

From: Tim and Karen Hudson <tkjehudson@sbcglobal.net>
Sent: Monday, December 9, 2019 10:41 PM
To: Tibbetts, Jack; Olivares, Ernesto; Rogers, Chris; Sawyer, John; Fleming, Victoria; Schwedhelm, Tom; City Clerk; CMOoffice; Gallagher, Sue; Guhin, David; McHenry, Eric; Reeve, Amy
Subject: [EXTERNAL] Please vote against the 100 additional cell towers in Santa Rosa

Santa Rosa City Council and staff,

Protect public health, property values, street views, public safety, and the environment. Deny the 100 + "small cell" towers pending in Santa Rosa. These towers will greatly increase radiofrequency radiation (RFR) in Santa Rosa neighborhoods, where people live, work, sleep and play. Peer-reviewed published science shows RFR harms people and nature. Children, the elderly, and those already ill are more vulnerable.

Cancer clusters have been located throughout the world within a 1/4 mile radius of cell towers. As someone who is RFR sensitive, I implore you to please vote against the addition of 100 new cell towers in Santa Rosa. Protect your constituents and their children. My son, his wife, and their two children live in Santa Rosa.

The harmful effects of RFR include: fatigue, headaches, sleep problems, anxiety, ringing in the ears, heart problems, learning and memory disorders, increased cancer risk, and more. The 30 million dollar, ten year US National Toxicology Program study found DNA damage and clear evidence of cancer and from exposure to RFR.

In 2018 Newsweek reported: "Technology is quite literally destroying nature, with a new report further confirming that electromagnetic radiation from power lines and cell towers can disorientate birds and insects and destroy plant health. The paper warns that as nations switch to 5G this threat could increase."

Peer-reviewed studies show worker bees did not return to their hives because of wireless radiation, which led to colony collapse. Radiation impacts on wild birds documented nest abandonment, plumage deterioration, and death. Lab studies of chick embryos documented heart attacks and death. In 2019 the Swiss environmental group Pro Natura reported 5G increases the body temperature of insects.

4G is the backbone for 5G. There is no scientific evidence to support any claim of 5G safety! Scientists and public health experts from around the world are calling for a moratorium on 5G.

The telecommunication industry's unbounded profit motive should never outweigh public and environmental safety.

Communications are faster, more reliable, and safer using wired and corded connections.

Thank you for your consideration,
Karen Hudson, 7816 Medallion Way, Rohnert Park.

Bliss, Sandi

31

From: Jasmine David <jasminesdavid@gmail.com>
Sent: Monday, December 9, 2019 8:22 PM
To: Tibbetts, Jack; Sawyer, John; City Clerk; Gallagher, Sue; CMOOffice; Guhin, David; Schwedhelm, Tom; Fleming, Victoria; Rogers, Chris; Olivares, Ernesto; Reeve, Amy; McHenry, Eric
Subject: [EXTERNAL] 100+ NEW Cell Antennas in County

Santa Rosa City Council and staff,

Protect public health, property values, street views, public safety, and the environment. Deny the 100 + "small cell" towers pending in Santa Rosa. These towers will greatly increase radio frequency radiation (RFR) in Santa Rosa neighborhoods, where people live, work, sleep and play. Peer-reviewed published science shows RFR harms people and nature. Children, the elderly, and those already ill are more vulnerable.

The harmful effects of RFR include: fatigue, headaches, sleep problems, anxiety, ringing in the ears, heart problems, learning and memory disorders, increased cancer risk, and more. The 30 million dollar, ten year US National Toxicology Program study found DNA damage and clear evidence of cancer and from exposure to RFR.

In 2018 Newsweek reported:"Technology is quite literally destroying nature, with a new report further confirming that electromagnetic radiation from power lines and cell towers can disorientate birds and insects and destroy plant health. The paper warns that as nations switch to 5G this threat could increase."

Peer-reviewed studies show worker bees did not return to their hives because of wireless radiation, which led to a colony collapse. Radiation impacts on wild birds documented nest abandonment, plumage deterioration and death. Lab studies of chick embryos documented heart attacks and death. In 2019 the Swiss environmental group Pro Natura reported 5G increases the body temperature of insects.

4G is the backbone for 5G. There is no scientific evidence to support any claim of 5G safety! Scientists and public health experts from around the world are calling for a moratorium on 5G.

The telecommunication industry's unbounded profit motive should never outweigh public and environmental safety. Communications are faster, more reliable, and safer using wired and corded connections.

Thank you for your consideration,

Jasmine David

Bliss, Sandi

3.1

From: Kim Atkinson <kim@pulsewave.com>
Sent: Monday, December 9, 2019 7:54 PM
To: Tibbetts, Jack; Sawyer, John; City Clerk; Reeve, Amy; McHenry, Eric; Gallagher, Sue; CMOOffice; Guhin, David; Schwedhelm, Tom; Fleming, Victoria; Rogers, Chris; Olivares, Ernesto
Subject: [EXTERNAL] increase of cell phone towers in Santa Rosa
Attachments: pastedGraphic.tiff

Santa Rosa City Council and staff,

I work and enjoy life and culture in Santa Rosa.

Please give deep consideration to the protection of public health, property values, street views, public safety, and the environment in Santa Rosa by denying the 100 + "small cell" towers pending in Santa Rosa.

These towers will greatly increase radio frequency radiation (RFR) in Santa Rosa neighborhoods, where people live, work, sleep and play. Peer-reviewed published science shows RFR harms people and nature. Children, the elderly, and those already ill are more vulnerable.

The harmful effects of RFR include: fatigue, headaches, sleep problems, anxiety, ringing in the ears, heart problems, learning and memory disorders, increased cancer risk, and more. The 30 million dollar, ten year US National Toxicology Program study found DNA damage and clear evidence of cancer and from exposure to RFR.

In 2018 Newsweek reported: "Technology is quite literally destroying nature, with a new report further confirming that electromagnetic radiation from power lines and cell towers can disorientate birds and insects and destroy plant health. The paper warns that as nations switch to 5G this threat could increase."

Peer-reviewed studies show worker bees did not return to their hives because of wireless radiation, which led to a colony collapse. Radiation impacts on wild birds documented nest abandonment, plumage deterioration and death. Lab studies of chick embryos documented heart attacks and death. In 2019 the Swiss environmental group Pro Natura reported 5G increases the body temperature of insects.

4G is the backbone for 5G. There is no scientific evidence to support any claim of 5G safety! Scientists and public health experts from around the world are calling for a moratorium on 5G.

The telecommunication industry's unbounded profit motive should never outweigh public and environmental safety.

Communications are faster, more reliable, and safer using wired and corded connections.

Thank you for your consideration,

Kim Atkinson

POBox 703

Sebastopol CA 95473

Santa Rosa City Council Member email addresses:



Kim Atkinson

Sebastopol CA 95473

www.pulsewave.com

[YouTube: KimAtkinsonDrums](https://www.youtube.com/KimAtkinsonDrums)

Ecstatic drummer, Master Facilitator/ Teacher,
Inspiring Musician, Sound Worker
World Drums, Gongs, Flutes, Voice, Movement

"Things flourish, then each returns to its root. Returning to the root is called Stillness, Stillness is called Return to Life, Return to Life is called the Constant; knowing the Constant is called Enlightenment." - Lao Tzu

Bliss, Sandi

311

From: Kathy McMorrow <kathymcmo@comcast.net>
Sent: Monday, December 9, 2019 7:20 PM
To: _CityCouncilListPublic
Subject: [EXTERNAL] Please move ahead with small cell towers

Hi,
I'm working during the hearing you're holding on Tuesday but I've read in the paper that the same band of anti-cell fanatics plans to show up and try to convince you to again delay or even stop plans to move ahead with more towers that will bring better coverage for the city of SR. Please please do not let that dissuade you.

Adequate cell service has become a necessity, not a luxury or just for people who "want to download the Avengers movie in 4 seconds." The return of wildfires to our city should keep that top of mind for you. There is no credible evidence that these towers pose any harm to humans, and the opponents are spouting a lot of pseudo science to stir up unnecessary alarm.

Please move ahead with the needed permissions to let cell coverage improve, and be aware that for every crackpot free to attend a meeting in the middle of a work day there are hundreds if not thousands of voters who support this initiative going forward.

Thank you,

Kathy McMorrow
2171 Alejandro Drive SR

Sent from my iPad

3.1

Bliss, Sandi

From: Nancy Hubert <nancyhubert1@gmail.com>
Sent: Monday, December 9, 2019 4:26 PM
To: Tibbetts, Jack; Olivares, Ernesto; Rogers, Chris; Sawyer, John; Fleming, Victoria; Schwedhelm, Tom; City Clerk; CMOOffice; Gallagher, Sue; Guhin, David; McHenry, Eric; Reeve, Amy
Subject: [EXTERNAL] Please stop small cell deployment

Dear Santa Rosa City Council and staff,

Protect public health, property values, street views, public safety, and the environment. Deny the 100 + "small cell" towers pending in Santa Rosa. These towers will greatly increase radio frequency radiation (RFR) in Santa Rosa neighborhoods, where people live, work, sleep and play. Peer-reviewed published science shows RFR harms people and nature. Children, the elderly, and those already ill are more vulnerable.

The harmful effects of RFR include: fatigue, headaches, sleep problems, anxiety, ringing in the ears, heart problems, learning and memory disorders, increased cancer risk, and more. The 30 million dollar, ten year US National Toxicology Program study found DNA damage and clear evidence of cancer and from exposure to RFR.

In 2018 Newsweek reported: "Technology is quite literally destroying nature, with a new report further confirming that electromagnetic radiation from power lines and cell towers can disorientate birds and insects and destroy plant health. The paper warns that as nations switch to 5G this threat could increase."

Peer-reviewed studies show worker bees did not return to their hives because of wireless radiation, which led to a colony collapse. Radiation impacts on wild birds documented nest abandonment, plumage deterioration and death. Lab studies of chick embryos documented heart attacks and death. In 2019 the Swiss environmental group Pro Natura reported 5G increases the body temperature of insects.

4G is the backbone for 5G. There is no scientific evidence to support any claim of 5G safety! Scientists and public health experts from around the world are calling for a moratorium on 5G.

The telecommunication industry's unbounded profit motive should never outweigh public and environmental safety. Communications are faster, more reliable, and safer using wired and corded connections.

Please help save all of us!

Thank you for your consideration,

Nancy Hubert

Bliss, Sandi

3.1

From: Alaya Babineau <alaya.babineau@gmail.com>
Sent: Sunday, December 8, 2019 10:23 PM
To: Tibbetts, Jack; Olivares, Ernesto; Rogers, Chris; Sawyer, John; Fleming, Victoria; Schwedhelm, Tom; City Clerk; CMOOffice; Gallagher, Sue; Guhin, David; McHenry, Eric; Reeve, Amy
Subject: [EXTERNAL] Cell Towers

Santa Rosa City Council and staff,

Protect public health, property values, street views, public safety, and the environment. Deny the 100 + "small cell" towers pending in Santa Rosa. These towers will greatly increase radio frequency radiation (RFR) in Santa Rosa neighborhoods, where people live, work, sleep and play. Peer-reviewed published science shows RFR harms people and nature. Children, the elderly, and those already ill are more vulnerable.

The harmful effects of RFR include: fatigue, headaches, sleep problems, anxiety, ringing in the ears, heart problems, learning and memory disorders, increased cancer risk, and more. The 30 million dollar, ten year US National Toxicology Program study found DNA damage and clear evidence of cancer and from exposure to RFR.

In 2018 Newsweek reported: "Technology is quite literally destroying nature, with a new report further confirming that electromagnetic radiation from power lines and cell towers can disorientate birds and insects and destroy plant health. The paper warns that as nations switch to 5G this threat could increase."

Peer-reviewed studies show worker bees did not return to their hives because of wireless radiation, which led to a colony collapse. Radiation impacts on wild birds documented nest abandonment, plumage deterioration and death. Lab studies of chick embryos documented heart attacks and death. In 2019 the Swiss environmental group Pro Natura reported 5G increases the body temperature of insects.

4G is the backbone for 5G. There is no scientific evidence to support any claim of 5G safety! Scientists and public health experts from around the world are calling for a moratorium on 5G.

The telecommunication industry's unbounded profit motive should never outweigh public and environmental safety.

Communications are faster, more reliable, and safer using wired and corded connections.

Thank you for your consideration,
Mia Babineau

From: Raven Fleps <ravendenis@sbcglobal.net>
Sent: Sunday, December 8, 2019 10:22 PM
To: Tibbetts, Jack; Olivares, Ernesto; Rogers, Chris; Sawyer, John; Fleming, Victoria; Schwedhelm, Tom; City Clerk; CMOOffice; Gallagher, Sue; Guhin, David; McHenry, Eric; Reeve, Amy
Subject: [EXTERNAL] Small Cell Towers

Santa Rosa City Council and staff,

Protect public health, property values, street views, public safety, and the environment. Deny the 100 + "small cell" towers pending in Santa Rosa. These towers will greatly increase radio frequency radiation (RFR) in Santa Rosa neighborhoods, where people live, work, sleep and play. Peer-reviewed published science shows RFR harms people and nature. Children, the elderly, and those already ill are more vulnerable.

The harmful effects of RFR include: fatigue, headaches, sleep problems, anxiety, ringing in the ears, heart problems, learning and memory disorders, increased cancer risk, and more. The 30 million dollar, ten year US National Toxicology Program study found DNA damage and clear evidence of cancer and from exposure to RFR.

In 2018 Newsweek reported: "Technology is quite literally destroying nature, with a new report further confirming that electromagnetic radiation from power lines and cell towers can disorientate birds and insects and destroy plant health. The paper warns that as nations switch to 5G this threat could increase."

Peer-reviewed studies show worker bees did not return to their hives because of wireless radiation, which led to a colony collapse. Radiation impacts on wild birds documented nest abandonment, plumage deterioration and death. Lab studies of chick embryos documented heart attacks and death. In 2019 the Swiss environmental group Pro Natura reported 5G increases the body temperature of insects.

4G is the backbone for 5G. There is no scientific evidence to support any claim of 5G safety! Scientists and public health experts from around the world are calling for a moratorium on 5G.

The telecommunication industry's unbounded profit motive should never outweigh public and environmental safety. Communications are faster, more reliable, and safer using wired and corded connections.

We urge you to deny the proposed cell towers for the health of our community!

Thank you for your consideration,
Raven and Denis Fleps
4380 Montgomery Drive, Santa Rosa

From: lendri purcell <lendrip@gmail.com>
Sent: Saturday, December 7, 2019 3:30 PM
To: Tibbetts, Jack; Olivares, Ernesto; Rogers, Chris; Sawyer, John; Fleming, Victoria; Schwedhelm, Tom; City Clerk; CMOffice; Gallagher, Sue; Guhin, David; McHenry, Eric; Reeve, Amy
Subject: [EXTERNAL] Why you don't want 100 + "small cell" towers in Santa Rosa

Greetings,

My name is Lendri Purcell. I am the president and founder of FACTS, Families Advocating for Chemical and Toxics Safety and the Jonas Family Fund. I live in Petaluma and do a lot of work in Santa Rosa and I do a lot of my shopping there and may be looking at moving up there soon. As part of my work funding environmental health research, I was skeptical when I first saw proposals to study EMF radiation. Once I dove into the science for work and personal reasons (my son's school district gave an IPAD to every kid starting in kindergarten), I was SHOCKED to see how much strong, peer-reviewed science there is showing how dangerous this technology can be and we still have to do so much more research to understand the full non-thermal effects of non-ionizing adiation (for instance to children). That said, given the clear results of the NTP (National Toxicology Program) (gold standard for research-25M federal study), it is clear we need to better study this technology before we unleash it on communities. My city council did their homework. Concerned citizens gave them the studies and they turned down Verizon's application and created set-backs for new towers that prevents the small-cell catastrophic roll-out. Please do you homework and read the science, the NTP, the Bioinitiative, the scientific statements, Babysafe Project, Environmental Health Trust, Physicians for Safe Technology, Americans for Responsible Technology and understand that the FCC is not supposed to regulate EMF safety (they explicitly say there are not a safety group). Also, see Harvard Ethics Review Paper- FCC Captured Agency. Also, you need to know that the last insurer of EMFs, Lloyd's of London dropped EMFS due to health concerns. Finally, there are studies about how property values shrink for people who live near cell towers. Please keep Santa Rosa safe. So many cities around the country are bagging this dangerous idea. Stand with them. Sincerely, Lendri Purcel

From: Roberta Godbe-Tipp <robertagodbetipp@gmail.com>
Sent: Saturday, December 7, 2019 12:49 PM
To: Tibbetts, Jack; Olivares, Ernesto; Rogers, Chris; Sawyer, John; Fleming, Victoria; Schwedhelm, Tom; City Clerk; CMOOffice; Gallagher, Sue; Guhin, David; McHenry, Eric; Reeve, Amy
Subject: [EXTERNAL] Re: Small Cell Towers in Santa Rosa

Dear Santa Rosa City Council,

Please protect public health, property values, street views, public safety, and the environment. Deny the 100+ "small cell" towers pending in Santa Rosa. These towers will greatly increase radio frequency radiation (RFR) in Santa Rosa neighborhoods, where people live, work, sleep and play. Peer-reviewed published science shows RFR harms people and nature. Children, the elderly, and those already ill are more vulnerable.

The harmful effects of RFR include: fatigue, headaches, sleep problems, anxiety, ringing in the ears, heart problems, learning and memory disorders, increased cancer risk, and more. The 30 million dollar, ten year US National Toxicology Program study found DNA damage and clear evidence of cancer and from exposure to RFR.

In 2018 Newsweek reported: "Technology is quite literally destroying nature, with a new report further confirming that electromagnetic radiation from power lines and cell towers can disorientate birds and insects and destroy plant health. The paper warns that as nations switch to 5G this threat could increase."

Peer-reviewed studies show worker bees did not return to their hives because of wireless radiation, which led to a colony collapse. Radiation impacts on wild birds documented nest abandonment, plumage deterioration and death. Lab studies of chick embryos documented heart attacks and death. In 2019 the Swiss environmental group Pro Natura reported 5G increases the body temperature of insects.

4G is the backbone for 5G. There is no scientific evidence to support any claim of 5G safety! Scientists and public health experts from around the world are calling for a moratorium on 5G.

The telecommunication industry's unbounded profit motive should never outweigh public and environmental safety. Communications are faster, more reliable, and safer using wired and corded connections.

Thank you for your consideration,

Roberta Godbe-Tipp, Ph.D.

From: jd@thetahealingintuitive.com
Sent: Saturday, December 7, 2019 1:23 AM
To: City Clerk
Subject: [EXTERNAL] Cell tower concerns

12/7/19

To Santa Rosa City Council and staff:

As a very sensitive (to EMF) citizen of Santa Rosa, I am more than concerned about the 100+ ‘small cell’ towers being considered in Santa Rosa. These towers WILL increase RFR (radio frequency radiation) in our neighborhoods and workplaces. They WILL affect every person, including all of you. They WILL affect the animals, the bees, the trees, and the birds...everything that we participate with.

Debra Greene, PhD, says that there are no safety studies and that 5G builds on existing infrastructure using extremely high (millimeter-wave) frequencies of 24 gigahertz (GHz) or more. These don’t travel far, so antennas will be installed approximately every 2-10 homes in residential neighborhoods and it will significantly increase our wireless RF radiation (radio frequency microwave) exposure on a 24/7 and 365 days a year basis. <https://childrenshealthdefense.org/child-health-topics/known-culprit/electromagnetic/5g-the-global-human-experiment-without-consent>

Big Wireless has made us think that cell phones are safe but it’s a disinformation campaign—and massive radiation increase will happen with a 5G rollout. This is a special investigation. <https://www.thenation.com/article/how-big-wireless-made-us-think-that-cell-phones-are-safe-a-special-investigation/>

Tom Wheeler, former head of the FCC during the Obama administration said at a June 2016 FCC 5G Conference in Washington DC about .

No testings, no standards, anything goes
Aimed and amplified signals
Ultra High Frequency-24 to 100 GHz
Rake in Billions
Share with satellites and military
Everything (and everyone?) must be microchipped
All areas including rural saturated with radiation
Bribe local gov'ts reps
Fast track all local deployment
<https://www.youtube.com/watch?v=P5AYRWvjiVg>

In researching, listening to conferences of scientists, and reading the information put out by many research groups, the issue of supporting an industry that has only profit as their motive is a dangerous trend. International independent scientists are calling for reducing RFR based on peer-reviewed published science showing RFR harms the public and nature, and children are especially vulnerable.

