. Most studies showing no harmful effects of RF are flawed.
2. Most studies showing harmful effects of RF are flawed.
3. Most studies on both sides are OK as far as they go. The important thing is the weight of evidence. This is presently such that causation is not proven. More research is needed.

4. Most studies on both sides are OK as far as they go. Abundant evidence already exists that RF *at some intensities and configurations* has harmful effects on some aspects of biological function. Therefore a precautionary approach is needed.

How does each of these conclusions stack up?

Conclusion 1 (that many or most studies showing no harmful effects of RF are flawed) is actually supported by a certain amount of published evidence. For example, statistically speaking, papers funded by the wireless industry are twice as likely as papers not funded by the wireless industry to report no harmful effects of RF.³⁴ Sometimes scientists funded by the wireless industry deliberately design their studies to produce the answer they know their funders want.³⁵ Sometimes honestly done industry funded work is suppressed if it produces the ‘wrong’ answer.³⁶ Pearce³⁷ summarises a number of documented situations in which epidemiologists have failed to declare conflicts of interest in relation to studies of other putative harms, and there is no reason to suppose that the wireless industry is any less active in this regard than the tobacco, pharmaceutical and chemical industries.

Conclusion 2, that most of the peer-reviewed papers which do show harmful effects of RF are less than credible, is on the present author’s understanding not supported by any published evidence. Yet it appears to be a core tenet of the official narrative that the entire corpus of work cited in the Evidence from Laboratory Studies section of the present paper can legitimately be ignored, on the grounds that no data exist on actual population exposures to RF.

Importantly, this approach avoids attacking the scientific validity of the lab studies on their own terms. Rather it argues that, since the emissions of cellphones have reportedly decreased over the last decade or so, all the lab experiments showing harmful effects of emission levels current a decade ago would have to be redone using current emission values before the results could reasonably be taken into account in setting policy. Further, since the wireless industry keeps shifting the goal posts in this regard, there is reason to believe that it will always

be possible to dismiss future lab studies as not demonstrably reflective of the current exposure environment.

This position is problematic. For one thing, the non-specific demand for population exposure figures sets an impossibly high bar. The RF output of cellphones varies with brand, year of manufacture and, most importantly, distance from a cell tower: the further any given phone is from a tower, the more RF it emits in an attempt to handshake with the tower. Actual measurement of emissions in, for example, a crowded city street populated by hundreds of people all walking purposefully about with their noses in their devices, is not feasible. The “PhoneGate” scandal, which recently revealed that measurements made by the French Government in 2015 showed 90% of the hundreds of phones tested emitting significantly more than the RF figures claimed by the manufacturer, suggests that it is not possible to estimate emissions with any degree of accuracy. There appear to be no official measurements at all available for cell tower emissions, perhaps partly because these (a) depend on both the configuration of individual antennae and local topography and are thus unique to each tower, (b) vary depending on traffic—the more cellphones are attempting to contact a particular tower at any given moment, the more RF the tower emits—and (c) again, the industry keeps

changing the goal posts (3G, 4G, now 5G). WiFi emissions come in either 2.4 GHz or 5 GHz frequencies, at intensities that depend entirely on (i) how many and what kinds of WiFi routers are active in the vicinity at any given moment, (ii) the distances between these routers and the measuring instrument and (iii) what concrete or earth barriers there are in the intervening space.

An arguably even greater problem concerns the fineness of the spatial grain that would be necessary in any meaningful measurement of population exposure. Figure 1 shows power density at various distances from an electricity smart meter. A smart meter is essentially a radio transmitter mounted on the wall of a dwelling: mesh smart meters transmit measurements of electricity usage in their dwelling to neighboring meters in the mesh, then collector smart meters collate the electricity use figures from all surrounding mesh meters and send the results directly to the electricity company. The figures used to construct Figure 1 are taken from a 2008 application to then Auckland City by Metrix (on behalf of Mighty River Power) for a resource consent allowing installation of smart aka ‘advanced’ meters throughout the Hauraki Gulf islands. The resulting consent allows each meter to emit 250ms bursts of RF, 96 times a day, 24/7, at the power densities shown in Figure 1.

Figure 1: RF emissions from an electricity smart aka advanced meter operating according to parameters allowed by Auckland Council.

