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Limiting liability with positioning to minimize negative health effects of cellular phone towers

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ABSTRACT

The use of cellular phones is now ubiquitous through most of the adult global population and is increasingly common among even young children in many countries (e.g. Finland, where the market for smart phones is nearly saturated). The basic operation of cellular phone networks demands widespread human exposure to radio-frequency radiation (RFR) with cellular phone base stations providing cellular coverage in most areas. As the data needs of the population increase from the major shift in the source of Internet use from personal computers to smart phones, this coverage is widely predicted to increase. Thus, both the density of base stations and their power output is expected to increase the global human RFR exposure. Although direct causation of negative human health effects from RFR from cellular phone base stations has not been finalized, there is already enough medical and scientific evidence to warrant long-term liability concerns for companies deploying cellular phone towers. In order to protect cell phone tower firms from the ramifications of the failed paths of other industries that have caused unintended human harm (e.g. tobacco) this Current Issue summarizes the peer-reviewed literature on the effects of RFR from cellular phone base stations. Specifically the impacts of siting base stations are closely examined and recommendations are made for companies that deploy them to minimize their potential future liability.

1. Negative human health effects from proximity to cellular phone base stations

There is a large and growing body of evidence that human exposure to RFR from cellular phone base stations causes negative health effects (Siddoo-Atwal, 2018; Singh et al., 2018; Faisal, et al., 2018) including both i) neuropsychiatric complaints such as headache, concentration difficulties, memory changes, dizziness, tremors, depressive symptoms, fatigue and sleep disturbance (Navarro et al., 2003;Hutter et al., 2006; Abdel-Rassoul et al., 2007); and ii) increased incidence of cancer and living in proximity to a cell-phone transmitter station (Wolf and Wolf, 2004; Havas, 2017). The mechanism for causing cancer could be from observed genetic damage using the single cell gel electrophoresis assay assessed in peripheral blood leukocytes of individuals residing in the vicinity of a mobile phone base station and comparing it to that in healthy controls (Gandhi et al., 2014). In epidemiological studies that assessed negative health effects of mobile phone base stations (seven studies explored the association between base station proximity and neurobehavioral effects (Navarro et al., 2003; Hutter et al., 2006; Abdel-Rassoul et al., 2007; Berg-Beckhoff et al., 2009; Blettner et al., 2009; Gadzicka et al., 2006; Santini et al., 2002) and three investigated cancer (Wolf and Wolf, 2004; Havas, 2017;Levitt and Lai, 2010), 80% reported increased prevalence of adverse neurobehavioral symptoms or cancer in populations living at distances < 500 m from base stations (Navarro et al., 2003).

The literature also indicates that these effects may be cumulative based on i) mice exposed to low-intensity RFR became less reproductive and after five generations of exposure the mice were not able to produce offspring indicating intergenerational transfer of effects (Magras and Xenos, 1997); ii) DNA damage in cells after 24 h exposure to low-intensity RFR, which can lead to gene mutation that accumulates over time (Phillips et al., 1998) and iii) increased sensitivity to behavior–disruption experiments in rats (D'Andrea et al., 1986) and monkeys (de Lorge, 1984), iv) an increase in permeability of the blood–brain barrier in mice suggesting that a short-term, high-intensity exposure can produce the same effect as a long-term, low-intensity exposure (Persson et al., 1997). Studies on short-term exposure generally show no effects. For example, early studies saw no effect from

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short-term exposure, however, studies found effects after prolonged, repeated exposure in guinea pigs and rabbits (Takashima et al., 1979).

There are several studies showing the effect intensifies with reduced distance to the cell tower. The first (Santini et al., 2002) found increased symptoms and complaints the closer a person lived to a tower (Santini et al., 2002) and similar results were found in later studies (Navarro et al., 2003; Hutter et al., 2006; Abdel-Rassoul et al., 2007).

2. U.S. law unhelpful for preventing future liability

Current U.S. law has created a somewhat peculiar overriding federal preemption that precludes taking the "environmental effects" of RFR into consideration in cell tower siting (see Section 704 of The Telecommunications Act of 1996). The current, U.S. standards are based solely on thermal effects (which do not appear to be a problem) and thus do not mitigate against non-thermal effects (for which there is a growing litany of concern in the medical/scientific community). Due to the findings of many studies briefly summarized above many researchers argue for the revision of standard guidelines for public exposure to RER from mobile phone base station antennas (Abdel-Rassoul et al., 2007; Hardell and Sage, 2008; Khurana et al., 2010). As Roda and Perry summarize (Roda and Perry, 2014), "… because scientific knowledge is incomplete, a precautionary approach is better suited to State obligations under international human rights law." This is perhaps most forcefully concluded by the *BioInitiative Report* published by the BioInitiative Working Group, which is based on an international research and public policy initiative to give an overview of what is known of biological effects that occur at low-intensity electromagnetic fields exposure. This precautionary approach is gaining favor in Europe, but is less common in the U.S. American companies are therefore ill advised to simply follow "regulatory compliance" on this front, as there appears to be a clear cause for concern in the scientific/medical communities. If causation were to be proven through detailed studies, cellular phone companies would potentially be in position of future legal exposure for causing widespread human health problems and premature death. It is, therefore, in American companies' best interest to act before government and regulation catches up with the science.