26,000 Scientists Oppose 5G Roll Out <https://principia-scientific.org/petition-26000-scientists-oppose-5g-roll-out>

Studies found radiation causes a wide range of health impacts: "Effects include increased cancer risk, cellular stress, increase in harmful free radicals, genetic damages, structural and functional changes of the reproductive

system, learning and memory deficits, neurological disorders, and negative impacts on general well-being in humans." There is more information on the adverse health effects of microwave radiation provided at the following link. <https://www.emfscientist.org/>

Sebastopol has already had several deaths due to cell towers. Personal Accounts of Residents of Petaluma and Walker Avenues in Sebastopol, Living Within 500 Feet of The Cell Tower

<http://www.radiation dangers.com/cell-towers/numerous-deaths-and-illnesses-near-cell-tower-in-sebastopol-ca/>

See this letter to Sebastopol which outlines the reasons to oppose 5G and provides peer-reviewed science references: <http://emfsafetynetwork.org/wp-content/uploads/2018/05/Letter-to-Seb-Verizon-5G.pdf>

After close to a dozen people attending and living near a school with a cell tower inside the campus in San Joaquine County, children have been diagnosed with cancer. The parents and officials have had the tower removed. <https://thefreethoughtproject.com/school-removes-cell-tower-cancer/> But the parents say 5G Cell Tower is causing cancer in their children, The District is taking kickbacks <https://prepforthat.com/5g-cell-tower-cancer-san-joaquin-county/>

Even LA Firefighters expose Cell Towers as Giant Microwaves

<https://www.youtube.com/watch?v=0ClAQuqEatc&feature=youtu.be>

Dr. Sharon Goldberg, an internal medicine physician & professor gives her testimony regarding 5g technology dangers specifically involving electromagnetic radiation. She says: "Wireless radiation has biological effects. Period." (diabetes, kidney disease) <https://www.youtube.com/watch?v=1Qt5B39LB7c>

In 2017 Governor Brown vetoed SB 649 which would have created a state mandated system of cell towers every couple hundred feet apart in California. SB 649 would have allowed unlimited refrigerator-size cell equipment on poles, sidewalks, and public property with no safety oversight. 300 cities, 47 counties and over 100 organizations opposed SB 649, including Sonoma County! Dozens of health, environment, consumer and justice organizations representing millions of Californians opposed SB 649 including: Environmental Working Group, Sierra Club California, California League of Conservation Voters, AARP American Association of Retired Persons (CA), Association of Environmental Professionals, Alliance of Nurses for Healthy Environments, Center for Environmental Health, Citizens for Health, The Utility Reform Network, Teens Turning Green, As You Sow, Baby Safe Project, and many more.

I urge you to retain local control and update the telecom ordinance to hold the telecommunications industry accountable. It's important to stop the roll out of 5 G completely. There are Cities like Chattanooga Tennessee, Portland Oregon, Olds Alberta, San Francisco and Seattle – cities that value data privacy, autonomy, local prosperity and wellbeing – have chosen or are choosing community-owned fiber optics. Wired fiber is faster, safer, cheaper, greener, more reliable, and more data secure than wireless 5G.

<https://digitalsurvivor.uk/2019/03/23/community-fibre-instead-of-5g/>

Thank you for your consideration,

Rev. Judy Dragon
193 Torzelli Ln.
95407

Bliss, Sandi

3.1

From: Dana Davis <dkdavis@sonic.net>
Sent: Friday, December 6, 2019 9:26 PM
To: Tibbetts, Jack; Olivares, Ernesto; Rogers, Chris; Sawyer, John; Fleming, Victoria; Schwedhelm, Tom; City Clerk; CMOoffice; Gallagher, Sue; Guhin, David; McHenry, Eric; Reeve, Amy
Subject: [EXTERNAL] 100 new cell towers in Santa Rosa

Dear Santa Rosa council members,

I am very concerned about the plan to consider allowing 100 new cell towers in Santa Rosa, and also about the new 5G technology. There is a lot of research showing the damaging effects of wireless technology, and especially the new 5G intensification. I use a cell phone rarely and it's a flip phone. I use a wired internet connection. This is all safer in terms of security and also for my health. I don't want to be exposed to more and more wireless radiation everywhere I go.

My 91-year-old mother lives in Santa Rosa, and I don't want her to be exposed to more wireless radiation. And research has shown that people, animals and bees are negatively affected by this.

More cell towers are not needed. I could care less about connecting my refrigerator to my toilet to my cell phone. This is silly conveniences that are being valued more than our health and the beauty of our environment.

Please do not approve any more cell towers, and do not approve 5G technology.

Thank you,
Dana Davis
Sebastopol, CA

Bliss, Sandi

3.1

From: rhianna miller <miller.rhianna12@gmail.com>
Sent: Friday, December 6, 2019 1:20 PM
To: Tibbetts, Jack; Olivares, Ernesto; Rogers, Chris; Sawyer, John; Fleming, Victoria; Schwedhelm, Tom; City Clerk; CMOOffice; Gallagher, Sue; Guhin, David; McHenry, Eric; Reeve, Amy
Subject: [EXTERNAL] More cell towers in Santa Rosa

Santa Rosa City Council and staff,

The 30 million dollar, ten year US National Toxicology Program study found DNA damage and clear evidence of cancer from exposure to RFR.

4G is the backbone for 5G. There is no scientific evidence to support any claim of 5G safety! Scientists and public health experts from around the world are calling for a moratorium on 5G.

Protect public health, property values, street views, public safety, and the environment. Deny the 100 + "small cell" towers pending in Santa Rosa. These towers will greatly increase radio frequency radiation (RFR) in Santa Rosa neighborhoods, where people live, work, sleep and play. Peer-reviewed published science shows RFR harms people and nature. Children, the elderly, and those already ill are more vulnerable.

The harmful effects of RFR include: fatigue, headaches, sleep problems, anxiety, ringing in the ears, heart problems, learning and memory disorders, increased cancer risk, and more.

In 2018 Newsweek reported: "Technology is quite literally destroying nature, with a new report further confirming that electromagnetic radiation from power lines and cell towers can disorientate birds and insects and destroy plant health. The paper warns that as nations switch to 5G this threat could increase."

Peer-reviewed studies show worker bees did not return to their hives because of wireless radiation, which led to a colony collapse. Radiation impacts on wild birds documented nest abandonment, plumage deterioration and death. Lab studies of chick embryos documented heart attacks and death. In 2019 the Swiss environmental group Pro Natura reported 5G increases the body temperature of insects.

The telecommunication industry's unbounded profit motive should never outweigh public and environmental safety.

Communications are faster, more reliable, and safer using wired and corded connections.

Thank you for your consideration,
Rhianna Miller

628 Mill Street
Santa Rosa, CA 95404

Bliss, Sandi

3.1

From: Gail Raborn <gailraborn@icloud.com>
Sent: Friday, December 6, 2019 12:50 PM
To: Tibbetts, Jack; Olivares, Ernesto; Rogers, Chris; Sawyer, John; Fleming, Victoria; Schwedhelm, Tom; City Clerk; CMOOffice; Gallagher, Sue; Guhin, David; McHenry, Eric; Reeve, Amy
Subject: [EXTERNAL] Small cell towers pending

Dear Santa Rosa City Council and Staff,

Protect public health, property values, street views, public safety, and the environment. Deny the 100 + "small cell" towers pending in Santa Rosa. These towers will greatly increase radio frequency radiation (RFR) in Santa Rosa neighborhoods, where people live, work, sleep and play. Peer-reviewed published science shows RFR harms people and nature. Children, the elderly, and those already ill are more vulnerable.

The harmful effects of RFR include: fatigue, headaches, sleep problems, anxiety, ringing in the ears, heart problems, learning and memory disorders, increased cancer risk, and more. The 30 million dollar, ten year US National Toxicology Program study found DNA damage and clear evidence of cancer and from exposure to RFR.

In 2018 Newsweek reported: "Technology is quite literally destroying nature, with a new report further confirming that electromagnetic radiation from power lines and cell towers can disorientate birds and insects and destroy plant health. The paper warns that as nations switch to 5G this threat could increase."

Peer-reviewed studies show worker bees did not return to their hives because of wireless radiation, which led to a colony collapse. Radiation impacts on wild birds documented nest abandonment, plumage deterioration and death. Lab studies of chick embryos documented heart attacks and death. In 2019 the Swiss environmental group Pro Natura reported 5G increases the body temperature of insects.

4G is the backbone for 5G. There is no scientific evidence to support any claim of 5G safety! Scientists and public health experts from around the world are calling for a moratorium on 5G.

The telecommunication industry's unbounded profit motive should never outweigh public and environmental safety.

Communications are faster, more reliable, and safer using wired and corded connections. Thank you, Gail Raborn - Santa Rosa citizen

Bliss, Sandi

3.1

From: Sandi Maurer <emfsafe@sonic.net>
Sent: Friday, December 6, 2019 11:36 AM
To: Tibbetts, Jack; Olivares, Ernesto; Rogers, Chris; Sawyer, John; Fleming, Victoria; Schwedhelm, Tom; City Clerk; CMOOffice; Gallagher, Sue; Guhin, David; McHenry, Eric; Reeve, Amy
Subject: [EXTERNAL] EMF Safety Network comments for 12/10 study session on "small cell" towers
Attachments: Letter-to-Santa Rosa-small cell.pdf

Please find attached letter to Santa Rosa City Council and staff. This pertains to your 12/10 study session:
3.1 WIRELESS SMALL CELL DEPLOYMENT ON CITY OWNED STREET LIGHTS AND JOINT UTILITY POLES

Thank you for your consideration and diligence on this important issue.

Sandi Maurer

www.emfsafetynetwork.org

Save Lives, Save Nature, Reduce EMFs



PO Box 1016 Sebastopol CA 95473 707-827-0109

www.emfsafetynetwork.org

Save Lives, Save Nature, Reduce EMFs

To: City of Santa Rosa
100 Santa Rosa Avenue
Santa Rosa, CA 95404

RE: 12/10 3 pm study Session: WIRELESS SMALL CELL DEPLOYMENT ON CITY OWNED STREET LIGHTS AND JOINT UTILITY POLES

Santa Rosa City Council and staff,

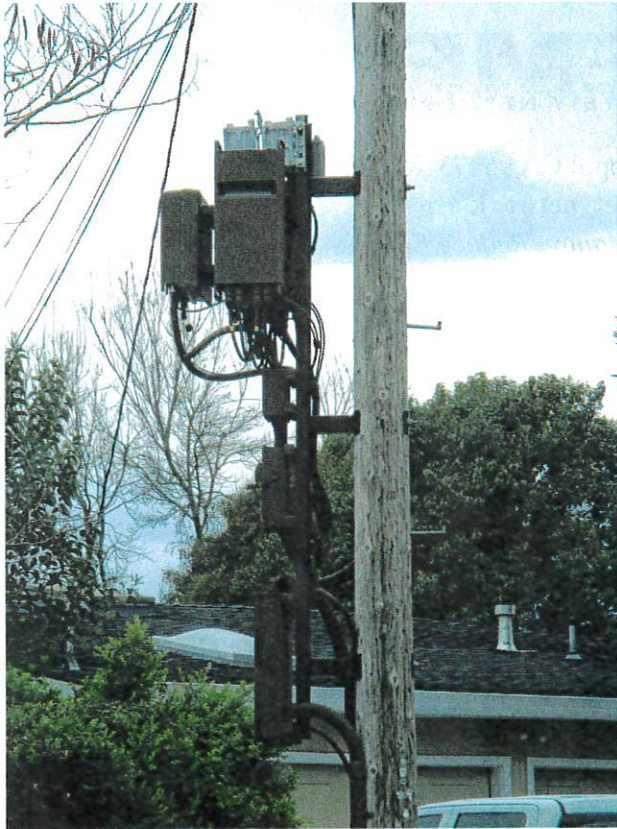
You have before you pending applications for 100 plus “small cell” towers to be deployed in Santa Rosa. These towers would lay the groundwork for 5G. The proposed towers would add unsightly equipment, overload poles, devalue property, and greatly increase radio frequency radiation (RFR) in Santa Rosa neighborhoods, where people live, work, sleep and play. Peer-reviewed published science shows RFR can cause a wide range of health problems: sleep problems, heart arrhythmias, anxiety, headaches, ringing in the ears, cancer and more. Peer-reviewed published science shows RFR is harmful to the environment. Children, the elderly, and those already ill are more vulnerable.

EMF Safety Network¹ requests the City Council deny the towers to protect the health, safety, and welfare of the community.

Attorney Gail Karish of Best Best and Krieger (BBK)² outlined the legal reasons a California city can deny “small cell” towers in the public rights-of-way. In general, cities still have some control over cell towers, including visual impacts and aesthetics, lack of a significant coverage

¹EMF Safety Network (EMFSN) is a Sebastopol based non-profit project founded in 2009. Our mission is to educate and empower people by providing science and solutions to reduce EMFs, achieve public policy change, and obtain environmental justice. We have participated in EMF issues at the local, state and federal level. www.emfsafetynetwork.org

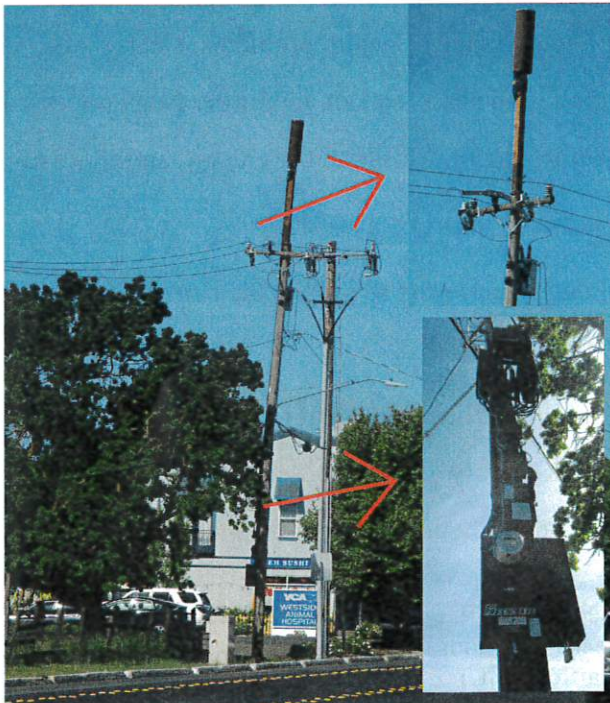
² <http://emfsafetynetwork.org/wp-content/uploads/2018/04/April-24-2018-Letter-to-EMF-Safety-Network-re-Wireless-c1.pdf>



gap, public utilities code protections, land use, and process rights. *Since this letter was written the Federal Communications Commission (FCC) has passed WT Docket 17-79 which went into effect on 1/13/2019. This is not included in the attorneys letter. The order adopts: new shot clock deadlines; limits on fees; and new standards governing aesthetic, under grounding, and spacing requirements.*

“Small cell” is a junkyard on a pole.

“Small cell” towers are not small, they are many feet taller than other telephone poles and loaded with electrical equipment. These photos to the left are of “small cell” towers on Link Lane and Sebastopol Road in Santa Rosa.



Overloading poles can cause a tower to fall or spark a fire like what happened in Malibu in 2007. *“When Santa Ana winds swept through the canyon on Oct. 21, 2007, three utility poles next to Malibu Canyon Road toppled and ignited the fire. The blaze burned 3,836 acres and destroyed or damaged dozens of structures and vehicles. The poles were jointly owned by SoCal Edison, AT&T Mobility, Verizon Wireless and NextG*

Networks of California.”³ (Note the Sebastopol Rd. tower in the photo on the left was newly installed and already leaning.)

“Small cell” energy output is similar to a macro cell according to expert: Lee Afflerbach, P.E., Principal Engineer, who was hired by the City of Sonoma said: *“To get around the capacity issue -- it's because so many people are streaming video and other services like that, they [Verizon] have to have multiple sources for this. That's why we have the smaller cells because each cell is capable of almost putting out the same energy as one macro cell.”*⁴

Loss of property value: Home or business owners risk property value loss where a cell tower is installed in the neighborhood. A survey by the National Institute for Science, Law & Public Policy found that 94 percent of homebuyers are “less interested and would pay less” for a property located near a cell tower or antenna.⁵

Public Utilities Code Section 7901 provides that use of the roads by telephone companies cannot *“incommode the public use of the road...”* The phrase “incommode the public use” in Section 7901 means *“to unreasonably subject the public use to inconvenience or discomfort; to unreasonably trouble, annoy, molest, embarrass, inconvenience; to unreasonably hinder, impede, or obstruct the public use.”*⁶ If ever there was a situation that caused discomfort, or unreasonably troubled residents, it is the case of cell towers near homes. Cell towers emit RFR and peer-reviewed published science shows RFR harms public health and the environment. The International Agency for Research on Cancer at the World Health Organization classifies RFR as a 2B (possible) carcinogen.⁷

³ <http://articles.latimes.com/2013/may/20/local/la-me-ln-edison-admits-errors-in-malibu-fire-settles-now-top-60-million-20130520>

⁴ At 3:10:24: <https://youtu.be/HRYFXx7oNN4?t=11424>

⁵ <https://www.businesswire.com/news/home/20140703005726/en/Survey-National-Institute-Science-Law-Public-Policy#.VNRBPp3F-So>

⁶ BBK letter page 2 paragraph 2: <http://emfsafetynetwork.org/wp-content/uploads/2018/04/April-24-2018-Letter-to-EMF-Safety-Network-re-Wireless-c1.pdf>

⁷ IARC/WHO <https://goo.gl/BrkpG8>

Why we cannot rely on the Federal Communications Commission (FCC): FCC proceedings 13-84 and 03-137 were initiated to determine whether their RFR exposure limits and policies created in 1996 need to be reassessed. These proceedings which were filed in 2013 remain incomplete⁸. The federal government has taken sole responsibility for the radiation safety of personal wireless service deployment⁹, however, no federal agency is acting responsibly, or being accountable for protecting the public and the environment from the health effects of RFR. The science has evolved greatly since 1996 meanwhile wireless devices have been widely adopted, as well as forced upon the public, for example: cell towers, wireless in schools, and smart meters. This rampant explosion is set to get much worse with 5G, Internet of Things, Smart Cities, radar in cars and more.

The FCC is a regulatory captured agency: Investigative journalist Norm Alster wrote: Captured Agency: How the Federal Communications Commission is dominated by the industries it presumably regulates.¹⁰ published by Harvard University. Alster calls on the FCC to acknowledge there may be wireless health risks, to back off wi-fi promotion, to acknowledge children and pregnant women may be especially vulnerable, and more. He writes, *“Personally, I don’t believe that just because something can be done it should heedlessly be allowed. Murder, rape and Ponzi schemes are all doable but subject to prohibition and regulation. Government regulators have the responsibility to examine the consequences of new technologies and act to at least contain some of the worst. Beyond legislators and regulators, public outrage and the courts can also play a role but these can be muffled indefinitely by misinformation and bullying.”*

Peer-reviewed published science shows wireless radiation harms public health.

The BioInitiative Reports reference more than 3800 peer-reviewed published studies. Summary of key scientific evidence includes:

⁸ On November 27, 2019 the FCC released a resolution essentially denying changes to their RFR guidelines, however comments and reply comments are still pending.

⁹ 47 U.S.C. § 332(c)(7); 47 C.F.R. 1.1307(b) and 1.1310, which are based on perceived harm of overheating of human tissues by RFR.

¹⁰ http://ethics.harvard.edu/files/center-for-ethics/files/capturedagency_alster.pdf

- Evidence for Damage to Sperm and Reproduction
- Evidence that Children are More Vulnerable
- Evidence for Effects on Autism (Autism Spectrum Disorders)
- Evidence for Electrohypersensitivity
- Evidence for Effects from Cell Tower-Level RFR Exposure
- Evidence for Effects on the Blood-brain Barrier
- Evidence for Effects on Brain Tumors
- Evidence for Effects on Genes (Genotoxicity)
- Evidence for Effects on the Nervous System (Neurotoxicity)
- Evidence for Effects on Cancer (Childhood Leukemia, Adult Cancers)
- Melatonin, Breast Cancer and Alzheimer's Disease
- Stress, Stress Proteins and DNA as a Fractal Antenna

“There is now much more evidence of risks to health affecting billions of people world-wide. The status quo is not acceptable in light of the evidence for harm.” David O. Carpenter, MD, co-editor BioInitiative Report. The authors conclude, *“EMF and RFR are preventable toxic exposures. We have the knowledge and means to save global populations from multi-generational adverse health consequences by reducing both ELF and RFR exposures. Proactive and immediate measures to reduce unnecessary EMF exposures will lower disease burden and rates of premature death.”*^{11, 12}

The 30 million dollar, ten year US National Toxicology Program (NTP) study, which is one of the largest and most comprehensive studies on cell phone radiation and cancer found clear evidence of cancer from exposure to wireless radiation. NTP scientists also found that RFR expo-

¹¹ BioInitiative Reports www.bioinitiative.org

¹² <https://ecfsapi.fcc.gov/file/7022117727.pdf>

sure was associated with an increase in DNA damage.¹³ *A recent Italian study produced similar results.*¹⁴

International scientists are calling for immediate measures to reduce RFR. The International EMF Scientist Appeal¹⁵ signed by 235 scientists from 41 nations warn: *“We are scientists engaged in the study of biological and health effects of non-ionizing electromagnetic fields (EMF). Based upon peer-reviewed, published research, we have serious concerns regarding the ubiquitous and increasing exposure to EMF generated by electric and wireless devices. These include—but are not limited to—radiofrequency radiation (RFR) emitting devices, such as cellular and cordless phones and their base stations, Wi-Fi, broadcast antennas, smart meters, and baby monitors as well as electric devices and infra-structures used in the delivery of electricity that generate extremely-low frequency electromagnetic field (ELF EMF).” “Effects include increased cancer risk, cellular stress, increase in harmful free radicals, genetic damages, structural and functional changes of the reproductive system, learning and memory deficits, neurological disorders, and negative impacts on general well-being in humans.”*

The following are quotes from science experts who signed the The International EMF Scientist Appeal.¹⁶

- *“Based upon epidemiological studies there is consistent evidence of increased risk for brain tumors (glioma and acoustic neuroma) associated with use of wireless phones.”* Lennart Hardell, MD, PhD University Hospital, Orebro, Sweden
- *“The harmful effects of electromagnetic fields, regardless of their frequencies, are now scientifically settled. Pregnant women (the fetus) and children and adolescents are particularly vul-*

¹³ NTP cell phone study, general info <http://ntp.niehs.nih.gov/results/areas/cellphones/index.html>

¹⁴ Report of final results regarding brain and heart tumors in Sprague-Dawley rats exposed from prenatal life until natural death to mobile phone radio frequency field representative of a 1.8 GHz GSM base station environmental emission
<https://www.sciencedirect.com/science/article/pii/S0013935118300367>

¹⁵ EMF Scientist appeal <https://www.emfscientist.org/index.php/emf-scientist-appeal>

¹⁶ <https://www.emfscientist.org/index.php/science-policy/expert-emf-scientist-quotations>

nerable.”- Dominique Belpomme, MD, MPH, Paris V Descartes University, European Cancer & Environment Research Institute.