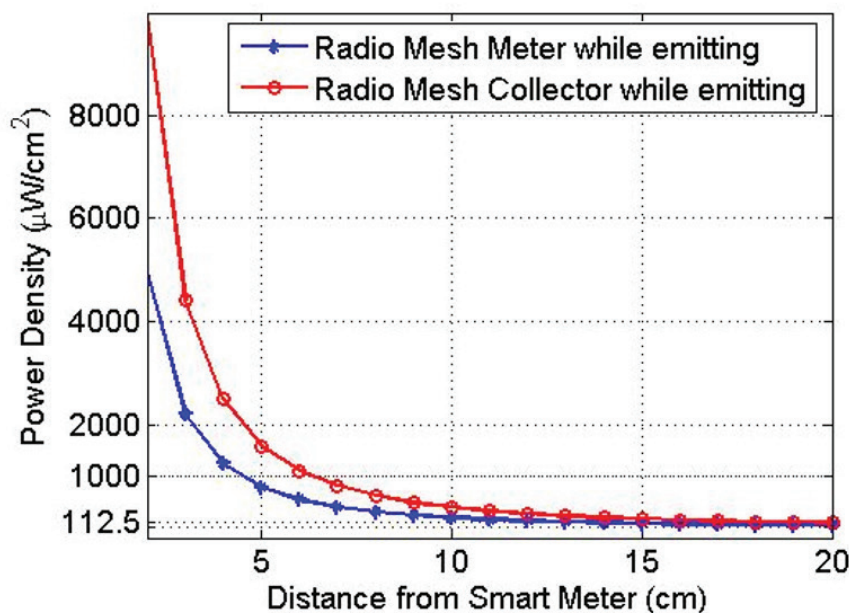


Figure 1 demonstrates that during the brief emission periods, these meters routinely expose people in their vicinity to very much more than the $0.25\mu\text{W}/\text{cm}^2$ of RF reported to cause overproduction of free radicals¹⁹ and indeed at short distances from the meter to considerably more than even NZS2772.1:1999's recommended limit of $1,000\mu\text{W}/\text{cm}^2$. This latter fact was hidden from the bureaucrat granting the consent by averaging emitted power over six minutes, during most of which time the meter is not emitting. This practice is reasonable on the assumption that tissue heating is the only biological effect of RF, but otherwise akin to contending that a single bullet is harmless, because if you average the energy it imparts over a month, being hit by a bullet is no worse than being brushed by a feather.

All of this renders the demand for current population exposure levels safely unfulfillable.

But in any case, the main official narrative in New Zealand at present is essentially Conclusion 3: weight of evidence, causation not proven, more research needed (but don't ask us for funding to do it, you'll have to get that from the industry). When analysed a little more closely, this conclusion appears to be based on an algebraic model. The implicit assumptions are that each negative study cancels out one positive study, with an algebraic sum of zero indicating no effect. Therefore, the argument seems to go, we should continue exposing the public to RF and doing epidemiological studies to see if it harms them, until either papers delivering one answer significantly outnumber papers delivering the other answer, or causation is proven. Unfortunately, there are a number of problems with this position, too.

First, it is completely unethical. What university or hospital Ethics Committee would approve such deliberate experimentation on human subjects who, so far from having given informed consent to participate in the experiment, will insist on doing things like demonstrating in the streets in a fruitless attempt to prevent the erection of cell towers metres from their homes?

Secondly, the algebraic model is overly open to manipulation. Given the preponderance of industry-funded studies showing no effect,³⁴ it might reasonably be seen that all Big Wireless has to do to tip the

'weight of evidence' in their favour is fund more studies than can be done without their funding. Given the depth of the industry's pockets and the current scarcity of government funding for any sort of research, this might not prove too difficult.

Thirdly, definitive proof of causation is problematic in general. Psychologist Daniel Wegner³⁸ argues that any cause-effect attribution is based on three factors: (i) the timing of the perceived cause, which must occur before the perceived effect, but not too far before it. (This makes attribution of cause especially difficult for long-latency disorders like cancer). (ii) The consistency of the perceived cause with the perceived effect. (This boils down to the existence of plausible mechanisms. The laboratory studies documented above show that RF produces a plethora of biological effects likely to result in cancer and any number of other diseases). (iii) The exclusivity of the perceived cause, ie, the absence of any other possible cause of the perceived effect. (As mentioned earlier, this is a perennial problem for epidemiology).