3. Current cell tower positioning

Current cell tower locations are chosen based on a "search ring" priority basis of geographic optimum for technical coverage of high concentration of wireless transmissions (e.g. users). This combination of technical parameters (e.g. geography) to enable coverage and dependable service and costs (e.g. positioning on mountaintops on accessibly by helicopter) is then weighed against and local regulations such as local zoning.

To overcome these challenges in urban areas cellphone companies often locate cellphone base stations at schools, because the monthly rental fee (~$1500) is welcome income for economically-challenged school districts that have influence on local zoning. However, some jurisdictions have already prohibited the placement of cell phone towers near schools or hospitals because of the increased sensitivity of these populations, as in India. Other regions such as Europe (Roda and Perry, 2014) could follow a similar approach. Now even in North America, Canada's Standing Committee on Health are considering more precautionary approaches to RFR.

4. Precautionary cell phone base station positioning

A review article of the health effects near base stations concluded that deployment of base stations should be kept as efficient as possible to minimize exposure of the public to RFR and should not be located less than 500 m from the population, and at a height of 50 m (Levitt and Lai, 2010). This potentially presents a serious challenge to cell phone company RF engineers. However, it is possible to obtain necessary coverage while at the same time minimizing human exposure at the highest intensities. There are several first steps a cellular phone company can take to minimize human exposure particularly of the most vulnerable populations.

First, voluntarily restrictions can be made on the placement of cellular phone base stations within 500 m of schools and hospitals. This will synchronize base station deployment strategies between regions. This can be done by utilizing the existing hexagon planning map structure of an area with an overlay using an additional semi-automated process with a geographic information system (GIS) (Al-Sahly et al., 2018) such as the Geographic Resources Analysis Support System (GRASS) to identify any regions within 500 m of existing schools and hospitals. All hexagons with schools or hospitals are marked as unusable for RF engineer planning (e.g. colored red). This restriction only makes planning slightly more difficult, but does present a challenge in regions where schools were specifically targeted as base station locations in (e.g. Verizon deployments in the U.S.). Future work is needed to determine if the increased legal exposure warrants the cost of moving existing stations. However, the increased cost to locate future stations away from schools and hospitals should be minimal.

The second technical hurdle is more challenging. Ideally, all cell phone users would have coverage while minimizing the population density near cellular phone base stations (thus minimizing health impacts). This can be planned using GIS tools, freely-accessible U.S. Census data, parcel data and/or satellite images. The population density can be color coded for straightforward decision making for RF engineers. As a cellphone base station costs $250–350,000 to install in the U.S., using a precautionary approach to potential future regulation can save substantial relocation fees.

The cell phone industry should also consider cell splitting, small cell deployment, beam and null steering antennae as possible technical means for reducing RF exposure. Moreover, more research on cognitive radio should also be conducted, so that the overall RF exposure is reduced. These measures will ultimately benefit the entire telecommunications industry, while potentially significantly reducing global RF pollution.

Finally, exposed companies should consider funding large-scale epidemiological studies with personal dosimeters for strict dose measurement and straight-forward tissue exposure. By quantifying the human medical threat themselves, more appropriate long-term planning can be made to minimize the risk of liability from unintended human harm due to cellular phone base station siting.

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Declaration of competing interest

The author has no conflict of interest.

References

Abdel-Rassoul, G., El-Fateh, O.A., Salem, M.A., Michael, A., Farahat, F., El-Batanouny, M., Salem, E., 2007. Neurobehavioral effects among inhabitants around mobile phone base stations. Neurotoxicology (Little Rock) 28 (2), 434–440.

AprilAl–Sahly, A., Hassan, M.M., Al–Rubaian, M., Al–Qurishi, M., 2018. Using GIS for measuring mobile tower radiation on human. In: 2018 1st International Conference on Computer Applications & Information Security (ICCAIS). IEEE, pp. 1–6.

Berg-Beckhoff, G., Blettner, M., Kowall, B., Breckenkamp, J., Schlehofer, B., Schmiedel, S., et al., 2009. Mobile phone base stations and adverse health effects: phase 2 of a cross-sectional study with measured radio frequency electromagnetic fields. Occup. Environ. Med. 66 (2), 124–130.

Blettner, Maria, Schlehofer, Brigitte, Breckenkamp, Juergen, Kowall, Bernd, Schmiedel, Sven, Reis, Ursula, Potthoff, Peter, Schuez, Joachim, Berg-Beckhoff, Gabriele, 2009. Mobile phone base stations and adverse health effects: phase 1 of a population-based, cross-sectional study in Germany. Occup. Environ. Med. 66 (2), 118–123.

de Lorge, J.O., 1984. Operant behavior and colonic temperature of *Macaca mulatta* exposed to radiofrequency fields at and above resonant frequencies.