- *“U.S. regulatory standards and international guidelines only control for short-term heating of tissue. The standards do not protect us from the low-intensity, chronic exposures to electromagnetic fields (EMF) that are common today. The scientists who signed the Appeal request that the UN and member nations protect the global human population, and animal and plant life from EMF exposures. There has been strong support from the international scientific community for the Appeal, even among those who believe that scientists should not take public policy positions. Some have taken personal risks to sign the Appeal because this is a public health issue that affects everyone now, as well as future generations.”* Joel Moskowitz, Ph.D., Director of the Center for Family and Community Health, School of Public Health, University of California, Berkeley, USA

Proximity to RFR antennas is harmful

The following peer-reviewed, published studies examine the adverse effects of wireless radiation in relation to antenna location.

- Biological effects from exposure to electromagnetic radiation emitted by cell tower base stations and other antenna arrays *“Both anecdotal reports and some epidemiology studies have found headaches, skin rashes, sleep disturbances, depression, decreased libido, increased rates of suicide, concentration problems, dizziness, memory changes, increased risk of cancer, tremors, and other neurophysiological effects in populations near base stations.”*¹⁷
- Neurobehavioral effects among inhabitants around mobile phone base stations *“The prevalence of neuropsychiatric complaints as headache (23.5%), memory changes (28.2%), dizziness (18.8%), tremors (9.4%), depressive symptoms (21.7%), and sleep disturbance (23.5%) were significantly higher among exposed inhabitants than controls...”*¹⁸

¹⁷<http://www.nrcresearchpress.com/doi/pdf/10.1139/A10-018?src=recsys&>

¹⁸ Neurobehavioral effects among inhabitants around mobile phone base stations <https://www.ncbi.nlm.nih.gov/pubmed/16962663>

- Epidemiological Evidence for a Health Risk from Mobile Phone Base Stations *“We found that eight of the 10 studies reported increased prevalence of adverse neurobehavioral symptoms or cancer in populations living at distances < 500 meters from base stations.”*¹⁹

Peer-reviewed, published science shows RFR harms nature

The US Department of the Interior states RFR threatens birds, and criticizes the FCC’s radiation guidelines, stating, *“the electromagnetic radiation standards used by the Federal Communications Commission (FCC) continue to be based on thermal heating, a criterion now nearly 30 years out of date and inapplicable today.”* Two hundred forty-one bird species suffer mortality risk from both tower collisions and from exposure to the radiation towers emit. This includes birds that are endangered or threatened, Birds of Conservation Concern, migratory birds, and eagles. Studies of radiation impacts on wild birds documented nest abandonment, plumage deterioration and death. Birds studied included House Sparrows, White Storks, Collared Doves, and other species. Studies in laboratories of chick embryos documented heart attacks and death.²⁰ Scientists in Germany studied tree damage in relation to wireless radiation from 2006-2015. They monitored, observed and photographed unusual or unexplainable tree damage, and measured the radiation which the trees were exposed. *“The aim of this study was to verify whether there is a connection between unusual (generally unilateral) tree damage and radio frequency exposure.”* They found significant differences between the damaged side of a tree facing a phone mast and the opposite side, as well as differences between the exposed side of damaged trees and all other groups of trees in both sides. The scientists concluded, *“Statistical analysis demonstrated that electromagnetic radiation from mobile phone masts is harmful for trees.”*²¹ The following studies show insects are harmed by radiation:

¹⁹ Epidemiological Evidence for a Health Risk from Mobile Phone Base Stations <https://goo.gl/Zz6dhk>

²⁰ US Department of Interior letter and background: http://www.ntia.doc.gov/files/ntia/us_doi_comments.pdf

²¹ Radiofrequency radiation injures trees around mobile phone base stations. <https://www.ncbi.nlm.nih.gov/pubmed/27552133?dopt=Abstract#>

- Food collection and response to pheromones in an ant species exposed to electromagnetic radiation found exposure to radiation caused colony deterioration and affected social insects' behavior and physiology.²²
- Oxidative and genotoxic effects of 900 MHz electromagnetic fields in the earthworm concluded radiation caused genotoxic effects and DNA damage in earthworms²³.
- Mobile Phone Induced Honey Bee Worker Piping. The study abstract states, "*The worldwide maintenance of the honeybee has major ecological, economic, and political implications.*" Cell phone RFR was tested for potential effects on honeybee behavior. Handsets were placed in the close vicinity of honeybees and the sound made by the bees was recorded and analyzed. The information revealed that active cell phone handsets induced the bees worker piping signal. "*In natural conditions, worker piping either announces the swarming process of the bee colony or is a signal of a disturbed bee colony.*"²⁴

The following are observations by International scientists of RFR effects on nature²⁵ :

- "*Migratory birds -- incredibly important to the global economy and for the ecological services they provide -- now appear to be negatively affected by non-ionizing radiation.*" Dr. Albert Manville, Adjunct Professor, Johns Hopkins University; Senior Wildlife Biologist, U.S. Fish & Wildlife Service (FWS), Emeritus/Retired
- "*Man-made electromagnetic fields impact all living organisms, acting first on the unit membrane. We must reduce our dependence on 'wireless' technologies, reduce the numbers of masts (i.e., cell towers), of Wi-Fi apparatus, of cordless phones and so on, and clearly indicate, in public spaces, the intensity of the ambient electromagnetic field.*" Prof. Marie-Claire Cammaerts, PhD., Free University of Brussels, Faculty of Science, Belgium.

²² Food collection and response to pheromones in an ant species exposed to electromagnetic radiation
<https://www.ncbi.nlm.nih.gov/pubmed/23320633>

²³ Oxidative and genotoxic effects of 900 MHz electromagnetic fields in the earthworm *Eisenia fetida*.
<https://www.ncbi.nlm.nih.gov/pubmed/?term=23352129>

²⁴ <https://link.springer.com/article/10.1007/s13592-011-0016-x>

²⁵ <https://www.emfscientist.org/index.php/science-policy/expert-emf-scientist-quotations>

5G millimeter waves are harmful

The desired future of the telecommunications industry is 5G which incorporates millimeter waves. A 5G deployment would require many cell towers close together throughout communities. Peer-reviewed published science shows millimeter waves penetrate the skin and affect human health.²⁶ A meta-analysis of studies on millimeter waves (MMWs) "State of knowledge on biological effects at 40–60 GHz"²⁷ states, "*At the cellular level, it stands out from the literature that skin nerve endings are probably the main targets of MMWs and the possible starting point of numerous biological effects.*" Effects reviewed include effects on capillaries and nerve endings, protein insults, epigenetic regulation, and the risk of homeostasis disruption, which would have dramatic consequences. In addition, millimeter wave technology has been developed as a crowd control weapon which causes acute burning pain, as if the body is on fire.²⁸

International independent scientists have called for a moratorium on the deployment of 5G²⁹. They state, "*We the undersigned, more than 180 scientists and doctors from 35 countries, recommend a moratorium on the roll-out of the fifth generation, 5G, for telecommunication until potential hazards for human health and the environment have been fully investigated by scientists independent from industry.*"

Conclusion

The telecommunication industry's unbounded profit motive should never outweigh the safety and well being of the public and our environment! Communications are safer using wired and corded connections.

Respectfully submitted on December 6, 2019:

/s/ _____

Sandi Maurer, Director, EMF Safety Network

²⁶ State of knowledge on biological effects at 40–60 GHz <https://goo.gl/gbBKHL>

²⁷ C. R. Physique 14 (2013) 402–411

²⁸ US Military Active Denial System <http://jnlwp.defense.gov/About/Frequently-Asked-Questions/Active-Denial-System-FAQs/>

²⁹ <http://emfsafetynetwork.org/wp-content/uploads/2017/11/Scientist-5G-appeal.pdf>

Rec'd at Meeting 12/10/19
Item No. 3.1
From: Jennifer LaPorta

3 min on legality +

I attest and affirm that the following statements are true, accurate and within my personal knowledge.

The Telecommunications Act of 1996 recognizes the actual environmental effects of radiofrequency radiation or RFR from Wireless Telecommunications Facilities or WTFs, indicating by extension its recognition of actual health effects.

This Act left regulation of the health effects entirely within state and local officials' authority, **obligating** said officials to protect its residents from health effects with regard to the placement, construction, modification and operations of WTFs.

In plain reading:

"No State or local government or instrumentality thereof may regulate the placement, construction, and modification of personal wireless service facilities on the basis of the environmental effects of radio frequency emissions to the extent that such facilities comply with the Commission's regulations concerning such emissions."

On 3/6/18, during this Council meeting, as recorded on video on the City's website, City Attorney Sue Gallagher stated: "the FCC pre-empts any state or local involvement on issues of RF emissions. There is federal law statute. There are FCC regs and also case law I looked at. . . went so far as to say 'if a local jurisdiction or a state made any decision that was even partially based on Rf emissions, that decision would be set aside, even if there were good valid other grounds for the decision. So that's pretty strict."

FCC is not the US Congress and does not make laws. Congress' TCA does NOT preempt local authority over WTF operations including emissions. Rather, when given the choice to preempt operations, Congress positively left all authority over operations entirely within state and local officials' hands. By making false representations, the City Atty is ultra viers (outside the law).

Due to these decisions, it is necessary that you **immediately** stop all placement, construction, modification and operations of new, recent, and applied-for WTFs.

Please write a letter to your wireless applicants that all of their applications are incomplete. The required EAs or EISs must include negative health consequences and safety concerns, as per the 4/4/19 CA Supreme court ruling in T Mobile vs San Francisco. This will give Santa Rosa time to update it's Telecommunications Ordinance. Let's have reasonable setbacks of these towers to where people sleep, live and heal.

I have expressed no "concern" or any other non-substantive matter, but solely matters of fact and law. I accept your oath of office.

Jennifer LaPorta
Santa Rosa homeowner and taxpayer
BS Environmental Health

Jla *scfarrt@gmail.com*

Rec'd at Meeting	12/10/19
Item No.	31
From:	Daciana Iancu

Daciana Iancu, MD

I attest and affirm that the following statements are true, accurate and within my personal knowledge.

The pulse-modulated microwave radiation from wireless telecommunications facilities (WTFs) is hazardous, causing DNA damage to the mitochondria, the energy generators inside the cells. It also damages the membrane of red blood cells. When cells are removed from microwave radiation exposure after a limited amount of time, they can still recover. However, their DNA damage does not recover. When cells are constantly exposed to microwave radiation, they are not able to recover.

Studies have shown that 1 microwatt/cm² of radiation can cause decreased sperm viability. 2.5 microwatts can affect the calcium metabolism in the heart muscle. 6.0 microwatt/cm² causes DNA damage. Exposure produces cumulative effects over time. Current radiation exposures in cities without 5G have can reach around 5000 microwatt/cm², not only exceeding FCC guidelines, but more importantly exceeding natural background levels by trillions of times. 5G is expected to deploy concentrated, focused, and constant radiation in excess of 100x current levels.

The cells most affected are those with rapid replication, like sperm cells, ova, and the cells of fetuses and young children. This causes problems with infertility, birth defects, memory problems and learning disabilities, cancers, etc. Adults can be affected as well, especially those with weaker constitutions and more stress. They can develop in the short-term neurologic and cardiac conditions, and in the longer-term chronic illnesses such as autoimmune disorders, cancer, memory problems, fatigue, etc.

The harmful effects of radiofrequency / microwave (RF/MW) radiation have been documented by over ten thousand studies over the last century. *Bioinitiative 2012*, now updated, is a review put together by 29 scientists from multiple countries about the harmful effects of RF/MW radiation on human health.

The global fertility rate has decreased by 3% just in the last year: much of this is due to male infertility. Many studies show that sperm exposed to RF/MW radiation loses its viability.

Girls who are exposed to RF/MW radiation while fetuses in utero can develop damaged DNA. When they become pregnant, this damaged DNA can cause birth

defects in their offspring, including infertility in their female children. The repercussions are that within 5 generations, humanity could become extinct.

There is currently an international appeal signed by 248 EMF scientists from 42 countries urging the UN and WHO to exert strong leadership on the development of more protective measures.

I have expressed no "concern" or any other non-substantive matter, but solely matters of fact and law. I accept your oath of office.

Sincerely,

Daciana Iancu, MD

3735 Coffey Lane

Santa Rosa, CA 95403

daciana@gmail.com

References:

1. EMF Scientist.org. International Appeal
2. Bioinitiative.org 2012 report
3. Pall, Martin. Wi-Fi is an important threat to human health. Environmental Research Volume 164, July 2018, Pages 405-416.
<https://www.sciencedirect.com/science/article/pii/S0013935118300355?via%3Dihub>
4. <https://www.webmd.com/children/news/20140819/children-cell-phones#2>
5. Santini et al. Role of Mitochondria in the Oxidative Stress Induced by Electromagnetic Fields: Focus on Reproductive Systems. Oxid Med Cell Longev. 2018; 2018: 5076271.
<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6250044/>
6. 5G Apocalypse – The extinction event. Documentary by Sacha Stone.
<https://www.youtube.com>

Rec'd at Meeting 12/10/19
Item No. 3.1
From: Tom LaPorta

To the City Council of Santa Rosa:

My name is Tom LaPorta, and I have a background as a RN and electronics technician. I attest and affirm that the following statements are true, accurate and within my personal knowledge.

Here is a simplified version of how data-carrying radiofrequency (RF) radiation, which includes microwave radiation, affects us all. This radiation creates chaos in our bodies. If you're healthy, you may not notice any immediate effects, but the radiation is adversely affecting you, nonetheless, suppressing your melatonin, interfering with whole-body central nervous system function, reducing sperm quality and quantity, impairing cells from communicating properly, and causing inappropriate cell division. Constant exposure slowly chips away at our defenses.

The main energy producers in our cells, the mitochondria, are like electricians who detach electrons from food and push them through our wiring. This is called the electron transport chain. The electrons complete a reaction resulting in the production of energy. However, RF radiation causes a work slow-down by those mitochondrial electricians. That's less energy for health, and more opportunity for disease to take hold. Or, if you're already sick, disease progresses.

The scientific literature has been out there for decades informing us that our cells are thrown into chaos when exposed to manmade RF radiation, via calcium channels. It's like a distracted hotel doorman who holds the door open too long, and a crowd rushes in. Now you have to corral the people and get them back out the front door. No way to run a hotel – or a cell.

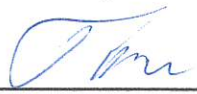
Over ten thousand studies indicate that RF radiation is not benign, no matter what the Telecom industry purports. You can't see what you're not looking for, but we're all here today because we DID look, and we found that exposure to RF radiation, is hazardous, particularly when modulated and when its wavelengths match the very dimensions of our brain and other organs, producing maximal absorption, and consequences to follow.

In the face of all this evidence, why do some studies show no ill effects? If the cell is healthy, it can maintain a higher voltage, a more intact cell wall, and repair minor injuries from other environmental hazards. The cell may initially absorb RF radiation without acute adverse effects, but damage is still being done.

What we don't see is hurting us. The evidence is clear: it's out there for the looking. Public officials need to use whatever tools they have to put the brakes on new WTFs in the City.

Let's not pay for faster download speeds with our health. 5G isn't as fast, reliable, secure, or energy-efficient as fiber-optic cable.

Signed, this 10th day of December 2019,



Tom LaPorta

Rec'd at Meeting 12/10/19
 Item No. 3.1
 From: Mark Sullivan

MEMO

<u>to:</u>	Tom Schwedhelm, Mayor and Santa Rosa City Council Members:
<u>from:</u>	Paul-André Schabracq, PAS Danan Schabracq Trust 131/139 Scott Street, Santa Rosa pas8@comcast.net
<u>date:</u>	December 7, 2019
<u>subject:</u>	Harry Lehman's letter regarding local jurisdictions face huge liabilities because reinsurance companies exclude wireless radiation hazards

Because telecom companies are not insured for injuries from microwave radiation, the City of Santa Rosa faces catastrophic liability from it approval of small cell antennas attached to City-owned poles as well as PG&E poles located in the public right-of-way. The enclosed letter from Harry Lehman, Attorney to Sonoma County Supervisor Rabbitt addressing the liability to local jurisdictions from 5G and related technologies applies to all local jurisdictions.

Twenty years ago, the telecommunications industry already knew their business models were a risk to the general public, especially because insurers were already refusing to cover their biggest liabilities. The insurers "*fears mobile phones will be linked to illnesses such as cancer and Alzheimer's disease.*" Source TruePublica <https://truepublica.org.uk/united-kingdom/from-dieselgate-to-phonegate-we-need-to-wake-up-to-another-pollution-crisis/> .

Crown Castle (a company building small cell infrastructure throughout the USA) has a statement in their 2016 10-K Annual Report that says: "*If radio frequency emissions from wireless handsets or equipment on our wireless infrastructure are demonstrated to cause negative health effects, potential future claims could adversely affect our operations, costs or revenues... We currently do not maintain any significant insurance with respect to these matters.*"

A vertical line to the left of text indicates the relevant portions of Harry Lehman's letter.

Harry Vere Lehmann
Principal Attorney

Law Offices of Harry V. Lehmann PC
4 Vineyard Court
Novato, California 94947

Area Code 415
Telephone: 897-2121
Facsimile: 898-6959

April 8, 2019

TO: Sonoma County Supervisor David Rabbitt

RE: 1) 5G Science sources provided:
2) Information on Telecom's Long Con,
3) Explanation of Sonoma's 5G Liability
4) Financial prudence requires an immediate Moratorium

Dear Supervisor Rabbitt -

Fast Overview

On Monday of last week the city of Brussels, Belgium, banned 5G:

"I cannot welcome such technology if the radiation standards, which must protect the citizen, are not respected, 5G or not. The people of Brussels are not guinea pigs whose health I can sell at a profit. We cannot leave anything to doubt."

– *Céline Fremault, Minister of the Government (Brussels-Capital Region), responsible for Housing, Quality of Life, Environment and Energy*

For further data on the ban in Brussels see the below link:

<https://ehtrust.org/brussels-belgium-and-rome-municipality-oppose-wireless-5g-antennas/>

For the health of all of its residents, especially kids, Sonoma County should not allow 5G here, nor the installation of high density 4G while treaties between cable and Big Wireless bring us Gilligan's Island and the rest of what is now via cable by wireless instead. Sonoma's **best immediate choice** is a Moratorium on density increase permits **until the currently pending 9th Circuit case on the recent FCC regulation is resolved.**

1. The telecom industry has managed an elaborate Long Con in which it has convinced us all that cell phones are safe, whereas the radiation from them causes cancer.
2. There exists overwhelming scientific evidence, some of it likely new to you proving that cell phone radiation causes cancer.
3. Sonoma County faces catastrophic liability from so-called 'small cell' towers erected on county-poles as does any public entity owning such poles. The telecom companies are not insured for injuries from microwave radiation and seek to stick taxpayers with the tab.

4. In terms of the scope of litigation risk, the *least* litigation risk appears to reside from a decision to outright deny all 5G permit requests.

5. Independent of the issues showing long term liability exposure, any permits or contract with industry should be avoided until the outcome of the now-pending 9th Circuit litigation in which many municipalities are challenging the FCC regulation.