Seen in this light, the wireless industry's familiar mantra "causation not proven" carries little weight. If a particular harm (cancer, for example) has increased since the introduction of a suspected agent (RF of the sort emitted by cellphones and their base stations, WiFi and smart meters)—and the suspected agent has been repeatedly shown to produce biological effects likely to result in that harm (overproduction of free radicals, opening of the blood brain barrier, damage to DNA, transformation of cultured cells to immortal cell lines that spontaneously replicate)—the jury should no longer be out on whether the public should be protected from the agent.

Finally, the "weight of evidence" argument fares no better. If even a fraction of the peer-reviewed papers describing harmful effects of low-level RF are reporting good science, it is unethical to ignore them. Positive results do not go away just because it is possible to design slightly different studies that return negative results.

Conclusion 4 is therefore the author's preferred response to the available evidence. The biological effects of RF are clearly complicated, but there is no longer any reasonable doubt that under some

circumstances, RF levels common in the present environment do have harmful biological effects. Like its cousin ionising radiation, RF is undoubtedly useful. However, until more is known about when and how RF does or does not cause harm, the precautionary principle must be applied as energetically with RF as it is with ionising radiation. In fact, even NZS2772.1:1999 counsels this approach (albeit in the weakest terms imaginable), advocating “minimising, as appropriate, RF exposure which is unnecessary or incidental to achievement of service objectives or process requirements, provided this can be readily achieved at modest expense”.

The next section offers some concrete suggestions about how to make a start on a genuine implementation of the precautionary principle with regard to RF.

Recommendations

1. For government regulators and their advisors

- Drag NZS2772.1:1999 into the 21st century. Stop ignoring evidence that heating is NOT the only biological effect of RF. Do not allow the committee considering the revision of NZS2772 to be dominated by bureaucrats with no scientific training, representatives of the wireless industry or scientists with a history of acting as paid industry consultants. Dare to break step with the rest of the English speaking world: look to Europe, China and Russia for examples of more biologically sensitive regulations.³⁹
- Once NZS2772.1:1999 has been revised, incorporate the revision into a coherent statute, which takes the precautionary principle seriously and sets legally enforceable limits on RF emissions. Repeal legislation permitting telcos to erect cell towers on roadside berms without a permit. Do not allow telcos to adopt measures explicitly designed to “migrate their customers” away from copper landlines. Especially in areas where fibre is not available, force Chorus to invest in replacement of aging copper line networks. Extend to all public transport existing legislation

banning the use of cellphones on airplanes—the issue is not whether radio emissions affect the vehicle’s navigation instruments, it is whether sitting in a metal box surrounded by radio transmitters impacts passengers’ health.

- Monitor compliance—pending the above, at least compliance with NZS 2772.1:1999 as it stands. Measure the emissions of a selection of cellphones, at various distances from a cell tower. Do not then emulate the French Government by refusing until threatened with legal action to make public the power densities measured at distances from the phone relevant to its carriage in a bra or pants pocket. If radiation values a few cm away from any phone do exceed the 1,000 μ W/cm² limit specified by NZS2772.1:1999, take appropriate action.
 - Ahead of regulatory reform, schools and universities could profitably lead the way in adopting safer practices. Make campuses cellphone and WiFi free zones, with internet access provided by cabled LANs.
- ### 2. For physicians
- Ask your patients where they carry their cellphones. See if you can predict from the answer the location of their primary cancer.
 - If you find that you can, do something about it. Communicate with colleagues. Collate data. Write a paper for the *NZMJ*.
- ### 3. For everyone
- Find out whether you have an electricity smart meter. If no meter readers come round any more, you probably do. To find out for sure, DO NOT peer closely at the meter (see Figure 1). Ask the power company. If you do have a smart meter, persevere until you find a power company willing to replace it with a dumb meter (ie, a smart meter from which the radio transmitter has been removed). In the meantime, avoid sleeping or sitting for long periods just through the wall from a smart meter.