Bioelectromagnetics 5 (2), 233–246. https://doi.org/10.1002/bem.2250050211.
D'Andrea, J.A., DeWitt, J.R., Gandhi, O.P., Stensaas, S., Lords, J.L., Nielson, H.C., 1986. Behavioral and physiological effects of chronic 2450 MHz microwave irradiation of the rat at 0.5 mW/cm2. Bioelectromagnetics 7 (1), 45–56. https://doi.org/10.1002/bem.2250070106.
OctoberFaisal, M.M.A., Mortuza, M.G., Alam, T., 2018. Cell tower radiation and effect on human body: Bangladesh perspective. In: 2018 International Conference on Innovations in Science, Engineering and Technology (ICISET). IEEE, pp. 423–426.
Gadzicka, E., Bortkiewicz, A., Zmyslony, M., Szymczak, W., Szyjkowska, A., 2006. Assessment of subjective complaints reported by people living near mobile phone base stations. Biuletyn PTZE Warszawa 14, 23–26.
Gandhi, G., Kaur, G., Nisar, U., 2014. A cross-sectional case control study on genetic damage in individuals residing in the vicinity of a mobile phone base station. Electromagn. Biol. Med. (0), 1–11.
Hardell, L., Sage, C., 2008. Biological effects from electromagnetic field exposure and public exposure standards. Biomed. Pharmacother. 62 (2), 104–109.
Havas, M., 2017. Carcinogenic effects of non-ionizing radiation: a paradigm shift. Clin Oncol 2, 1278 2017.
Hutter, H.P., Moshammer, H., Wallner, P., Kundi, M., 2006. Subjective symptoms, sleeping problems, and cognitive performance in subjects living near mobile phone base stations. Occup. Environ. Med. 63 (5), 307–313.
Khurana, V.G., Hardell, L., Everaert, J., Bortkiewicz, A., Carlberg, M., Ahonen, M., 2010. Epidemiological evidence for a health risk from mobile phone base stations. Int. J. Occup. Environ. Health 16 (3), 263–267.
Levitt, B.B., Lai, H., 2010. Biological effects from exposure to electromagnetic radiation emitted by cell tower base stations and other antenna arrays. Environ. Rev. 18, 369–395.
Magras, I.N., Xenos, T.D., 1997. RF radiation-induced changes in the prenatal development of mice. Bioelectromagnetics 18 (6), 455–461. https://doi.org/10.1002/(SICI)1521-186X(1997)18:6<455::AID-BEM8>3.0.CO;2-1.
Navarro, A.E., Sequra, J., Portoleés, M., Gómez-Perretta de Mateo, C., 2003. The microwave syndrome: a preliminary study in Spain. Electromagn. Biol. Med. 22 (2–3), 161–169. https://doi.org/10.1081/JBC-120024625.
Persson, B.R.R., Salford, L.G., Brun, A., 1997. Blood–brain barrier permeability in rats exposed to electromagnetic fields used in wireless communication. Wirel. Netw. 3 (6), 455–461. https://doi.org/10.1023/A:1019150510840.
Phillips, J.L., Ivaschuk, O., Ishida-Jones, T., Jones, R.A., Campbell-Beachler, M., Haggren, W., 1998. DNA damage in Molt-4 T-lymphoblastoid cells exposed to cellular telephone radiofrequency fields in vitro. Bioelectrochem. Bioenerg. 45 (1), 103–110. https://doi.org/10.1016/S0302-4598(98)00074-9.
Roda, C., Perry, S., 2014. Mobile phone infrastructure regulation in Europe: scientific challenges and human rights protection. Environ. Sci. Policy 37, 204–214.
Santini, R., Santini, P., Danze, J.M., Le Ruz, P., Seigne, M., 2002. Enquête sur la sante' de riverains de stations relais de te'lé- phonie mobile : incidences de la distance et du sexe. Pathol. Biol. 50, 369–373. https://doi.org/10.1016/S0369-8114(02)00311-5.
Siddoo-Atwal, C., 2018. Electromagnetic radiation from cellphone towers: a potential health hazard for birds, bees, and humans. Curr. Underst. Apoptosis: Program. Cell Death 137.
Singh, R., Nath, R., Mathur, A.K., Sharma, R.S., 2018. Effect of radiofrequency radiation on reproductive health. Indian J. Med. Res. 148 (Suppl 1), S92.
Takashima, S., Onaral, B., Schwan, H.P., 1979. Effects of modulated RF energy on the EEG of mammalian brain. Radiat. Environ. Biophys. 16 (1), 15–27. https://doi.org/10.1007/BF01326893.
Wolf, R., Wolf, D., 2004. Increased incidence of cancer near a cell-phone transmitter station. Int. J. Cancer Prev. 1 (2), 123–128.