Sonoma County taxpayers face crushing liability from 5G antennas

California state and regional and local governments cannot be sued for 'negligence.' For a lawsuit to proceed against the State or an element thereof, the case must be grounded in a statutorily prescribed Cause of Action. In governmental tort situations, seasoned counsel will file a Governmental Tort Claim alleging **Dangerous Condition of Public Property**, and after of the claim, the central plead liability theory of most such cases is just that, **Dangerous Condition of Public Property**, as provided for in Government Code 835.

The defendants in a lawsuit do not get to choose whether to be sued. That choice is made by plaintiffs' counsel. There is no way for any industry representative to honestly claim that the State will not be sued for such injuries. Once the involved cellular antenna box is attached to the involved governmental utility pole, for several reasons including the Doctrine of Fixtures as seen in tenancy situations, a melding takes place, and plaintiffs counsel will allege, consistent with law, that the melded unit as a whole is Public Property.

These *public* utility poles are demonstrably 'Dangerous' within the meaning of Government Code 835, because the radiation they emit has been scientifically proven to be carcinogenic, and the radiation is damaging to the human biological system. Therefore on the above basis, and on other theories including Joint Venture and Joint and Several Liability for the Concurring Acts of Independent Tortfeasors (Summers v. Tice et al) public entities face becoming the insurers for telecom where 5G is concerned.

Whether the FCC power grabs will be found Constitutional or not is now before the Ninth Circuit Court of Appeals. Respectfully, you can't put a puzzle together if the pieces are changing shape and it would be fiscally irresponsible to issue any increased density permits until the 9th Circuit cases are resolved. An immediate Moratorium is financially prudent.

Refusal to issue 5G permits means *less* potential litigation, not more.

If telecom were to sue any public entity, that entity faces only one suit or a few related suits likely to be consolidated. That's only a few lawsuits and Sonoma has strong positions including those mentioned here.

Alternatively, in contractually allowing telecom to use regional entity utility poles binds that entity as a participant in the tort, due to joint venture, doctrine of fixtures et al, leaving pole owners permanently open to cases without end. It is reasonable to expect that if 5G is allowed by public entities, each such entity will face suits from injured persons or their survivors, including under ADA. If such an entity will simply say no to 5G, the scope of litigation will remain narrow. A Moratorium on 5G presents the greatest opportunity to do good that you will ever encounter in your life in public service.

Financial Prudence favors a Moratorium on 5G permits until 9th Circuit case resolved.

There are legal and Constitutional issues now before the 9th Circuit, where many municipalities, San Jose, Newport Beach, Fairfax, Seattle, et al, have sued to stop the FCC from seizing utility poles owned by public entities. That action was originally in the 10th Circuit, but has been recently transferred to the 9th. It is reasonable and prudent to hold off on any permit issuance until the law has become clarified through this 9th Circuit litigation.

The Long Con

All of us, me too, were misled into thinking that dense towers posed no big risk. For convincing data on this point and well-researched history, see the March 29, 2018 edition of The Nation magazine, here is the link to the article which describes this advertising history:

<https://www.thenation.com/article/how-big-wireless-made-us-think-that-cell-phones-are-safe-a-special-investigation/>

Please make an Internet search for: 'Dr. Henry Lai Seattle Magazine,' see the disclosed industry memo which pitched that the company involved needed to 'war game,' against Dr. Lai of the University of Washington, who proved that cellular radiation breaks DNA strands.

The Science

Most important, please see the below-linked letter from Dr. Golomb, a Professor at the University of California School of Medicine, San Diego, referencing more than 360 scientific sources showing that non-ionizing microwave radiation is dangerous to health.

<https://ehtrust.org/wp-content/uploads/Golomb-SB-649-5G-letter-2017-08-18b.pdf>

For access to a large selection of peer reviewed science on this issue please see the collection at the website of Epidemiologist and Toxicology expert Dr. Devra Davis at:

<https://ehtrust.org/peer-reviewed-published-science-on-radiation-from-4g-5g-small-cell-wireless-antennas/>

The industry's historic position is that living tissue can't be damaged by the non-ionizing radiation from cellular radiation boils down to: "*Non-ionizing radiation does not have sufficient power to displace an electron from its shell. Therefore it is impossible for microwave radiation to cause any direct non-thermal chemical change in tissue.*"

However, contrary to the industry pitch, the final report from **the National Toxicology Program of the U. S. National Institutes of Health** on the NTP's \$25 million study of whether cellular radiation causes cancer **shows such causation, and by non-thermal means**, even though the *current* FCC risk standards are thermal, way remote from the science. As first announced on May 27, 2016 (see the article that date in Mother Jones), and as said by NTP using the term 'clear evidence' on March 28, 2018, cellular radiation causes the formation of glioma cells, the rootstock of glioblastoma, the brain cancer that kills as demonstrated in the NTP's final report of November 2, 2018. Details at the this link:

<https://www.niehs.nih.gov/news/newsroom/releases/2018/november1/index.cfm>

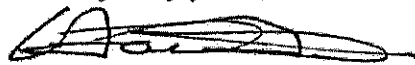
I respectfully submit that the 'shaken DNA syndrome' nature of DNA strand breakage is illustrated in the University of Maryland interferometer experiments of 1983. As I recall it, that University of Maryland interferometer study showed that addition of a 7.43 percent DNA into plain water caused a 24 fold (*24 times*) increase in Specific Absorption Rate (how much energy the fluid absorbed), **which change in energy absorption was determined to be non-ionic, but rather 'acoustic.'** meaning by transmitted vibration. In that study there was DNA molecular change (increased energy absorption in the DNA molecule) but it was **not ionic** .

In my opinion, a decade of study having lost friends: All these years the industry had been saying, ' the vibration won't hurt you, no harm until you cook.' However, Dr. Henry Lai's findings from the University of Washington School of Medicine proved that DNA strand is broken by exposure to cellular signal, established beyond rational scientific doubt. More recently, please see the calcium ion analysis from **Dr. Martin Pall**, late of the University of Washington School of Medicine proving cellular damage: Please see a 15 minute video of his 2015 presentation at The Commonwealth Club event organized by EMF safety expert Camilla Rees, <https://vimeo.com/132870272> . For Dr. Pall's scientific studies on the effects of EMF see: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3780531/> .

Conclusion

An immediate Moratorium is the only financially prudent choice to avoid long term contractually based litigation exposure of massive extent.

Very truly yours,



Harry V. Lehmann

1. CITY ONLY
2. PEOPLE
- 3 THERMAL RATION 1996
4. BODY BIO ELEC.
- 5 HUMAN TECH ASSUME BE CAREFUL
6. CITY OPEN TO LAWSUITS

PRESS RELEASE



U.N. Environment Programme Urged to Protect Nature and Humankind from Electromagnetic Fields (EMF) *4G/5G antenna densification is escalating health risks - a global crisis*

New York, NY, July 22, 2019. The Advisors to the International EMF Scientist Appeal, representing 248 scientists from 42 nations, have resubmitted *The Appeal* to the United Nations Environment Programme (UNEP) Executive Director, Inger Andersen, requesting the UNEP reassess the potential biological impacts of next generation 4G and 5G telecommunication technologies to plants, animals and humans.

There is particular urgency at this time as new antennas will be densely located throughout residential neighborhoods using much higher frequencies, with greater biologically disruptive pulsations, more dangerous signaling characteristics, plus transmitting equipment on, and inside, homes and buildings. The Advisors to *The Appeal* recommend UNEP seriously weigh heavily the findings of the independent, non-industry associated EMF science.

See [video](#) of spokesperson for *The Appeal*, the late Martin Blank, Ph.D. of Columbia University, and read the recent [letter to the UNEP](#) and the [Appeal](#).

The Appeal highlights the World Health Organization's (WHO) conflicting positions about EMF risk. The WHO's International Agency for Research on Cancer classified radiofrequency radiation as a Group 2B "Possible Carcinogen" in 2011, and extremely low frequency fields in 2001. Nonetheless, the WHO continues to ignore its own agency's recommendations and favors guidelines recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP), a private German NGO with industry ties long criticized for promoting guidelines not protective of humans, and falsely assuming authority. In addition, it should be noted that no nation has established EMF exposure guidelines aiming to protect animals and plants.

The Appeal calls on the United Nations to resolve the inconsistencies among its sub-organizations and to seriously address the rapidly escalating health and environmental crisis caused by man-made EMF pollution. Leadership is needed now, especially in light of urgent warnings from international scientists about 4G/5G antenna densification, the Internet of Things (IoT), and plans for significant radiation from space emitted by tens of thousands of satellites now being launched.

The Advisors to the International EMF Scientist Appeal - Annie Sasco, MD, Dr.PH., Henry Lai, Ph.D., Joel Moskowitz, PhD., Ronald Melnick, Ph.D. and Magda Havas, Ph.D., call on the UNEP to be a strong voice for the total environment of the planet, and an effective catalyst within the United Nations with regards to the biological and health effects of electromagnetic pollution.

In the letter to UNEP, Dr. Havas, Professor Emeritus, Trent University's School of the Environment, Canada, details serious effects on plants, insects and wildlife from electromagnetic fields that are well documented in the scientific literature.

Ronald Melnick, Ph.D., Advisor to *The Appeal* and former scientist at the U.S. National Toxicology Program (NTP) within the National Institutes of Health (NIH), who managed the design and development of the NTP's recently published \$30 million animal study showing a clear link between radio frequency radiation (RFR) and cancer, states: "Results from the NTP study show that the previously held assumption that radiofrequency radiation cannot cause cancer or other adverse health effects is clearly wrong." Policymakers the world over should take note.

See [International EMF Scientist Appeal](#) and [Letter to UNEP \(June 25, 2019\)](#)

Contacts:

Elizabeth Kelley, M.A., Director
EMFscientist.org
info@EMFscientist.org
1-520-912-4878

Joel M. Moskowitz, Ph.D.
School of Public Health, UC Berkeley
jmm@berkeley.edu
1-510-643-7314



**To: His Excellency Antonio Guterres, Secretary-General of the United Nations;
Honorable Dr. Tedros Adhanom Ghebreyesus, Director-General of the World Health Organization;
Honorable Inger Andersen, Executive Director of the U.N. Environment Programme;
U.N. Member Nations**

International Appeal: Scientists call for Protection from Non-ionizing Electromagnetic Field Exposure

We are scientists engaged in the study of biological and health effects of non-ionizing electromagnetic fields (EMF). Based upon peer-reviewed, published research, we have serious concerns regarding the ubiquitous and increasing exposure to EMF generated by electric and wireless devices. These include—but are not limited to—radiofrequency radiation (RFR) emitting devices, such as cellular and cordless phones and their base stations, Wi-Fi, broadcast antennas, smart meters, and baby monitors as well as electric devices and infra-structures used in the delivery of electricity that generate extremely-low frequency electromagnetic field (ELF EMF).

Scientific basis for our common concerns

Numerous recent scientific publications have shown that EMF affects living organisms at levels well below most international and national guidelines. Effects include increased cancer risk, cellular stress, increase in harmful free radicals, genetic damages, structural and functional changes of the reproductive system, learning and memory deficits, neurological disorders, and negative impacts on general well-being in humans. Damage goes well beyond the human race, as there is growing evidence of harmful effects to both plant and animal life.

These findings justify our appeal to the United Nations (UN) and, all member States in the world, to encourage the World Health Organization (WHO) to exert strong leadership in fostering the development of more protective EMF guidelines, encouraging precautionary measures, and educating the public about health risks, particularly risk to children and fetal development. By not taking action, the WHO is failing to fulfill its role as the preeminent international public health agency.

Inadequate non-ionizing EMF international guidelines

The various agencies setting safety standards have failed to impose sufficient guidelines to protect the general public, particularly children who are more vulnerable to the effects of EMF. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) established in 1998 the “Guidelines For Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (up to 300 GHz)”¹. These guidelines are accepted by the WHO and numerous countries around the world. The WHO is calling for all nations to adopt the ICNIRP guidelines to encourage international harmonization of standards. In 2009, the ICNIRP released a statement saying that it was reaffirming its 1998 guidelines, as in their opinion, the scientific literature published since that time “has provided no evidence of any adverse effects below the basic restrictions and does not necessitate an immediate revision of its guidance on limiting exposure to high frequency electromagnetic fields”². ICNIRP continues to the present day to make these assertions, in spite of growing scientific evidence to the contrary. It is our opinion that, because the ICNIRP guidelines do not cover long-term exposure and low-intensity effects, they are insufficient to protect public health.

The WHO adopted the International Agency for Research on Cancer (IARC) classification of extremely low frequency magnetic fields (ELF MF) in 2002³ and radiofrequency radiation (RFR) in 2011⁴. This classification states that EMF is a *possible human carcinogen (Group 2B)*. Despite both IARC findings, the WHO continues to maintain that there is insufficient evidence to justify lowering these quantitative exposure limits.

Since there is controversy about a rationale for setting standards to avoid adverse health effects, we recommend that the United Nations Environmental Programme (UNEP) convene and fund an independent multidisciplinary committee to explore the pros and cons of alternatives to current practices that could substantially lower human exposures to RF and ELF fields. The deliberations of this group should be conducted in a transparent and impartial way. Although it is essential that industry be involved and cooperate in this process, industry should not be allowed to bias its processes or conclusions. This group should provide their analysis to the UN and the WHO to guide precautionary action.

Collectively we also request that:

1. children and pregnant women be protected;
2. guidelines and regulatory standards be strengthened;
3. manufacturers be encouraged to develop safer technology;
4. utilities responsible for the generation, transmission, distribution, and monitoring of electricity maintain adequate power quality and ensure proper electrical wiring to minimize harmful ground current;

¹ <http://www.icnirp.org/cms/upload/publications/ICNIRPemfgdl.pdf>

² <http://www.icnirp.org/cms/upload/publications/ICNIRPStatementEMF.pdf>

³ <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono80.pdf>

⁴ <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono102.pdf>

5. the public be fully informed about the potential health risks from electromagnetic energy and taught harm reduction strategies;
6. medical professionals be educated about the biological effects of electromagnetic energy and be provided training on treatment of patients with electromagnetic sensitivity;
7. governments fund training and research on electromagnetic fields and health that is independent of industry and mandate industry cooperation with researchers;
8. media disclose experts' financial relationships with industry when citing their opinions regarding health and safety aspects of EMF-emitting technologies; and
9. white-zones (radiation-free areas) be established.

Initial release date: May 11, 2015

Date of this version: September 21, 2019

Inquiries, including those from qualified scientists who request that their name be added to the Appeal, may be made by contacting Elizabeth Kelley, M.A., Director, EMFscientist.org, at info@EMFscientist.org.

Note: the signatories to this appeal have signed as individuals, giving their professional affiliations, but this does not necessarily mean that this represents the views of their employers or the professional organizations they are affiliated with.

Signatories

Armenia

Prof. Sinerik Ayrapetyan, Ph.D., UNESCO Chair - Life Sciences International Postgraduate Educational Center, Armenia

Australia

Dr. Priyanka Bandara, Ph.D., Independent Environmental Health Educator/Researcher, Advisor, Environmental Health Trust; Doctors for Safer Schools, Australia

Dr. Peter French BSc, MSc, MBA, PhD, FRSM, Conjoint Senior Lecturer, University of New South Wales, Australia

Dr. Bruce Hocking, MD, MBBS, FAFOEM (RACP), FRACGP, FARPS, specialist in occupational medicine; Victoria, Australia

Dr. Gautam (Vini) Khurana, Ph.D., F.R.A.C.S., Director, C.N.S. Neurosurgery, Australia Dr. Don Malsch, Ph.D., Australia

Dr. Mary Redmayne, Ph.D., Department of Epidemiology & Preventive Medicine, Monash University, Australia

Dr. Charles Teo, BM, BS, MBBS, Member of the Order of Australia, Director, Centre for Minimally Invasive Neurosurgery at Prince of Wales Hospital, NSW, Australia

Austria

Dr. Michael Kundi, MD, University of Vienna, Austria

Dr. Gerd Oberfeld, MD, Public Health Department, Salzburg Government, Austria

Dr. Bernhard Pollner, MD, Pollner Research, Austria

Prof. Dr. Hugo W. Rüdiger, MD, Austria

Bahrain

Dr. Amer Kamal, MD, Physiology Department, College of Medicine, Arabian Gulf University, Bahrain

Belgium

Prof. Marie-Claire Cammaerts, Ph.D., Free University of Brussels, Faculty of Science, Brussels, Belgium

Joris Everaert, M.Sc., Biologist, Species Diversity team, Research Institute for Nature and Forest, Belgium

Dr. Andre Vander Vorst, PhD, professor emeritus, University Louvain-la-Neuve, Belgium

Brazil

Vânia Araújo Condessa, MSc., Electrical Engineer, Belo Horizonte, Brazil

Prof. Dr. João Eduardo de Araujo, MD, University of Sao Paulo, Brazil

Dr. Francisco de Assis Ferrelra Tejo, D. Sc., Universidade Federal de Campina Grande, Campina Grande, State of Paraíba, Brazil

Prof. Alvaro deSalles, Ph.D., Federal University of Rio Grande Del Sol, Brazil

Prof. Adilza Dode, Ph.D., MSc. Engineering Sciences, Minas Methodist University, Brazil

Dr. Daiana Condessa Dode, MD, Federal University of Medicine, Brazil

Michael Condessa Dode, Systems Analyst, MRE Engenharia Ltda, Belo Horizonte, Brazil
Prof. Orlando Furtado Vieira Filho, PhD, Cellular & Molecular Biology, Federal University of Rio Grande do Sul, Brazil

Canada

Dr. Magda Havas, Ph.D., Environmental and Resource Studies, Centre for Health Studies, Trent University, Canada
Dr. Paul Héroux, Ph.D., Director, Occupational Health Program, McGill University; InvitroPlus Labs, Royal Victoria Hospital McGill University, Canada
Dr. Tom Hutchinson, Ph.D., Professor Emeritus, Environmental and Resource Studies, Trent University, Canada
Prof. Ying Li, Ph.D., InVitroPlus Labs, Dept. of Surgery, Royal Victoria Hospital, McGill University, Canada
James McKay M.Sc., Ecologist, City of London; Planning Services, Environmental and Parks Planning, London, Canada
Prof. Anthony B. Miller, MD, FRCP, University of Toronto, Canada
Prof. Klaus-Peter Ossenkopp, Ph.D., Department of Psychology (Neuroscience), University of Western Ontario, Canada
Dr. Malcolm Paterson, PhD, Molecular Oncologist (ret.), British Columbia, Canada
Prof. Michael A. Persinger, Ph.D., Behavioural Neuroscience and Biomolecular Sciences, Laurentian University, Canada
Dr. Margaret Sears MEng, PhD, Ottawa Hospital Research Institute, Prevent Cancer Now, Ottawa, ON, Canada
Sheena Symington, B.Sc., M.A., Director, Electrosensitive Society, Peterborough, Canada

China

Prof. Hual Chiang, Bioelectromagnetics Key Laboratory, Zhejiang University School of Medicine, China
Prof. Yuqing Duan, Ph.D., Food & Bioengineering, Jiangsu University, China
Dr. Kaijun Liu, Ph.D., Third Military Medical University, Chongqing, China
Prof. Xiaodong Liu, Director, Key Lab of Radiation Biology, Ministry of Health of China; Associate Dean, School of Public Health; Jilin University, China
Prof. Wenjun Sun, Ph.D., Bioelectromagnetics Key Lab, Zhejiang University School of Medicine, China
Prof. Minglian Wang, Ph.D., College of Life Science & Bioengineering, Beijing University of Technology, China
Prof. Qun Wang, Ph.D., College of Materials Science & Engineering, Beijing University of Technology, China
Prof. Haihu Zhang, Ph.D., School of Food & BioEngineering, Jiangsu University, China
Prof. Jianbao Zhang, Associate Dean, Life Science and Technology School, Xi'an Jiaotong University, China
Prof. Hui-yan Zhao, Director of STSCRW, College of Plant Protection, Northwest A & F University, Yangling Shaanxi, China
Prof. J. Zhao, Department of Chest Surgery, Cancer Center of Guangzhou Medical University, Guangzhou, China

Croatia

Ivančica Trosic, Ph.D., Institute for Medical Research and Occupational Health, Croatia

Egypt

Prof. Dr. Abu Bakr Abdel Fatth El-Bediwi, Ph.D., Physics Dept., Faculty of Science, Mansoura University, Egypt
Prof. Dr. Emad Fawzy Eskander, Ph.D., Medical Division, Hormones Department, National Research Center, Egypt
Prof. Dr. Heba Salah El Din Aboul Ezz, Ph.D., Physiology, Zoology Department, Faculty of Science, Cairo University, Egypt
Prof. Dr. Nasr Radwan, Ph.D., Neurophysiology, Faculty of Science, Cairo University, Egypt

Estonia

Dr. Hiie Hinrikus, Ph.D., D.Sc., Tallinn University of Technology, Estonia
Mr. Tarmo Koppel, Tallinn University of Technology, Estonia

Finland

Dr. Mikko Ahonen, Ph.D., University of Tampere, Finland
Dr. Marjukka Hagström, LL.M., M.Soc.Sc., Principal Researcher, Radio and EMC Laboratory, Finland
Prof. Dr. Osmo Hänninen, Ph.D., Dept. of Physiology, Faculty of Medicine, University of Eastern Finland, Finland;
Editor-In-Chief, Pathophysiology, Finland
Dr. Dariusz Leszczynski, Ph.D., Adjunct Professor of Biochemistry, University of Helsinki, Finland
Member of the IARC Working Group that classified cell phone radiation as possible carcinogen.
Dr. Georgiy Ostroumov, Ph.D. (in the field of RF EMF), independent researcher, Finland

France

Prof. Dr. Dominique Belpomme, MD, MPH, Professor in Oncology, Paris V Descartes University, ECERI Executive Director
Dr. Pierre Le Ruz, Ph.D., Criirem, Le Mans, France

Dr Annie J Sasco, MD, MPH, MS, DrPH, Fmr. Research Dir., French NIH (INSERM); Former. Chief, Unit of Epidemiology for Cancer Prevention
International Agency for Research on Cancer; Former Acting Head, Programme for Cancer Control, World Health Organization; France.