- If you must use a cellphone, avoid lengthy conversations. Do not hold the device against your ear; use speaker mode or text. If you need a long chat, use a landline—preferably not one accessed through a cordless phone. All cordless phones emit RF, although cordless landlines emit less than cellphones.
- Do not carry in your clothing any cellphone that is not either in airplane mode or switched off. Cellphones not in one of those conditions continually emit RF, even when not in use. Figure 1 illustrates how much more intense these emissions are very close to the phone.
- Do not use a WiFi-enabled laptop on your lap, for the same reason.
- Preferably obtain your home internet access through a cable, instead of via WiFi. Failing that, turn off household WiFi at night.
- Stop even taking an active phone into the bedroom at night, let alone sleeping with it under your pillow.
- Restrict cellphone use to emergencies.
- Gradually phase out device use altogether.

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Nil.

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REFERENCES:

1. International Commission on Non-Ionizing Radiation Protection. ICNIRP Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 GHz). *Health Physics*. 1998; 74(4):494–522.
2. Stodolnik-Baranska W. Lymphoblastoid transformation of lymphocytes in vitro after microwave irradiation. *Nature*. 1967; 214:102–103.
3. Chen KM, Samuel A, Hoopingarner R. Chromosomal aberrations of living cells induced by microwave radiation. *Environmental Letters*. 1974; 6(1):37–46.
4. Adey WR. Joint actions of environmental nonionizing electromagnetic fields and chemical pollution in cancer promotion. *Environmental Health Perspectives*. 1990; 86:297–305.
5. Adey WR. Biological effects of electromagnetic fields. *Journal of Cellular Biochemistry*. 1993; 51:410–416.
6. Belyaev I. Non-thermal biological effects of microwaves. *Microwave Review*. 2005; 11(2):13–29.
7. Belyaev IY. Dependence of non-thermal biological effects of microwaves on physical and biological variables: implications for reproducibility and safety standards. *European Journal of Oncology Library*. 2010; 5:187–217.
8. Pakhomov AG, Murphy MR. A comprehensive review of the research on biological effects of pulsed radiofrequency radiation in Russia and the former Soviet Union. In *Advances in Electromagnetic Fields in Living Systems*. (2000); Ed. JC Lin Kluwer academic/Plenum 3: 265–302.
9. Czerska EM, Elson EC, Davis CC, et al. Effects of continuous and pulsed 2450-MHz radiation on spontaneous lymphoblastoid transformation of human lymphocytes in vitro. *Bioelectromagnetics*. 1992; 13(4):247–259.
10. Chiang H. Microwave and ELF electromagnetic field effects on intercellular