Georgia

Prof. Besarion Partsvania, Ph.D., Head of Bio-cybernetics Department of Georgian Technical University, Georgia

Germany

Prof. Dr. Franz Adlkofer, MD, Chairman, Pandora Foundation, Germany

Prof. Dr. Hynek Burda, Ph.D., University of Duisburg-Essen, Germany

Dr. Horst Eger, MD, Electromagnetic Fields in Medicine, Association of Statutory Health Insurance Physicians, Bavaria, Germany

Prof. Dr. Karl Hecht, MD, former Director, Institute of Pathophysiology, Charité, Humboldt University, Berlin, Germany

Dr.Sc. Florian M. König, Ph.D., Florian König Enterprises (FKE) GmbH, Munich, Germany

Dr. rer. nat. Lebrecht von Klitzing, Ph.D., Dr. rer. nat. Lebrecht von Klitzing, Ph.D., Head, Institute of Environ.Physics; Ex-Head, Dept. Clinical Research, Medical University, Lubeck, Germany

Dr. Cornelia Waldmann-Selsam, MD, Member, Competence Initiative for the Protection of Humanity, Environment and Democracy e.V., Bamberg, Germany

Dr. Ulrich Warnke, Ph.D., Bionik-Institut, University of Saarlandes, Germany

Greece

Dr. Adamantia F. Fragopoulou, M.Sc., Ph.D., Department of Cell Biology & Biophysics, Biology Faculty, University of Athens, Greece

Dr. Christos Georgiou, Ph.D., Biology Department, University of Patras, Greece

Prof. Emeritus Lukas H. Margaritis, Ph.D., Depts. Cell Biology, Radiobiology & Biophysics, Biology Faculty, Univ. of Athens, Greece

Dr. Alkaterini Skourliakou, M.Sc., Ph.D., Department of Energy Technology Engineering, Technological Educational Institute of Athens, Greece

Dr. Stelios A Zinells, MD, Hellenic Cancer Society-Kefalonia, Greece

Iceland

Dr. Ceon Ramon, Ph.D., Affiliate Professor, University of Washington, USA; **Professor**, Reykjavik University, Iceland

India

Prof. Dr. B. D. Banerjee, Ph.D., Former Head, Environmental Biochemistry & Molecular Biology Laboratory, Department of Biochemistry University College of Medical Sciences, University of Delhi, India

Prof. Jitendra Behari, Ph.D., Ex-Dean, Jawaharlal Nehru University; presently, Emeritus Professor, Amity University, India

Prof. Dr. Madhukar Shivajirao Dama, Institute of Wildlife Veterinary Research, India

Associate Prof. Dr Amarjot Dhami, Ph.D., Lovely Professional University, Phagwara, Punjab, India

Dr. Kavindra K. Kesari, MBA, Ph.D., Resident Environmental Scientist, University of Eastern Finland, Finland; Assistant Professor, Jaipur National University, India

Er. Piyush A. Kokate, MTECH, Scientist C, Analytical Instrumentation Division (AID), CSIR-National Environmental Engineering Research Institute (NEERI), India

Prof. Girish Kumar, Ph.D., Electrical Engineering Department, Indian Institute of Technology, Bombay, India

Dr. Pabrita Mandal Ph.D. Department of Physics, Indian Institute of Technology, Kanpur, India

Prof. Rashmi Mathur, Ph.D., Head, Department of Physiology, All India Institute of Medical Sciences, New Delhi, India

Prof. Dr. Kameshwar Prasad MD, Head, Dept of Neurology, Director, Clinical Epidemiology, All India Institute of Medical Sciences, India

Dr. Sivani Saravanamuttu, Ph.D., Dept. Advanced Zoology and Biotechnology, Loyola College, Chennai, India

Dr. N.N. Shareesh, Ph.D., Melaka Manipal Medical College, India

Dr. R.S. Sharma, MD, Sr. Deputy Director General, Scientist - G & Chief Coordinator - EMF Project, Indian Council of Medical Research, Dept. of Health Research, Ministry/Health and Family Welfare, Government of India, New Delhi, India

Prof. Dr. Dorairaj Sudarsanam, M.Sc., M.Ed., Ph.D., Fellow - National Academy of Biological Sciences, Prof. of Zoology, Biotechnology and Bioinformatics,

Department of Advanced Zoology & Biotechnology, Loyola College, Chennai, South India

Iran (Islamic Republic of)

Prof. Dr. Soheila Abdi, Ph.D., Physics, Islamic Azad University of Safadasht, Tehran, Iran

Prof. G.A. Jelodar, D.V.M., Ph.D., Physiology, School of Veterinary Medicine, Shiraz University, Iran

Prof. Hamid Mobasher, Ph.D., Head BRC; Head, Membrane Biophysics & Macromolecules Laboratory;

Institute of Biochemistry & Biophysics, University of Tehran, Iran

Prof. Seyed Mohammad Mahdavi, Ph.D., Dept of Biology, Science and Research, Islamic Azad University, Tehran, Iran

Prof. S.M.J. Mortazavi, Ph.D., Head, Medical Physics & Engineering; Chair, NIER Protection Research Center, Shiraz University of Medical Sciences, Iran

Prof. Amirnader Emami Razavi, Ph.D., Clinical Biochem., National Tumor Bank, Cancer Institute, Tehran Univ. Medical Sciences, Iran

Dr. Masood Sepehrimanesh, Ph.D., Gastroenterohepatology Research Center, Shiraz University of Medical Sciences, Iran

Prof. Dr. Mohammad Shabani, Ph.D., Neurophysiology, Kerman Neuroscience Research Center, Iran

Israel

Michael Peleg, M.Sc., radio communications engineer and researcher, Technion - Israel Institute of Technology, Israel

Prof. Elihu D. Richter, MD, MPH, Occupational & Environmental Medicine, Hebrew University-Hadassah School of Public Health & Community Medicine, Israel

Dr. Yael Stein, MD, Hebrew University of Jerusalem, Hadassah Medical Center, Israel

Dr. Danny Wolf, MD, Pediatrician and General Practitioner, Sherutey Briut Clalit, Shron Shomron district, Israel

Dr. Ronni Wolf, MD, Assoc. Clinical Professor, Head of Dermatology Unit, Kaplan Medical Center, Rehovot, Israel

Italy

Prof. Sergio Adamo, Ph.D., La Sapienza University, Rome, Italy

Prof. Fernanda Amicarelli, Ph.D., Applied Biology, Dept. of Health, Life and Environmental Sciences, University of L'Aquila, Italy

Dr. Pasquale Avino, Ph.D., INAIL Research Section, Rome, Italy

Dr. Fiorella Belpoggi, Ph.D., FIATP, Director, Cesare Maltoni Cancer Research Center, Ramazzini Institute, Italy

Prof. Giovanni Di Bonaventura, PhD, School of Medicine, "G. d'Annunzio" University of Chieti-Pescara, Italia

Prof. Emanuele Calabro, Department of Physics and Earth Sciences, University of Messina, Italy

Prof. Franco Cervellati, Ph.D., Department of Life Science and Biotechnology, Section of General Physiology, University of Ferrara, Italy

Vale Crocetta, Ph.D. Candidate, Biomolecular and Pharmaceutical Sciences, "G. d'Annunzio" University of Chieti, Italy

Dr. Agostino Di Ciaula, MD, President Scientific Committee, International Society of Doctors for Environment (ISDE), Italy

Prof. Stefano Falone, Ph.D., Researcher in Applied Biology, Dept. of Health, Life & Environmental Sciences, University of L'Aquila, Italy

Prof. Dr. Speridione Garbisa, ret. Senior Scholar, Dept. Biomedical Sciences, University of Padova, Italy

Dr. Settimio Grimaldi, Ph.D., Associate Scientist, National Research Council, Italy

Prof. Livio Giuliani, Ph.D., Principal Investigator of Finalized Research of the Italian National Health Service; Spokesman, ICEMS-International

Commission for Electromagnetic Safety, Italy

Prof. Dr. Angelo Levis, MD, Dept. Medical Sciences, Padua University, Italy

Prof. Salvatore Magazu, Ph.D., Department of Physics and Science, Messina University, Italy

Dr. Fiorenzo Marinelli, Ph.D., Researcher, Molecular Genetics Institute of the National Research Council, Italy

Dr. Arianna Pompillo, PhD, Dept. Medical, Oral & Biotechnological Sciences. G. d'Annunzio University of Chieti-Pescara, Italy

Prof. Dr. Raoul Saggini, MD, School of Medicine, University G. D'Annunzio, Chieti, Italy

Dr. Morando Soffritti, MD, Honorary President, National Institute for the Study and Control of Cancer and Environmental Diseases, B. Ramazzini, Bologna, Italy

Prof. Massimo Sperini, Ph.D., Center for Inter-University Research on Sustainable Development, Rome, Italy

Japan

Prof. Tsuyoshi Hondou, Ph.D., Graduate School of Science, Tohoku University, Japan

Prof. Hidetake Miyata, Ph.D., Department of Physics, Tohoku University, Japan

Dr. Yasuhiko Ishihara, PhD., Biomedical Sciences Program, Graduate School of Integrated Sciences for Life, Hiroshima University, University, Japan

Jordan

Prof. Mohammed S.H. Al Salameh, Jordan University of Science & Technology, Jordan

Kazakhstan

Prof. Dr. Timur Saliev, MD, Ph.D., Life Sciences, Nazarbayev University, Kazakhstan; Institute Medical Science/Technology, University of Dundee, UK

New Zealand

Ukraine

Prof. Igor Yakymenko, Ph.D., D.Sc., Institute of Experimental Pathology, Oncology & Radiobiology, National Academy of Sciences of Ukraine

United Kingdom

Michael Bevington, M.A., M.Ed., Chair of Trustees, ElectroSensitivity UK (ES-UK), UK

Mr. Roger Coghill, MA, C Biol, MI Biol, MA Environ Mgt; Member Institute of Biology; Member, UK SAGE Committee on EMF Precautions, UK

Mr. David Gee, Associate Fellow, Institute of Environment, Health and Societies, Brunel University, UK

Dr. Andrew Goldsworthy BSc PhD, Lecturer in Biology (retired), Imperial College, London, UK

Emeritus Professor Denis L. Henshaw, PhD., Human Radiation Effects, School of Chemistry, University of Bristol, UK

Dr. Mae-Wan Ho, Ph.D., Institute of Science in Society, UK

Dr. Gerard Hyland, Ph.D., Institute of Biophysics, Neuss, Germany, UK

Dr. Isaac Jamieson, Ph.D., Biosustainable Design, UK

Emeritus Professor, Michael J. O'Carroll, PhD., former Pro Vice-Chancellor, University of Sunderland, UK

Mr. Alasdair Phillips, Electrical Engineer, UK

Dr. Syed Ghulam Sarwar Shah, M.Sc., Ph.D., Public Health Consultant, Honorary Research Fellow, Brunel University, London, UK

Dr. Cyril W. Smith, DIC, PhD, Retired 1990 UK

Dr. Sarah Starkey, Ph.D., independent neuroscience and environmental health research, UK

United States

Dr. Martin Blank, Ph.D., Columbia University, USA

Prof. Jim Burch, MS, Ph.D., Dept. of Epidemiology & Biostatistics, Arnold School of Public Health, University of South Carolina, USA

Prof. David O. Carpenter, MD, Director, Institute for Health and the Environment, University of New York at Albany, USA

Prof. Prof. Simona Carrubba, Ph.D., Biophysics, Daemen College, Women & Children's Hospital of Buffalo Neurology Dept., USA

Dr. Sandra Cruz-Pol, PhD., Professor Electrical Engineering, on Radio Frequencies, Electromagnetics, University of Puerto Rico at Mayaguez; Member of US National Academies of Sciences Committee for Radio Frequencies; Puerto Rico, USA

Dr. Zoreh Davanipour, D.V.M., Ph.D., Friends Research Institute, USA

Dr. Devra Davis, Ph.D., MPH, President, Environmental Health Trust; Fellow, American College of Epidemiology, USA

Dr. James DeMeo, PhD, retired in private research, USA

Paul Raymond Doyon, EMRS, MAT, MA, Doyon Independent Research Associates, USA

Prof. Om P. Gandhi, Ph.D., Department of Electrical and Computer Engineering, University of Utah, USA

Prof. Beatrice Golomb, MD, Ph.D., University of California at San Diego School of Medicine, USA

Dr. Reba Goodman Ph.D, Columbia University, USA

Dr. Martha R. Herbert, MD, Ph.D., Harvard Medical School, Harvard University, USA

Dr. Gunnar Heuser, M.D., Ph.D., F.A.C.P. Emeritus member, Cedars Sinai Medical Center, Los Angeles, CA; Former Assistant Clinical Professor, UCLA; Former member, Brain Research Institute, UCLA. USA

Dr. Donald Hillman, Ph.D., Professor Emeritus, Michigan State University, USA

Elizabeth Kelley, MA, Former. Managing Secretariat, ICEMS, Italy; Director, EMFscientist.org, USA

Dr. Seungmo Kim, Ph.D., Assistant Professor, Department of Electrical and Computer Engineering, Georgia Southern University, USA

Dr. Ronald N. Kostoff, Ph.D., Gainesville, VA, USA

Neha Kumar, Founder, Nonionizing Electromagnetic Radiation Shielding Alternatives, Pvt. Ltd; B.Tech - Industrial Biotech., USA

Dr. Henry Lai, Ph.D., University of Washington, USA

B. Blake Levitt, medical/science journalist, former New York Times contributor, EMF researcher and author, USA

Prof. Trevor G. Marshall, PhD, Autoimmunity Research Foundation, USA

Dr. Albert M. Manville, II, Ph.D. and C.W.B., Adj. Professor, Johns Hopkins University Krieger Graduate School of Arts & Sciences Migratory Bird Management, U.S. Fish & Wildlife Service, USA

Dr. Andrew Marino, J.D., Ph.D., Retired Professor, LSU Health Sciences Center, USA

Dr. Marko Markov, Ph.D., President, Research International, Buffalo, New York, USA

Dr. Jeffrey L. Marrongelle, DC, CCN, President/Managing Partner of BioEnergiMed LLC, USA

Dr. Ronald Melnick, PhD, Senior Toxicologist, (Retired, leader of the NTP's health effects studies of cell phone radio frequency radiation) US National Toxicology Program, National Institute of Environmental Health Sciences, USA

Dr. Samuel Milham, MD, MPH, USA

L. Lloyd Morgan, Environmental Health Trust, USA

Dr. Joel M. Moskowitz, Ph.D., School of Public Health, University of California, Berkeley, USA

Imtiaz Nasim, Graduate Research Assistant, Department of Electrical and Computer Engineering, Georgia Southern University, USA
Dr. Martin L. Pall, Ph.D., Professor Emeritus, Biochemistry & Basic Medical Sciences, Washington State University, USA
Dr. Jerry L. Phillips, Ph.D. University of Colorado, USA
Dr. William J. Rea, M.D., Environmental Health Center, Dallas, Texas, USA
Camilla Rees, MBA, Electromagnetichealth.org; CEO, Wide Angle Health, LLC, USA
Dr. Cindy Lee Russell, M.D. Physicians for Safe Technology, USA
Prof. Narendra P. Singh, MD, University of Washington, USA
Prof. Eugene Sobel, Ph.D., Retired, School of Medicine, University of Southern California, USA
David Stetzer, Stetzer Electric, Inc., Blair, Wisconsin, USA
Dr. Lisa Tully, Ph.D., Energy Medicine Research Institute, Boulder, CO, USA

Supporting Scientists who have published peer reviewed papers in related fields

Olga Ameixa, PhD, Post-Doctoral Researcher, Dept of Biology & CESAM, University of Aveiro Campus, Universitário de Santiago, Portugal
Dr. Pilar Muñoz-Calero, MD, specialist in Pediatrics, Neonatology, Stomatology and Addiction Medicine; President of Fundación Alborada;
Medical Director of Alborada Outpatient Hospital; Co-chair of Pathology and Environment and Associate Professor at the Medicine at the Universidad Complutense de Madrid, Spain
Michelle Casciani, MA, Environmental Science, President/Chief Executive Officer, Salvator Mundi International Hospital, Rome, Italy
Enrico Corsetti, Engineer, Research Director, Salvator Mundi International Hospital, Rome, Italy
Dr. Dietmar Hildebrand, Ph.D., Biophysicist, Coinvestigator Blastock Experiments, Germany
Xin Li, PhD candidate MSc, Department of Mechanical Engineering, Stevens Institute of Technology, New Jersey, USA
Dr. Carlos A. Loredó Ritter, MD, Pediatrician, Pediatric Neurologist; President, Restoration Physics, North American Sleep Medicine Society, USA
Dr. Robin Maytum, PhD, Senior Lecturer in Biological Science, University of Bedfordshire, Luton, UK
Prof. Dr. Raúl A. Montenegro, Ph.D., Evolutionary Biology, National University of Cordoba; President, FUNAM; Recognitions: Scientific Investigation Award from University of Buenos Aires, UNEP 'Global 500' Award (Brussels, Belgium), the Nuclear Free Future Award (Salzburg, Austria), and Alternative Nobel Prize (Right Livelihood Award, Sweden), Argentina.
Dr. Hugo Schooneveld, PhD, Biologist, Neuroscientist, Advisor to the Dutch EHS Foundation, Netherlands
Dr. Carmen Adella Sirbu, MD, Neurology, Lecturer, Titu Mateoescu University, Romania
Jacques Testart, Biologist, Honorary Research Director at I.N.S.E.R.M. (French National Medical Research Institute), France
Sumeth Vongpanitlerd, Ph.D., retired Electrical Engineer, Thailand Development Research Institute, Bangkok, Thailand

Review Article

Role of Mitochondria in the Oxidative Stress Induced by Electromagnetic Fields: Focus on Reproductive Systems

Silvano Junior Santini,¹ Valeria Cordone¹, Stefano Falone¹, Mahmut Mijit,¹
Carla Tatone^{1,2}, Fernanda Amicarelli^{1,3} and Giovanna Di Emidio^{1,2}

¹Dept. of Life, Health and Environmental Sciences, University of L'Aquila, 67100 L'Aquila, Italy

²Infertility Service, San Salvatore Hospital, L'Aquila, 67100 L'Aquila, Italy

³Institute of Translational Pharmacology (IFT), CNR, 67100 L'Aquila, Italy

Correspondence should be addressed to Giovanna Di Emidio; giovanna.diemidio@univaq.it

Received 13 July 2018; Accepted 15 October 2018; Published 8 November 2018

Academic Editor: Victor M. Victor

Copyright © 2018 Silvano Junior Santini et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Modern technologies relying on wireless communication systems have brought increasing levels of electromagnetic field (EMF) exposure. This increased research interest in the effects of these radiations on human health. There is compelling evidence that EMFs affect cell physiology by altering redox-related processes. Considering the importance of redox *milieu* in the biological competence of oocyte and sperm, we reviewed the existing literature regarding the effects of EMFs on reproductive systems. Given the role of mitochondria as the main source of reactive oxygen species (ROS), we focused on the hypothesis of a mitochondrial basis of EMF-induced reproductive toxicity. MEDLINE, Web of Science, and Scopus database were examined for peer-reviewed original articles by searching for the following keywords: “extremely low frequency electromagnetic fields (ELF-EMFs),” “radiofrequency (RF),” “microwaves,” “Wi-Fi,” “mobile phone,” “oxidative stress,” “mitochondria,” “fertility,” “sperm,” “testis,” “oocyte,” “ovarian follicle,” and “embryo.” These keywords were combined with other search phrases relevant to the topic. Although we reported contradictory data due to lack of uniformity in the experimental designs, a growing body of evidence suggests that EMF exposure during spermatogenesis induces increased ROS production associated with decreased ROS scavenging activity. Numerous studies revealed the detrimental effects of EMFs from mobile phones, laptops, and other electric devices on sperm quality and provide evidence for extensive electron leakage from the mitochondrial electron transport chain as the main cause of EMF damage. In female reproductive systems, the contribution of oxidative stress to EMF-induced damages and the evidence of mitochondrial origin of ROS overproduction are reported, as well. In conclusion, mitochondria seem to play an important role as source of ROS in both male and female reproductive systems under EMF exposure. Future and more standardized studies are required for a better understanding of molecular mechanisms underlying EMF potential challenge to our reproductive system in order to improve preventive strategies.

1. Introduction

Power transmission and electrical equipment have changed our lives. In addition, modern technologies relying on wireless communication systems are among the fastest-growing industries worldwide. Since 1986 when the first study investigated the impact of electric blankets and heated water on fertility potential [1], there has been an increasing interest in studying the effects of exposure to nonionizing electromagnetic radiations on reproductive functions. A significant

decline in sperm quality from 1940 to date has been well documented [2, 3] in association to increased environmental pollution and changes in the lifestyle [4]. In this regard, it is important to consider the contribution of electromagnetic fields (EMFs), since decline in sperm quality has been correlated to the level of industrialization and urbanization, rather than to a specific job [4, 5]. Further, it should be considered that Wi-Fi-equipped mobile phones and personal computers are typically positioned close to the reproductive organs. Being reproductive functions highly sensitive to

microenvironment perturbations, effects on fertility potential can be also considered as an early sign of environmental hazard. In addition, a recent study on pregnant women with different habits in mobile phone use revealed that utilization for more than 1 h per day may affect biochemical parameters of cord blood, evaluated after delivery [6, 7].

In this review, we provide evidence that EMFs affect cell physiology mainly by altering redox *milieu* by influencing ROS production, antioxidant response, and mitochondrial functionality. Considering the importance of redox-related processes in the acquisition and maintenance of the biological competence of oocyte and sperm [8, 9], the purpose of the present contribution was to review the existing literature regarding the effects of EMFs on reproductive systems. Given the specifics of mitochondrial energy production during reproduction and the role of these organelles as the main source of reactive oxygen species (ROS), we focused on the hypothesis of a mitochondrial basis of EMF-induced reproductive toxicity.

2. Physical Basics of EMF

Electromagnetic waves are characterized by simultaneous oscillations of both electric field (EF) and magnetic field (MF). Electromagnetic waves may be characterized by parameters such as frequency (f), wavelength (λ), and electric/magnetic field strength [10]. The “frequency” describes the number of complete cycles per second, and the Hertz (Hz) is the common unit of measurement, while the term “wavelength” describes the distance over which the wave’s shape repeats. A negative correlation between wavelength and frequency exists: the higher the frequency, the shorter the wavelength. When an electrical charge, positive or negative, exists, an EF is generated, whereas every moving electric charge generates a MF. Unlike EF, MFs are not easily shielded by walls and buildings [11].

Humans are exposed everyday to several natural and human-made sources of EMFs. In particular, many human activities have increased the biosphere pollution due to electromagnetic fields (EMFs) that include extremely low-frequency electromagnetic fields (ELF-EMFs), radio waves, and microwaves (MWs) [11, 12].

Natural sources generate EMFs with intensities several orders of magnitude smaller than those produced by human activity [10]. In particular, the production, distribution and use of electricity involve the generation of electric and magnetic fields, and such fields are ubiquitous in the modern societies. In addition, the impressive evolution and diffusion of mobile communication systems and wireless network technologies are dramatically increasing the exposure of humans to radiofrequency radiation and microwaves [10].

3. EMF and Health Effects

Among the electromagnetic fields of major interest for the potential impact on health are the ELF-EMFs and the radiofrequencies (RF). Unlike radiofrequencies, at extremely low frequencies, the electric field and the magnetic field propagate independently, and the shielding of the electric field is

much simpler than that of the magnetic field, so many studies concerning electromagnetic pollution have focused their attention on EMF-induced bioeffects [13, 14]. Furthermore, it is worth mentioning that the level of penetration of the magnetic field in biological tissues is higher at lower frequencies [11, 14].

EMFs with very low frequencies (VLFs) or extremely low frequencies (ELFs) have been the object of considerable research efforts aimed at addressing the question as to whether they can cause acute or chronic diseases. Several studies suggest that ELF-EMFs do not act as initiators in the process of carcinogenesis, because the energy of the radiation is not strong enough to break chemical bonds in biological molecules. However, it has been speculated that the ELF-EMFs could have a role as co-carcinogens in the promotion and progression of cancer [15-17]. Unfortunately, conclusive information about the link between EMF exposure and cancer is difficult to obtain, given the countless reports and papers published over the decades, with different biological models, diverse physical exposure settings, and controversial findings [17]. Furthermore, potential confounding factors in the epidemiological analysis still remain an unresolved issue [18].

Beyond cancer, evidence of a correlation between exposure to different forms of EMFs and increased risks of other diseases, such as neurodegeneration and autism, is growing [19-23].

The radiofrequency (RF) portion of the electromagnetic spectrum includes MWs, along with the frequencies mostly used for wireless communication (radio and television broadcast, mobile phones, radar, Bluetooth, Wi-Fi, etc.) [21]. The most common frequencies of mobile phones used in the United States ranges from 900 to 1900 MHz. In this regard, the new network standard for next-generation wireless technology (i.e., 5G) was finalized in June 2018, thus representing a very new milestone for the upcoming mobile infrastructure, operating at frequencies between 30 and 300 GHz [24].

For both RF and MW exposure, the characteristic parameter that identifies the interaction with biosystems is the specific absorption rate (SAR), which is expressed as the power (W) deposited by an electromagnetic radiation in a unitary mass (g) of the biological target, in a fixed time period (s). SAR is expressed as W/kg . Research has shown a negative impact of RF radiations on neurodevelopment, blood-brain barrier integrity, neurite outgrowth, neurotransmitter release, cognitive impairment, and behaviour [25-28]. Moreover, RF radiations exhibit other cellular effects such as alterations of intracellular molecular pathways, impairment of extracellular signal-regulated kinase pathway, apoptosis, and deregulation of the cell cycle [29, 30].

4. Biological Aspects of EMF Action: Reactive Oxygen Species, Oxidative Stress, and Mitochondria

Among the potentially toxic by-products formed in aerobic cells, reactive oxygen species (ROS) are certainly the most

fascinating and most studied ones [31]. It is well recognized that low levels of ROS may play a critical role as second messengers, triggering signalling cascades, which lead to cell proliferation, apoptosis, and other key cellular processes. However, uncontrolled ROS production or impaired ROS scavenging can lead to oxidative damage to membrane phospholipids, nucleic acids, and proteins, which can disrupt normal cellular processes and trigger severe cell dysfunctions [32, 33].

In order to protect cells and organs against ROS, living organisms have evolved a highly sophisticated antioxidant protection system, which use both enzymatic and nonenzymatic strategies [34]. Antioxidant enzymes include catalase (CAT), thioredoxin reductase, superoxide dismutase (SOD), and glutathione peroxidases (GPx) [35], whereas nonenzymatic antioxidants include low-molecular-weight ascorbic acid, tocopherols, tocotrienols, melatonin, carotenoids, natural flavonoids, and thiol-containing antioxidants, among which tripeptide glutathione (GSH) plays a crucial role, being an essential cofactor for several antioxidant and detoxification enzymes [36]. Given the tight correlation between the production of ROS and mitochondrial function, a growing interest is emerging on the role of such organelles in the responses evoked by EMF insult in biosystems.

Several studies showed that the exposure of different cell types to a 50 Hz ELF-EMF induced an increase in intracellular ROS levels [37–40] that was able to trigger a temporary mitochondrial permeability transition [41, 42]. By contrast, Luukkonen and coworkers [43] showed that an increase in mitochondrial activity induced by ELF-EMFs could be the cause of the raise in ROS and lipid peroxidation levels in the SH-SY5Y cell line. Moreover, neuroblastoma cells exposed to ELF-EMFs for 5 days exhibited decreased mitochondrial respiration, whereas these cells treated for 15 days showed enhanced aerobic mitochondrial function and biogenesis [44–46]. Recently, it has been proposed that ELF-EMFs may reduce proton leaks or affect ATP-demanding events, by inducing a compensatory transient increase in mitochondrial respiratory activity [47]. Nevertheless, other studies did not observe these effects on mitochondrial potential after ELF-EMFs, probably due to differences linked to the field intensity and experimental model employed [48]. Similarly, numerous authors did not find the increase in ROS levels described above [44, 49–51]. In particular, the exposure to low-intensity ELF-EMFs was able to diminish ROS levels in dermal fibroblasts, human keratinocytes [40, 52], and neutrophils [53].

Several reports evaluated also the influence of the ELF magnetic field on the enzymatic and nonenzymatic antioxidant defence systems [17, 54–59]. Manikonda and colleagues [60] found that rats exposed to ELF-MF for 90 days continuously showed oxidative stress with an increase in lipid peroxidation end products and altered glutathione (GSH/GSSG) levels in a dose-dependent manner in various regions of the brain. On the contrary, other works suggested that ELF-EMF could lower SOD, CAT, and GPx activities in rodent brain [61–63]. A recent work of our group demonstrated that human neuroblastoma cells responded to a long-term 50 Hz, 1 mT ELF-EMF by increasing CAT- and GPx-dependent

scavenging efficiency, as well as by improving the availability of reduced glutathione, together with the upregulation of three of the major redox-responsive controllers of cellular response towards oxidative stress (i.e., sirtuins 1/3, and NRF2), thus resulting in a reduced vulnerability against ROS-based treatments [59].

Besides ELF-EMFs, RF-EMFs have been under the researchers' attention for decades, as a potential threat to human health, with a particular focus on their capacity to promote ROS production and oxidative stress [64–72]. Apart from few discordant studies [73, 74], it is widely recognized that RF exposure induced a significant increase in intracellular ROS levels, as well as lipid peroxidative products, along with the downregulation of transcriptional and protein levels of antioxidant genes, such as SOD1, SOD2, CAT, and GPx1 in different cell lines [75–78]. These effects were associated with a time-dependent decline in mitochondrial potential, increased mtDNA damage, and reduction in mtDNA copy number and mtRNA transcript level [79–82]. Mitochondrial alterations have been ascribed to ROS-related mutation at the origin of replication and transcription in the mtDNA or to alterations of the mtDNA nucleoid structure [79, 82]. Moreover, the observation of reduced intracellular ATP content supports the hypothesis that less functional mitochondria needed time to restore their original capacity to synthesize ATP to the control levels [82].

Consistently, pretreatment with antioxidant compounds, such as melatonin, was able to detoxify ROS, prevented mtDNA damage, and stimulated antioxidative enzymes in different pathophysiological states, especially in the brain [79, 83, 84].

Recently, it has been proposed that mitochondria could represent one of the targets of noninvasive RF treatment for pancreatic tumors [85]. Indeed, Curley and colleagues [85] demonstrated that RF induced changes in the shape of mitochondrial cristae of human pancreatic cancer cells, by altering the polarization of mitochondrial membrane, impairing the oxidative respiration, and increasing ROS production, thus supporting the hypothesis of RF-EMF-induced stress on mitochondria.

Taken together, most of these results show that EMFs are able to induce alterations in ROS production, antioxidant response, and mitochondrial imbalance, although these effects seem to be strictly related to the experimental set-up, including the EMF shape/intensity/frequency/exposure time and different cell lines and tissues.

5. EMF Effects in Male Reproductive System and Fertility

The male reproductive system is under regulation of complex processes based on the cross-talk among the hypothalamus, pituitary gland, and testis, which is the site of spermatogenesis. Endocrine stimulation of this process is operated by follicle-stimulating hormone (FSH) and luteinizing hormone (LH), which acts by means of testosterone produced by Leydig cells in the testis. Sertoli cells and peritubular cells play a main role in these complex signalling processes where, in addition to hormonal signals, a plethora of growth factors

and cytokines act to control the mitotic and meiotic phases of spermatogenesis. At maturity, A1 spermatogonia undergo an asymmetric division resulting in the formation of another A1 spermatogonium and a type 2 spermatogonium, which divides to produce A3 spermatogonia, followed by A4 spermatogonia and then intermediate spermatogonium. This cell divides to form type B spermatogonia that generate the primary spermatocytes, which undergo the first meiotic division to produce secondary spermatocytes. These cells complete the second meiosis division to form the haploid cells also known as spermatids. During the divisions described above, the cells migrate from the basal membrane of seminiferous tubules towards the lumen. Spermatids undergo a complex cytodifferentiation, during which active gene transcription ceases, the chromatin is remodelled, and the assembly of sperm flagellum occurs to form spermatozoa that will ultimately be released from the seminiferous epithelium via a process known as spermiation [86, 87].

Throughout spermatogenesis, mitochondria undergo peculiar morphological changes in concomitance with increased metabolic requirements [88]. During spermiogenesis, the number of these organelles is severely reduced, and the remaining mitochondria form the mitochondrial sheath around the axonemal complex and the outer dense fibers of the middle piece [89]. Although sperm mitochondria are destroyed within the fertilized oocyte, their functionality is crucial for the process of fertilization and embryo development. Loss of sperm functions has been correlated with genomic, transcriptomic, and proteomic mitochondrial alterations [90]. Particularly sensitive to mitochondrial dysfunctions are the events, which follow the epididymal storage including passage in the female reproductive tract and sperm capacitation. Searching for the roles of mitochondria in sperm functions, it emerges that mitochondria-derived ATP is not essential for sperm motility that rather relies on glycolysis-derived ATP [91]. A relevant role of sperm mitochondria is associated with the production of ROS, which at controlled levels can properly regulate sperm function [92]. Sperm are particularly susceptible to oxidative stress due to limited cytoplasmic antioxidant capacity and abundance of sensitive ROS targets including DNA, thiol-rich proteins, and polyunsaturated fatty acids (PUFAs) with a main role in supporting sperm motility and fusion during fertilization [93]. Thus, increased levels of mitochondrial ROS are hypothesized to activate a feedback loop leading to increased lipid peroxides and DNA oxidation gradually compromising sperm functions and initiate apoptosis [94].

5.1. Impact of ELF-EMFs. Many experimental studies have been carried out in order to evaluate the risk of ELF-EMFs on male reproductive function and sperm quality in mammalian species including humans, but data obtained are often contradictory. Nevertheless, apart from the individual endpoints considered in different studies, there is general consensus regarding the negative impact of ELF-EMFs on the fertility potential of exposed males. Contradictions may be due to the different experimental settings or animal models or even explained by different impacts of ELF-EMFs in animals of different sizes [95]. It was observed that male mice

exposed to 50 Hz ELF-EMF for 90 days were able to impregnate unexposed females with the same potential of sham control [96, 97]. By contrast, in the rat model, a reduced reproductive outcome was observed when males exposed to 50 Hz ELF-EMF for 90 days were mated with unexposed females soon after removal of the field, or 45 days later [98]. Indeed, although soon after the ELF-EMF exposure only half of the males were able to impregnate the female, the fertility potential improved after 45 days and was recovered after 90 days from ELF-EMF exposure. Moreover, although similar numbers of viable fetuses were observed in all experimental groups in comparison to control, the number of foetus resorptions increased regardless of postirradiation time. Nevertheless, the authors suggested that resorptions soon after ELF-EMF exposure could be ascribed to poor embryo competence, while resorptions after 90 days could be a bias linked to reduced quality of semen due to male aging. Furthermore, prolonged ELF-EMF exposure induced reduction of sperm count and serum testosterone level, which is probably the cause for reduced functionality of seminal vesicles and preputial gland observed after ELF-EMF [99, 100].

According to some studies, the intensity of exposure may have an important role in the quantity and quality of the effects in the male reproductive system. Indeed, the exposure to 5 μ T, 83.3 μ T, or 500 μ T doses at a frequency of 60 Hz during foetal life and early life was reported to have no impact on anogenital distance, preputial separation, testis weight, and testicular cell populations of newborn rat males [101]. By contrast, a 1 mT, 60 Hz dose during the same period caused a delay in testis development, characterized by reduced volume of seminiferous tubules and seminiferous epithelium. This effect was also observed in mice born from dams exposed to 50 Hz at 500 mG for 1 week [102] and may be ascribed to a reduced functionality of Sertoli cells, which are deputed to support epithelium growth and blood-testis barrier [103]. Furthermore, a reduction in number of Leydig cells with no effects on testosterone levels has been reported [103]. By prolonging the exposure to 90 days of age, ultrastructural studies demonstrated that testicular degeneration was more marked in comparison to rats exposed until 21 days of age, suggesting the ability to repair damage and activate spermatogenesis after a postexposure recovery [104]. In particular, ELF-EMF testes were characterized by germ cells with extended abnormal morphology such as vacuolization and signs of apoptosis like fragmentation, condensed nucleus, and apoptotic bodies [104, 105]. Cytoplasmic vacuolization was also observed in Sertoli cells, and some Leydig cells showed alterations in chromatin condensation that may be interpreted as an apoptotic phenotype [104, 106]. Ultrastructural studies reporting apoptotic modifications of cells of seminiferous tubules are in accordance with DNA apoptotic damage observed in testes of mice exposed to 60 Hz [107, 108]. Although further investigation is required to clarify the mechanism by which ELF-EMF exerts its deleterious effects, some authors have suggested that increased apoptosis may be a mechanism to prevent the maturation of abnormal germinal cells that may lead to the formation of defective sperm [104, 105, 107–109]. An important feature

shared by all cell populations of seminiferous tubules was the presence of abnormal mitochondria, which appeared more electron-dense and lost their cristae. Mitochondria of elongating spermatids did not show the normal well-organized distribution after ELF-EMF exposure [104]. Accordingly, alterations in mitochondria functionality induced by ELF-EMFs have been suggested as the main cause of reduced sperm motility and vitality observed in rodent and human spermatozoa [97, 110, 111].

In contrast to the results reported above, some studies discovered beneficial effects of ELF-EMF on male reproductive potential. Hori and coworkers [112] observed that males of a mouse strain with a low reproductive performance increased their copulation rate when exposed to ELF-EMF for 11 days prior to caging with superovulated females. Since this occurred without alterations of plasma levels of testosterone, LH, and nitric oxide, the authors suggested that ELF-EMF exposure may be beneficial for the treatment of male sexual dysfunctions [112]. Finally, in a revision of the literature, Darbandi et al. [113] hypothesized that exposures of a few hours to 50 Hz ELF-EMF with a square waveform may be associated to beneficial effects of sperm morphology and motility, whereas longer periods of exposure or ELF-EMFs with different characteristics may negatively influence sperm quality or have no effects.

5.2. Impact of RF-EMFs. In 2009, a large study that followed the growth, development, and fertility potential of mice living under constant exposure to three doses of RFs (in particular, Universal Mobile Telecommunications System (UMTS)) over four generations of mice reported no effects on the male reproductive system in terms of appearance of reproductive organs, fertility potential, and offspring development [114]. The lack of embryo toxicity and teratogenic effects was also confirmed by studies conducted in rats exposed to 2.14 GHz or Wi-Fi signal during gestation and lactation and followed over two generations [115–117].

By contrast, other studies reported a reduction in litter size obtained from males exposed to RFs and mated with unexposed females in comparison to control rats [118, 119]. These effects were associated with decreased weight of testes, disorganized seminiferous tubules, reduced testosterone levels, and production of apoptotic damaged sperm [119–121]. In particular, a marked reduction in germline cells, hypospermatogenesis, maturation arrest, and increased sperm with morphology alterations were observed after 7 days of RF exposure [122]; a decline in testis weight with increased DNA damage, marked reduction of seminiferous tubule diameter, and drop in sperm production and quality were reported under prolonged exposures [123–128]. Ultra-structural analysis revealed that sperm produced after RF were characterized by distortion in the head and alterations in mitochondrial distribution in the mid-piece [119, 127]. Since a proper mitochondrial distribution has a key role in sperm motility, these alterations may account for the reduced sperm motility reported after RF [124, 129]. Sperm obtained from mice exposed to RF for 30 days had a reduced ability to fertilize oocytes *in vitro* and lead to reduced quantity and quality of embryos at blastocyst stage [130].

A plethora of studies focused on the impact of RFs on human spermatozoa [67, 131–135]. The increased use of mobile phones in the 2000s has led researchers to investigate the possible relationship between daily mobile phone use and semen parameters [131, 132]. These results were concordant in highlighting a decrease in the quality of sperm obtained from men using mobile phones, with more pronounced effects in heavy users [131, 132]. Afterwards, in most studies, human sperm donated from normozoospermic volunteers were exposed to RF emitted by mobile phone, laptop Wi-Fi, or other sources and then evaluated after a few hours for the presence of effects on sperm parameters [67, 133–135]. In some cases, samples were employed after selection of highly motile sperm [134, 135]. As a result of the similar experimental settings, all the studies reported above agreed on the detrimental effects of RFs on sperm vitality, motility, and morphology.