- communication. Proceedings of the 20th Annual International Conference of the IEEE Engineering in Medicine and Biology Society. 1998; 20:2798–2801.
11. Dutta SK, Das K, Ghosh B, Blackman CF. Dose dependence of acetylcholinesterase activity in neuroblastoma cells exposed to modulated radiofrequency electromagnetic radiation. *Bioelectromagnetics*. 1992; 13(4):317–322.
 12. Panagopoulos DJ, Chavdoula ED, Margaritis LH. Bioeffects of mobile telephony radiation in relation to its intensity or distance from the antenna. *Int J Radiat Biol*. 2010; 86(5):345–357.
 13. Panagopoulos DJ, Margaritis LH. The identification of an intensity ‘window’ on the bioeffects of mobile telephony radiation. *Int J Radiat Biol*. 2010; 86(5):358–366. Erratum in *Int J Radiat Biol*. 86(9):809
 14. Panagopoulos DJ, Margaritis LH. The effect of exposure duration on the biological activity of mobile telephony radiation. *Mutat Res*. 2010; 699(1–2):17–22.
 15. Nittby H, Grafstrom G, Eberhardt JL, et al. Radiofrequency and extremely low frequency electromagnetic field effects on the blood-brain barrier. *Electromagnetic biology and medicine*. 2008; 27:103–126.
 16. Nittby H, Brun A, Eberhardt J, et al. Increased blood-brain barrier permeability in mammalian brain 7 days after exposure to the radiation from a GSM-900 mobile phone. *Pathophysiology*. 2009; 16:103–112.
 17. Frey AH, Feld SR, Frey B. Neural function and behaviour: defining the relationship. *Ann. NY Acad. Sci*. 1975; 247:433–439.
 18. Bas O, Odaci E, Kaplan S, et al. 900 MHz electromagnetic field exposure affects qualitative and quantitative features of hippocampal pyramidal cells in the adult female rat. *Brain Research*. 2009; 1265:178–185.
 19. Burlaka A, Tsybulin O, Sidorik E, et al. Overproduction of free radical species in embryonal cells exposed to low intensity radiofrequency radiation. *Experimental Oncology*. 2013; 35(3):219–225.
 20. Valko M, Rhodes CJ, Moncol J, et al. Free radicals, metals and antioxidants in oxidative stress-induced cancer. *Chemico-Biological Interactions*. 2006; 160:1–40.
 21. Repacholi MH, Basten A, Gebiski V, et al. Lymphomas in E mu-Pim1 transgenic mice exposed to pulsed 900 MHz electromagnetic fields. *Radiat Res*. 1997; 147(5):631–640.
 22. Adey WR, Byus CV, Cain CD, et al. Spontaneous and nitrosourea-induced primary tumors of the central nervous system in Fischer 344 rats exposed to frequency-modulated microwave fields. *Cancer Research*. 2000; 60:1857–1863.
 23. Adey WR, Byus CV, Cain CD, et al. Spontaneous and nitrosourea-induced primary tumors of the central nervous system in Fischer 344 rats chronically exposed to 836 MHz modulated microwaves. *Radiation Research*. 1999; 152:293–302.
 24. Pawl R. Editorial: Cell phones more dangerous than cigarettes! *Surgical Neurology*. 2008; 70:445–446.
 25. Vocht F, Burstyn I, Cherrie JW. Time trends (1998–2007) in brain cancer incidence rates in relation to mobile phone use in England. *Bioelectromagnetics*. 2011; 32:334–339.
 26. Aydin D, Feychting M, Schuz J, et al. Mobile phone use and brain tumors in children and adolescents: a multi-center case-control study (CEFALO). *J Natl Cancer Inst* 2011; 103:1264–1276.
 27. Kundi M. Study of mobile phone use and glioma risk was fatally flawed. *BMJ*. 2012; 344:e3078 doi: 10.1136/bmj.e3078
 28. Cherry N. Letter to the editor re: “Cancer incidence near radio and television transmitters in Great Britain. I. Sutton Coldfield transmitter; II. All high power transmitters”. *American Journal of Epidemiology*. 2001; 153: 204–205.
 29. Hardell L, Carlberg M. Increasing rates of brain tumours in the Swedish National Inpatient Register and the Causes of Death Register. *International Journal of Environmental Research and Public Health*. 2015; 12:3793–3813.
 30. Khurana VG, Teo C, Kundi M, et al. Cell phones and brain tumors: a review including the long-term epidemiologic data. *Surgical Neurology*. 2009; 72: 205–215.
 31. Hardell L, Carlberg M, Mild KH. Pooled analysis of two case-control studies on use of cellular and cordless telephones and the risk for malignant brain tumours diagnosed in 1997–2003. *International Archives of Occupational and Environmental Health*. 2006; 79:630–639.

32. INTERPHONE Study Group. Brain tumour risk in relation to mobile telephone use: results of the INTERPHONE international case-control study. *International Journal of Epidemiology*. 2010; 39:675–694.
33. Kundi M, Hutter H-P. Mobile phone base stations - effects on wellbeing and health. *Pathophysiology*. 2009; 16:123–135.
34. Huss A, Egger M, Hug K, et al. Source of funding and results of studies of health effects of mobile phone use: systematic review of experimental studies. *Environmental Health Perspectives*. 2007; 115:1–4.
35. Frey AH, Parascandola M. Hold the (cell) phone ... *Science*. 2002; 295:440–441.
36. Kovac S. Dangers of cell phone radiation. *Life extension Magazine* 2007; http://www.lifeextension.com/magazine/2007/8/report_cellphone_radiation/Page-01
37. Pearce N. Corporate influence on epidemiology. *International Journal of Epidemiology*. 2008; 37:46–53.
38. Wegner DM, Wheatley T. (1999) Apparent mental causation: sources of the experience of will. *American Psychologist*. 1999; 54:480–91.
39. Redmayne M. International policy and advisory response regarding children's exposure to radio frequency electromagnetic fields (RF-EMF). *Electromagnetic Biology and Medicine* 2016; 35:176–185.