5.3. EMF-Associated Oxidative Stress and Male Fertility: Role of Mitochondria. Although the mechanisms by which EMFs can interact with biological systems are not yet understood, increasing evidence leads us to assume that EMFs can interfere with the cellular oxidative/antioxidant balance, both *in vitro* and *in vivo* [56, 136–138]. Oxidative stress is one of the most recognized causes of male infertility, and this is exacerbated by the fact that spermatozoa are especially vulnerable to oxidative stress [139]. There is a growing body of evidence suggesting that EMF exposure during spermatogenesis induces a redox imbalance due to both an increase of ROS production and a decrease in ROS scavenging activity (Table 1). A plethora of studies demonstrated that prolonged RF exposure caused an increase in ROS production and an imbalance in total antioxidant capacity in terms of reduction of GPx, CAT, and SOD which leads to increased lipid peroxidation in rat sperm and testes [140–143]. The resulting imbalance in the redox status altered the sperm cycle progression and activated the apoptotic program through the reduction of bcl-2 expression and the raise of bax, cytochrome c, and caspase 3 protein and gene expression [140, 141, 144]. Interestingly, diet supplementation of vitamins C and E reverted the reduction in GSH level and GPx activity and the increase in lipid peroxidation observed in testes of rats exposed for 14 days to a RF (900, 1800, and 1900 MHz, SAR 0.9 W/kg) [124, 145]. Similarly, diet supplementation with melatonin and *Moringa oleifera* leaf extract prevented alterations in sperm count and motility, increased lipid peroxidation and DNA damage, and decreased intracellular GSH levels and SOD enzymatic activity recognized after 902.4 MHz RF, SAR 0.0516 W/kg [122, 146].

Exposure of *in vitro* mouse spermatogenesis pathway cell lines (GC-1 spg and GC-2 spd) to 50 or 120 Hz ELF-MF determined an increase in superoxide anion production, which was associated to activation of the intrinsic apoptotic pathway and proliferation inhibition, although after a 48-hour postexposure recovery, an increased activation of NF- κ B, a transcription factor involved in the maintenance of redox balance, was found [147, 148]. These effects were abolished by medium supplementation with Aloe arborescens's juice [148].

TABLE 1: Review of studies investigating the effect of RF and ELF-MF on mitochondria and redox balance.

(a)						
Reference	Radiation	SAR	Exposure time	Model	Temperature	Effect
[157]	RF 900 MHz	0.090 W/kg	Long-term exposure	Mice	—	Mitochondrial DNA damage
[158]	RF 900 MHz	2–5.7 W/kg	Short-term exposure	Human spermatozoa	Constant	No effect on mitochondria
[67]	RF 850 MHz	1.46 W/kg	Short-term exposure	Human semen	Room temperature	Loss in sperm motility and viability Increased ROS production
[133]	RF 1.8 GHz	0.4–27.5 W/kg	Short-term exposure	Human spermatozoa	Constant	Mitochondrial ROS generation Alterations of electron potential of mitochondrial membrane, Oxidative DNA damage
[124]	RF 900–1800 MHz	—	Long-term exposure	Rat	Constant	Lower sperm motility Decreased GSH levels Oxidative damage
[140]	RF 900 MHz	0.9 W/kg	Long-term exposure	Rat	—	Decreased antioxidant enzyme activity Increased ROS production Lipid peroxidation Increased apoptosis
[144]	MW 10 GHz	0.014 W/kg	Long-term exposure	Rat	—	Spermatozoa cell cycle arrest ROS production
[145]	RF 900–1800–1900 MHz	0.9 W/kg	Long-term exposure	Rat	—	Decreased antioxidant defences Lipid peroxidation
[122]	RF 900 MHz	—	Long-term exposure	Rat	—	Decreased sperm count Decreased antioxidant defences Lipid peroxidation
[141]	RF 900 MHz	0.66 W/kg	Long-term exposure	Rat	—	Decreased sperm viability Increased ROS production Increased apoptosis
[156]	RF 1800–1900 MHz	—	Long-term exposure	Human	—	Mitochondrial damage
[154]	RF 900 MHz pulsed	0.0516–0.0054 W/kg	Long-term exposure	Mice	—	Alterations of electron potential of mitochondrial membrane DNA damage
[146]	RF 902.4 MHz	0.00516–0.0054 W/kg	Long-term exposure	Mice	—	Decreased antioxidant defences Lipid peroxidation DNA damage
[142]	RF 900 MHz	0.0067 W/kg	Long-term exposure	Rat	Constant	Decreased sperm count Imbalance in total antioxidant capacity Lipid peroxidation
[155]	RF 1800 MHz	0.15 W/kg	Short-term exposure	Mouse germ cells	—	Increased ROS production DNA fragmentation Oxidative DNA damage
[143]	RF 1800 MHz	4 W/kg	Short-term exposure	Mouse germ cells	—	Oxidative DNA damage Increased autophagy
(b)						
References	Radiation	Magnetic flux density	Exposure time	Model	Temperature	Effect
[159]	ELF-MF 50 Hz	1 mT	Short-term exposure	Boar	—	Lower mitochondrial activity
[160]	ELF-MF 50 Hz	8 mT	Long-term exposure	Rat	—	Mitochondrial damage

TABLE 1: Continued.

References	Radiation	Magnetic flux density	Exposure time	Model	Temperature	Effect
[161]	ELF-MF 50 Hz	5 mT	Short-term exposure	Human spermatozoa	Constant	Increased mitochondrial metabolism efficiency
[149]	ELF-MF 50 Hz	100 μ T	Long-term exposure	Rat	Constant	Decreased antioxidant defences Decreased sperm motility
[103]	ELF-MF 60 Hz	1 mT	Long-term exposure	Rat	—	Mitochondrial damage
[150]	ELF-MF 50 Hz	100–500 μ T	Long-term exposure	Rat	Constant	No on effect rat sperm count No effect on oxidative stress Increased caspase 3 activity
[109]	ELF-MF 50 Hz	500 μ T	Long-term exposure	Rat	—	No effect on oxidative stress
[147]	ELF-MF 120 Hz	2.5–8 mT	Short-term exposure	Mouse germ cells	—	Decreased viability Increased ROS production Increased apoptosis
[148]	ELF-MF 50 Hz	2.5 mT	Short-term exposure	Mouse germ cells	—	No effect on mitochondria Increased ROS production Decreased bcl-2 protein level

Similarly to RFs, Saadeldin and colleagues [149] reported that a 50 Hz, 100 μ T ELF-MF exposure for 21 days caused a reduction in SOD and CAT activity, along with a decrease in rat epididymal sperm motility and vitality. Since a partial recovery of redox imbalance was recognized after a 48-day postexposure, a transitory ELF-EMF effect was hypothesized. By contrast, several authors demonstrated that long-term exposure of rat to ELF-MF did not affect sperm count and morphology and oxidative and antioxidative parameters such as malondialdehyde (MDA) levels, total antioxidant capacity (TAC), and CAT and SOD activity although increased levels of apoptotic markers were observed [109, 150].

Spermatozoa are particularly vulnerable to oxidative stress because of their limited cytoplasmic volume restricting the availability of intracellular antioxidant defences [151]. In humans, a close correlation was observed between reduction in sperm motility and decrease in mitochondrial membrane potential [152, 153]. De Iuliis and colleagues [133] demonstrated that an overnight exposure to RF significantly increased the amounts of ROS in functional human spermatozoa and that the site of production of these free radicals was mainly the mitochondria. Indeed, they showed a strong correlation between ROS production and electron leakage from the mitochondrial electron transport chain. Furthermore, when human spermatozoa were exposed to increasing levels of RF-EMFs, a significant dose-depending mitochondrial ROS generation was observed. As a result, increased levels of 8-OH-dG, the main marker of oxidative DNA damage, were observed and associated with reduction in both sperm vitality and motility [133]. Moreover, Pandey et al. [154] demonstrated that mice exposed to 900 MHz EMF for 4 or 8 h daily for 35 days showed an increase in the number of germ cells with alterations of electron potential of mitochondrial membrane. Houston and colleagues [155] also showed that a 4 h exposure of mouse spermatogonial and spermatocyte cell lines to RF-EMF induced the generation

of mitochondrial ROS, probably produced by complex III of the electron transport chain, able to increase DNA oxidative damage and fragmentation. According to the authors, the depolarization of the mitochondrial membrane could be the trigger for the ROS generation which in turn caused the DNA breaks observed in exposed mice. In a case-control study, Hagrais et al. [156] found that patients with prolonged cell phone use (>4 h daily) showed a significant imbalance in sperm motility. In the same work, it was revealed that mitochondrial isoenzyme NAD⁺-dependent isocitrate dehydrogenase (IDH) activity was increased in the seminal plasma of exposed patients. It is known that this isoenzyme is localized only in the mitochondrial matrix, where it regulates the ATP generation in the TCA cycle. Thus, the same authors speculated that the NAD⁺-dependent IDH in seminal plasma could be due to a probable mitochondrial loss of this protein after EMF-related damage. As shown by Aitken et al. [157], a 900 MHz RF-EMF exposure for 12 h/day for a week at a SAR of 90 mW/kg significantly caused genotoxic effects on mitochondrial DNA in mouse epididymal spermatozoa. They chose this temporal range of exposure to collect spermatozoa from cauda epididymis or rather during epididymal transit because at this stage spermatozoa are more vulnerable to genotoxic factors.

On the other hand, other researchers reported no significant EMF effects on spermatozoa. Falzone and colleagues [158] demonstrated that a 1 h exposure to a pulsed 900 MHz GSM mobile phone radiation at an average SAR of either 2.0 or 5.7 W/kg and at constant temperature did not result in mitochondrial membrane potential changes in human spermatozoa. However, they found a decrease in all velocity parameters in RF-EMF-exposed spermatozoa at 5.7 W/kg SAR value when compared to controls. The same authors observed a correlation between an increase in intrinsic ROS generation and a decrease in sperm motility at the higher SAR level, so they hypothesize that mitochondrial membrane

potential could not be correlated with ROS production in human spermatozoa.

Bernabò et al. [159] reported that a 4 h exposure to a 50 Hz, 1 mT ELF-MF significantly decreased intracellular Ca^{2+} storage together with lower mitochondrial activity and spermatozoa motility in boar. EMF exposure is able to generate free radicals, and this fact would seem to produce structural aberrations. In 2011, Tenorio and colleagues [103] described how rats exposed to a 60 Hz, 1 mT ELF-MF from gestation to adult period showed spermatids with mitochondria near the acrosome and not around the mitochondrial annulus. Moreover, the same work reported the presence of extremely electron-dense mitochondria with loss of cristae in rats exposed to spermatids. An electron microscopy study performed by Khaki et al. [160] showed that a pre- and post-natal chronic exposure to 50 Hz, 8 mT EMF induced cell damage including mitochondrial dilatation in stromal cells of rat prostate glands. Conversely, Iorio et al. [161] gave evidence for a stimulatory effect on human sperm motility exerted by a 50 Hz, 5 mT ELF-MF exposure in association with a greater activity of mitochondrial metabolism efficiency. On the other hand, Solek et al. [148] reported no significant effects of EMF exposure (50 Hz, 2.5 mT, for 2 h) on mitochondrial function in mouse germ cells.

As summarized in Table 1, we can conclude that both ELF- and RF-EMF exposure could be crucial factors responsible for mitochondrial ROS production in spermatozoa. Indeed, EMFs could induce perturbations to the mitochondrial proton motive force with subsequent impairment of the balance between ROS generation and ROS scavenging [162]. The resulting oxidative stress could play a pivotal role in the mitochondrial damage causing the loss in sperm motility, one of the most significant causes of fertility impairment.

The involvement of both mitochondrial metabolism and oxidative balance can suggest that ELF-EMFs could act as an environmental trigger for the intrinsic apoptosis pathway during spermatogenesis, although more studies are needed to understand the molecular mechanisms involved (Figure 1).

6. EMF Effects on Female Reproductive System and Fertility

The female reproductive system is a fine-tuned system that relies upon precise coordination of a complex series of interactive events involving hypothalamus, pituitary gland, ovaries, and uterus. Under hypothalamic GnRH (gonadotropin-releasing hormone) pulses, the pituitary gland activates the release of gonadotropins, FSH and LH. FSH activity is critical for recruitment and maturation of ovarian follicles, expression of the LH receptor, and differentiation of follicle cells in outer theca cells and inner granulosa cells. Theca cells provide androgens to granulosa cells that operate androgen conversion to estradiol, whose increase contributes to the onset of LH surge and the inhibition of FSH secretion. The peak of LH triggers oocyte resumption of meiosis, progression to the second meiotic metaphase, and ovulation of the oocyte-cumulus complex. Then, estradiol levels decline and luteinization of the follicle increases production of progesterone, reducing GnRH/LH pulse frequency and preparing the

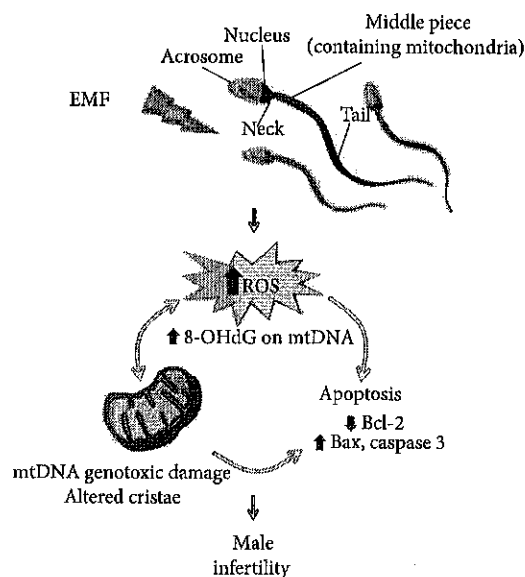


FIGURE 1: Involvement of oxidative stress and mitochondrial dysfunction after EMF exposure in the male reproductive system. EMF: electromagnetic fields; ROS: reactive oxygen species; 8-OHdG: 8-hydroxy-2'-deoxyguanosine; Bcl-2: apoptosis regulator Bcl-2; Bax: Bcl-2-associated X protein.

endometrium for embryo implantation [163]. The functional unit of the ovary is the ovarian follicle formed by the oocyte and surrounding follicle cells. Once recruited in the growing phase, primordial follicles develop into primary, secondary, and eventually antral follicles reaching the preovulatory stage under gonadotropin stimulation. The antral follicle is characterized by the presence of an antrum filled with follicular fluid bathing an oocyte surrounded by cumulus cells [163]. The pool of primordial follicles, also known as ovarian reserve, is nonrenewable and provides fertilizable oocytes from the onset of puberty to menopause when primordial follicles are exhausted [164]. An accelerated depletion of ovarian reserve can be caused by exposure to environmental insults during reproductive lifespan with huge effects on female fertility [165, 166].

6.1. Impact of ELF-EMFs. When focusing on ELF-EMF effects on female fertility potential, data present in literature are rather conflictual. In rats, exposure to a 50 Hz sinusoidal magnetic field of approximately $25 \mu\text{T}$ for 90 days before mating significantly reduced their fertility in terms of reduced number of implantations and living foetuses per litter [98]. By contrast, when female mice were exposed to the same electromagnetic field (50 Hz, $25 \mu\text{T}$ for 90 days), the number of pregnant females, implantations per litter, and viable foetuses was similar to control [96]. Mice presented an increase in ovarian weight in association with similar body and uterine weight [96]. In rats, two studies demonstrated that cumulative ovarian and uterus weight increased after 1 month of exposure, decreased to normal levels after two months, and was lower than control after 3 months of exposure [167, 168]. Apart from differences linked to the use of

two rodent species, these contradictory results may be explained by the fact that induced eddy currents generated by the same alternating field intensity may depend on the size of the animal models [95].

Exposure to the ELF-EMFs from womb to adult life reduced weight at birth, delayed weight gain, and puberty onset in females in comparison to exposure started at birth or sham conditions in mice and rats [102, 169]. When focusing on the effects of the ELF-EMFs on folliculogenesis and ovarian reserve of pups born from dams exposed to a 50 Hz ELF-EMF and grown to adulthood in normal conditions, histological analysis showed that newborn pups presented a reduced number of primordial follicles cysts, most of them showing abnormal follicle or pregranulosa (stromal) cells. Ultrastructural studies revealed that oocytes from ELF-EMF pups presented irregular nucleus with condensed heterochromatin and numerous vacuoles in the cytoplasm [170, 171]. When female mice exposed to ELF-EMFs *in utero* grew to adulthood, their ovarian reserve was reduced in association with an increase in atretic follicles. These follicles were characterized by abnormal oocytes with zona pellucida damage and granulosa cells with absent or condensed mitochondrial cristae and separated from surrounding stromal cells and vacuolization of theca interna [170]. Similar features were observed in ovaries from rats exposed to ELF-EMFs during foetal and adult life [169, 172, 173], suggesting that exposure to ELF-EMFs during embryonic development induces morphological changes that affect irreversibly folliculogenesis, inducing loss of oocytes, degeneration of granulosa cells, and decreased ovarian reserve, leading to a condition of subfertility.

In vitro studies on preantral ovarian follicles demonstrated that ELF-EMF exposure affected the ability of follicles to develop antral cavities, and this detrimental effect was associated with the production of oocytes with a reduced ability to undergo meiosis resumption. Nevertheless, it seems that ELF-EMFs did not affect mechanisms controlling meiotic maturation *per se* since preovulatory cumulus-enclosed oocytes obtained from primed mice and exposed to ELF-EMFs reached the MII stage during *in vitro* culture at a similar extent as control [174]. Moreover, ovulated mature oocytes exposed to 4 kHz pulsed ELF-EMFs for 5 h after IVF showed fertilization rates similar to controls [175]. Taken together, this evidence supports the conclusions that ELF-EMFs affect folliculogenesis by targeting the ovarian and follicle microenvironment. As consequence, oocytes lack proper support during growth and differentiation [170, 172, 174]. Moreover, oocyte susceptibility to ELF-EMFs seems to be reduced once reaching the preovulatory stage.

By focusing on the effects of ELF-EMFs during mating and early stages of pregnancy, similar numbers of pregnant mice were observed [176, 177]. Nevertheless, Borhani and colleagues [176] reported the harvest of fewer blastocysts in the ELF-EMF group in comparison to the control. Moreover, although presenting similar numbers of blastocysts, blastocysts from ELF-EMF-exposed mice presented an increase in DNA fragmentation (Figure 2). By contrast, Bayat and coworkers [177] observed no differences in the number of collected blastocysts, but described a reduction

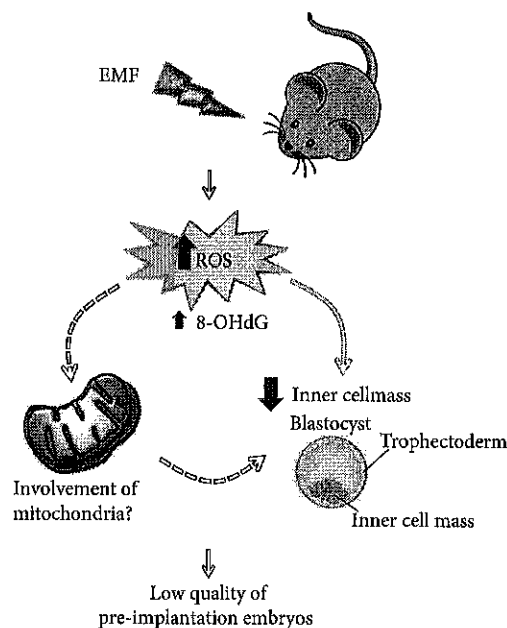


FIGURE 2: Involvement of oxidative stress and possible role of mitochondria-related pathways in embryos produced from females exposed to EMF. EMF: electromagnetic fields; ROS: reactive oxygen species; 8-OHdG: 8-hydroxy-2'-deoxyguanosine.

in cells composing the blastocyst with a prominent reduction in inner cell mass component. Collectively, these works highlighted that ELF-EMF exposure during preimplantation embryo development affects reproductive outcome by decreasing the quality of blastocysts produced [176, 177].

Alterations of the reproductive performance caused by ELF-EMFs may also be ascribed to effects on the hypothalamic-pituitary-gonadal (HPG) axis [178]. In rats, ELF-EMFs induced a transient increase in progesterone level and a transient decrease in estradiol, FSH, and LH. Normal levels of these hormones were recovered after a longer exposure time or the removal of the field [167–169]. A reduction in IGF1 in females exposed from foetal life may be responsible for the reduction in growth and delay in sexual maturity observed in these rats [169].

6.2. Impact of RF-EMFs. The impact of RF-EMFs on female reproduction and fertility has been so far poorly investigated. The main reason behind this lack of interest is that most of the studies in the field highlighted no differences or hotspots. In 2009, Sommer and colleagues [114] investigated the impact of three doses of RFs (UMTS) over four generations of mice without observing any anomalies in reproductive organs, fertility potential, and offspring development, apart from a slight reduction in food intake in the generation of F0- and F1-exposed groups, although without a clear dose-response relationship. In accordance, female rats exposed to low or high RF doses during pregnancy and lactation presented no abnormalities in terms of growth, gestational condition, and organ weights. The F1 generated from these females showed survival rates, development, growth, physical and functional development, hormonal status, memory

function, and reproductive ability similar to sham control, and no teratogenic effects were observed in the generation of F2 [115–117]. Neither the exposure to the very high level of 4 W/kg was demonstrated to have deleterious effects on newborn developmental potential [117, 179]. By contrast, Sangun et al. [180] reported a reduction in postnatal growth and delay in puberty onset in female Wistar rats exposed to 900 MHz during foetal life. Interestingly, low postnatal growth was associated with increased food consumption and similar levels of IGF1, suggesting an effect of RFs on rat metabolism. Since normal pubertal development is strictly linked to the interplay between central and peripheral signals in order to have the pulsatile release of LH and FSH, the authors investigated the hormonal profile of these rats exposed during foetal life. Nevertheless, in addition to delayed puberty onset, increased serum LH levels were observed, a condition associated to accelerated loss of primordial follicles in the adult [181], whereas no differences in ovarian follicle count were revealed [180].

Several studies demonstrated detrimental effects of RF on ovarian follicle population. Gul and coworkers [182] placed a mobile phone under the cages of female rats during the entire pregnancy for 11 h and 45 min in standby and 15 min in speech mode. This exposure affected the volume and the primordial follicle content of newborn ovaries sacrificed on the 21st day after delivery. However, a great limitation of this study was the lack of measurement of the amount of MWs emitted by the cell phone. To avoid bias linked to animal movements inside the cage, Bakacak and colleagues [183] used an experimental device to apply RF-EMF of 900 MHz directly on the abdomen region of female rats for 15 min/d for 15 days. In these conditions, the observation of a significant reduction of ovarian reserve in terms of reduction of primordial ovarian follicles in RF-EMF rats was confirmed.

Females born from dams exposed to 900 MHz RF-EMF during pregnancy presented severe ovarian damage, with a reduction of primordial and tertiary follicle, increase of atretic follicle, pronounced vasocongestion, and stromal fibrosis. Moreover, most of primary follicles had lost their oocytes and granulosa cells presented extended degeneration, vacuolization, and loss of connection with cumulus cells [184], as observed after exposure to ELF-EMFs. When looking for mechanisms behind ovarian damage and follicle loss, the authors observed an increase in apoptosis in ovaries from exposed rats, suggesting that the activation of the programmed cell death machinery may be responsible for impairment of the follicle development process and decrease of ovarian follicle reserve [184].

Finally, exposure of mouse oocytes and sperm to RF for 60 min prior to *in vitro* fertilization techniques had no effects on fertilization rates, blastocyst formation, and chromosomal aberration [185].

6.3. EMF-Associated Oxidative Stress and Female Fertility: Role of Mitochondria. The impact of oxidative damage on RF effects in the female reproductive system was investigated in ovaries from female rats exposed to 900 MHz during foetal

or postnatal life. Total antioxidant status (TAS), total oxidant status (TOS), and oxidative stress index (OSI) were increased in RF ovaries regardless of time of exposure. Although the exposure conditions did not alter ovarian follicle population, increase in TAS, TOS, and OSI values highlighted the oxidative nature of the stressing condition experienced by the ovary under RF exposure [180]. This is in accordance with studies in nonmammalian models. An interesting contribution to the knowledge on oxidative stress impact on ovarian physiology came from a study on *Drosophila melanogaster* [186]. Genome-wide microarray analysis performed on early- and middle-stage follicles under RF exposure revealed the activation of more than 150 genes and the downregulation of only 15 genes involved in various cellular functions. Since a twofold increase in ovarian ROS content and activation of follicle cell death were observed, authors suggested that genome-wide and nontargeted transcriptional perturbation of gene-expression profiling, probably induced by RF-dependent ROS increase, could compel sensitive ovarian-cell subpopulations and lead to sporadic follicle apoptosis [186]. Similarly, exposure of quail embryos to 900 MHz determined overproduction of superoxide and nitrogen oxide, in association with increased level of lipid peroxidation and depression of key antioxidant enzymes activity, resulting in increased level of oxidative damage of DNA in the embryo [187]. Since authors used electron paramagnetic resonance (EPR) spin-trapping technique for the specific detection of superoxide in mitochondria, this work represents a strong evidence of mitochondrial origin of superoxide overproduction under RF exposure in embryonic cells. Nevertheless, the site of interaction of RF with mitochondria structures/electron transport chain and the mechanisms by which RF-EMR exposure induces free radical overproduction remain unclear.

Despite the well-known connection between ELF-EMFs and oxidative stress, only two studies investigated the oxidative status of females exposed to ELF-EMFs [168, 173]. Prolonged exposure to 50 Hz induced increased MDA levels in rat uterus and ovaries [173]. By contrast, Aydin and colleagues [168] observed a significant reduction in CAT serum activity, but no significant differences were found in GSH and MDA serum levels.

Finally, it is important to remark that animal models have different sensitivities to physical and chemical exposure; therefore, RF effects observed in all biological models here reported are not directly applicable to the situation in humans and should be interpreted with caution.

7. Conclusions and Final Remarks

Based on the current literature, the analysis of ELF-EMF and RF impact on the maintenance of male and female fertility potential reports contradictory results. The main reason for these discrepancies may be the lack of uniformity in the experimental design, including the use of different models and the extremely variable exposure sources and protocols. Moreover, since ROS levels can be influenced by temperature, a possible criticism to many of these works is the lack of control of this parameter during EMF exposure [188].

On the other hand, growing evidence suggests that the damage induced by EMFs to reproductive cells and organs is caused by deregulation of redox homeostasis [140, 144–146, 149, 168, 180, 186, 187].

Based on *in vitro* studies, there is a general consensus on the effects of EMFs from mobile phones, laptops, and other electric devices on human sperm quality with possible negative influence on fertility [67, 113, 131–135, 189–192].

The role of mitochondria as one of the main targets of ELF- and RF-EMF exposure has emerged, especially in the male reproductive system. Indeed, these radiations seem to directly target the electron transport chain thus establishing mitochondrial dysfunctions and ROS overproduction, self-reinforced in a vicious cycle [103, 133, 154, 156, 159, 187].

According to recent data reported here [122, 146, 148], the strict link between EMF-related damage of reproductive systems and oxidative stress is reinforced by the observations of protective effects of antioxidant supplementations that require to be confirmed in humans. This approach, although still unexplored in the female reproductive system, could represent an important preventive strategy.

A further criticism emerging from the literature is the difficulty to understand whether EMF-induced fertility abnormalities are caused by direct gonadal damage or by disruption of the hypothalamic-pituitary-gonadal axis. Indeed, most studies rely on total body exposure of small animals within cages. In this regard, the application of EMF-emitting devices to abdominal regions [183] or the use of large animal models may help to elucidate the mechanisms underlying ELF-EMF and RF biological effects, as suggested by Bernabò and colleagues [193]. This kind of approach would aid to clarify the impact of ELF-EMF and RF on human health, also considering the entry in our lives of the new 5G standard that may increase environmental EMF pollution.

Finally, an interesting aspect of EMF-related biomedical research that has been poorly investigated regards what happens to reproductive cells and organs when the exposure to EMFs occurs in concomitance with other environmental pollutants. This issue would be of great interest since our everyday life is characterized by the continuous presence of some environmental agents (e.g., EMFs) and the sporadic or frequent occurrence of exposure to other chemicals and physical toxicants. In support to these concerns, Tenorio et al. [106] observed that the exposure to ELF-EMF after testis heat shock irreversibly damages the spermatogenic process. Thus, EMFs may represent a risk factor for fertility in males suffering from reversible testicular damage.

In conclusion, future and more standardized studies are needed in order to understand the molecular mechanisms underlying EMF challenge to reproductive systems and establish preventive strategies.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

Authors' Contributions

Silvano Jr Santini and Valeria Cordone contributed equally to the manuscript.

References

- [1] N. Wertheimer and E. Leeper, "Possible effects of electric blankets and heated waterbeds on fetal development," *Bioelectromagnetics*, vol. 7, no. 1, pp. 13–22, 1986.
- [2] E. Carlsen, A. Giwercman, N. Keiding, and N. E. Skakkebaek, "Evidence for decreasing quality of semen during past 50 years," *BMJ*, vol. 305, no. 6854, pp. 609–613, 1992.
- [3] M. N. Mascarenhas, S. R. Flaxman, T. Boerma, S. Vanderpoel, and G. A. Stevens, "National, regional, and global trends in infertility prevalence since 1990: a systematic analysis of 277 health surveys," *PLoS Medicine*, vol. 9, no. 12, article e1001356, 2012.
- [4] M. Mima, D. Greenwald, and S. Ohlander, "Environmental toxins and male fertility," *Current Urology Reports*, vol. 19, no. 7, p. 50, 2018.
- [5] N. H. Hjollund, J. H. Skotte, H. A. Kolstad, and J. P. Bonde, "Extremely low frequency magnetic fields and fertility: a follow up study of couples planning first pregnancies. The Danish First Pregnancy Planner Study Team," *Occupational and Environmental Medicine*, vol. 56, no. 4, pp. 253–255, 1999.
- [6] H. Bektas and S. Dasdag, "Effect of radiofrequencies emitted from mobile phones and Wi-Fi on pregnancy," *Journal of International Dental and Medical Research*, vol. 10, no. 3, pp. 1084–1095, 2017.
- [7] H. Bektas, M. S. Bektas, and S. Dasdag, "Effects of mobile phone exposure on biochemical parameters of cord blood: a preliminary study," *Electromagnetic Biology and Medicine*, pp. 1–8, 2018.
- [8] C. Tatone, G. Di Emidio, M. Vento, R. Ciriminna, and P. G. Artini, "Cryopreservation and oxidative stress in reproductive cells," *Gynecological Endocrinology*, vol. 26, no. 8, pp. 563–567, 2010.
- [9] C. Tatone, G. Di Emidio, A. Barbonetti et al., "Sirtuins in gamete biology and reproductive physiology: emerging roles and therapeutic potential in female and male infertility," *Human Reproduction Update*, vol. 24, no. 3, pp. 267–289, 2018.
- [10] S. Kottou, D. Nikolopoulos, E. Vogianis, D. Koulougliotis, E. Petraki, and P. H. Yannakopoulos, "How safe is the environmental electromagnetic radiation?," *Journal of Physical Chemistry & Biophysics*, vol. 4, no. 3, 2014.
- [11] R. A. Serway and J. JWJ, "Principles of physics: a calculus-based text," in *International Edition*, Pacific Grove, Calif: Brooks/Cole, Boston, Massachusetts, 5th edition, 2013.
- [12] I. Belyaev, A. Dean, H. Eger et al., "EUROPAEM EMF Guideline 2016 for the prevention, diagnosis and treatment of EMF-related health problems and illnesses," *Reviews on Environmental Health*, vol. 31, no. 3, pp. 363–397, 2016.
- [13] D. W. Fugate and F. S. Young, "Magnetic shielding," in *Wiley Encyclopedia of Electrical and Electronics Engineering*, John Wiley & Sons, Inc., New York City, United States, 2000.
- [14] World Health Organization, *Establishing a Dialogue on Risks from Electromagnetic Fields*, World Health Organization 2002, Geneva, Switzerland, 2002.

- [15] J. Schütz, K. Grell, S. Kinsey et al., "Extremely low-frequency magnetic fields and survival from childhood acute lymphoblastic leukemia: an international follow-up study," *Blood Cancer Journal*, vol. 2, no. 12, p. e98, 2012.
- [16] M. Sulpizio, S. Falone, F. Amicarelli et al., "Molecular basis underlying the biological effects elicited by extremely low-frequency magnetic field (ELF-MF) on neuroblastoma cells," *Journal of Cellular Biochemistry*, vol. 112, no. 12, pp. 3797–3806, 2011.
- [17] S. Falone, S. Santini Jr., V. Cordone et al., "Extremely low-frequency magnetic fields and redox-responsive pathways linked to cancer drug resistance: insights from co-exposure-based in vitro studies," *Frontiers in Public Health*, vol. 6, p. 33, 2018.
- [18] V. J. Coglianò, R. Baan, K. Straif et al., "Preventable exposures associated with human cancers," *JNCI Journal of the National Cancer Institute*, vol. 103, no. 24, pp. 1827–1839, 2011.
- [19] M. Feychting, F. Jonsson, N. L. Pedersen, and A. Ahlbom, "Occupational magnetic field exposure and neurodegenerative disease," *Epidemiology*, vol. 14, no. 4, pp. 413–419, 2003.
- [20] A. M. García, A. Sisternas, and S. P. Hoyos, "Occupational exposure to extremely low frequency electric and magnetic fields and Alzheimer disease: a meta-analysis," *International Journal of Epidemiology*, vol. 37, no. 2, pp. 329–340, 2008.
- [21] D. O. Carpenter, "Human disease resulting from exposure to electromagnetic fields," *Reviews on Environmental Health*, vol. 28, no. 4, pp. 159–172, 2013.
- [22] M. R. Herbert and C. Sage, "Autism and EMF? Plausibility of a pathophysiological link part II," *Pathophysiology*, vol. 20, no. 3, pp. 211–234, 2013.
- [23] Y. J. Jeong, G. Y. Kang, J. H. Kwon et al., "1950 MHz electromagnetic fields ameliorate $A\beta$ pathology in Alzheimer's disease mice," *Current Alzheimer Research*, vol. 12, no. 5, pp. 481–492, 2015.
- [24] A. C. Sodré, I. F. da Costa, R. A. dos Santos, H. R. D. Filgueiras, and D. H. Spadoti, "Waveguide-based antenna arrays for 5G networks," *International Journal of Antennas and Propagation*, vol. 2018, Article ID 5472045, 10 pages, 2018.
- [25] T. S. Aldad, G. Gan, X. B. Gao, and H. S. Taylor, "Fetal radio-frequency radiation exposure from 800-1900 mhz-rated cellular telephones affects neurodevelopment and behavior in mice," *Scientific Reports*, vol. 2, no. 1, p. 312, 2012.
- [26] D. Hao, L. Yang, S. Chen et al., "Effects of long-term electromagnetic field exposure on spatial learning and memory in rats," *Neurological Sciences*, vol. 34, no. 2, pp. 157–164, 2013.
- [27] C. Chen, Q. Ma, C. Liu et al., "Exposure to 1800 MHz radiofrequency radiation impairs neurite outgrowth of embryonic neural stem cells," *Scientific Reports*, vol. 4, no. 1, p. 5103, 2014.
- [28] J. Tang, Y. Zhang, L. Yang et al., "Exposure to 900 MHz electromagnetic fields activates the mkp-1/ERK pathway and causes blood-brain barrier damage and cognitive impairment in rats," *Brain Research*, vol. 1601, pp. 92–101, 2015.
- [29] M. Buttiglione, L. Roca, E. Montemurno, F. Vitiello, V. Capozzi, and G. Cibelli, "Radiofrequency radiation (900 MHz) induces Egr-1 gene expression and affects cell-cycle control in human neuroblastoma cells," *Journal of Cellular Physiology*, vol. 213, no. 3, pp. 759–767, 2007.
- [30] Y. X. Liu, J. L. Tai, G. Q. Li et al., "Exposure to 1950-MHz TD-SCDMA electromagnetic fields affects the apoptosis of astrocytes via caspase-3-dependent pathway," *PLoS One*, vol. 7, no. 8, article e42332, 2012.
- [31] V. Sosa, T. Moliné, R. Somoza, R. Paciucci, H. Kondoh, and M. E. LLeonart, "Oxidative stress and cancer: an overview," *Ageing Research Reviews*, vol. 12, no. 1, pp. 376–390, 2013.
- [32] B. D'Autréaux and M. B. Toledano, "ROS as signalling molecules: mechanisms that generate specificity in ROS homeostasis," *Nature Reviews Molecular Cell Biology*, vol. 8, no. 10, pp. 813–824, 2007.
- [33] R. Stefanatos and A. Sanz, "The role of mitochondrial ROS in the aging brain," *FEBS Letters*, vol. 592, no. 5, pp. 743–758, 2018.
- [34] M. Valko, D. Leibfritz, J. Moncol, M. T. D. Cronin, M. Mazur, and J. Telser, "Free radicals and antioxidants in normal physiological functions and human disease," *The International Journal of Biochemistry & Cell Biology*, vol. 39, no. 1, pp. 44–84, 2007.
- [35] J. É. M. MatÊs, C. Pérez-Gómez, and I. N. De Castro, "Antioxidant enzymes and human diseases," *Clinical Biochemistry*, vol. 32, no. 8, pp. 595–603, 1999.
- [36] M. R. McCall and B. Frei, "Can antioxidant vitamins materially reduce oxidative damage in humans?," *Free Radical Biology and Medicine*, vol. 26, no. 7-8, pp. 1034–1053, 1999.
- [37] I.-G. İ. AyŞe, A. Zafer, O. Şule, I. Ş.-T. IŞil, and T. Kalkan, "Differentiation of K562 cells under ELF-EMF applied at different time courses," *Electromagnetic Biology and Medicine*, vol. 29, no. 3, pp. 122–130, 2010.
- [38] A. C. Mannerling, M. Simkó, K. H. Mild, and M. O. Mattsson, "Effects of 50-Hz magnetic field exposure on superoxide radical anion formation and HSP70 induction in human K562 cells," *Radiation and Environmental Biophysics*, vol. 49, no. 4, pp. 731–741, 2010.
- [39] A. Patruno, S. Tabrez, M. Pesce, S. Shakil, M. A. Kamal, and M. Reale, "Effects of extremely low frequency electromagnetic field (ELF-EMF) on catalase, cytochrome P450 and nitric oxide synthase in erythro-leukemic cells," *Life Sciences*, vol. 121, pp. 117–123, 2015.
- [40] C. Calcabrini, U. Mancini, R. De Bellis et al., "Effect of extremely low-frequency electromagnetic fields on antioxidant activity in the human keratinocyte cell line NCTC 2544," *Biotechnology and Applied Biochemistry*, vol. 64, no. 3, pp. 415–422, 2017.
- [41] B. Feng, C. Ye, L. Qiu, L. Chen, Y. Fu, and W. Sun, "Mitochondrial ROS release and subsequent Akt activation potentially mediated the anti-apoptotic effect of a 50-Hz magnetic field on FL cells," *Cellular Physiology and Biochemistry*, vol. 38, no. 6, pp. 2489–2499, 2016.
- [42] B. Feng, L. Qiu, C. Ye, L. Chen, Y. Fu, and W. Sun, "Exposure to a 50-Hz magnetic field induced mitochondrial permeability transition through the ROS/GSK-3 β signaling pathway," *International Journal of Radiation Biology*, vol. 92, no. 3, pp. 148–155, 2016.
- [43] J. Luukkonen, A. Liimatainen, J. Juutilainen, and J. Naarala, "Induction of genomic instability, oxidative processes, and mitochondrial activity by 50Hz magnetic fields in human SH-SY5Y neuroblastoma cells," *Mutation Research/Fundamental and Molecular Mechanisms of Mutagenesis*, vol. 760, pp. 33–41, 2014.
- [44] C. Osera, M. Amadio, S. Falone et al., "Pre-exposure of neuroblastoma cell line to pulsed electromagnetic field prevents H₂O₂-induced ROS production by increasing MnSOD activity," *Bioelectromagnetics*, vol. 36, no. 3, pp. 219–232, 2015.

- [45] S. Falone, N. Marchesi, C. Osera et al., "Pulsed electromagnetic field (PEMF) prevents pro-oxidant effects of H₂O₂ in SK-N-BE(2) human neuroblastoma cells," *International Journal of Radiation Biology*, vol. 92, no. 5, pp. 281–286, 2016.
- [46] S. Falone, S. Santini Jr, S. di Loreto et al., "Improved mitochondrial and methylglyoxal-related metabolisms support hyperproliferation induced by 50 Hz magnetic field in neuroblastoma cells," *Journal of Cellular Physiology*, vol. 231, no. 9, pp. 2014–2025, 2016.
- [47] M. Destefanis, M. Viano, C. Leo, G. Gervino, A. Ponzetto, and F. Silvagno, "Extremely low frequency electromagnetic fields affect proliferation and mitochondrial activity of human cancer cell lines," *International Journal of Radiation Biology*, vol. 91, no. 12, pp. 964–972, 2015.
- [48] M. Farina, M. Farina, M. A. Mariggio et al., "ELF-EMFs induced effects on cell lines: controlling ELF generation in laboratory," *Progress In Electromagnetics Research B*, vol. 24, pp. 131–153, 2010.
- [49] M. N. Hong, N. K. Han, H. C. Lee et al., "Extremely low frequency magnetic fields do not elicit oxidative stress in MCF10A cells," *Journal of Radiation Research*, vol. 53, no. 1, pp. 79–86, 2012.
- [50] S. Lim, S. C. Kim, and J. Y. Kim, "Protective effect of 10-Hz, 1-mT electromagnetic field exposure against hypoxia/reoxygenation injury in HK-2 cells," *Biomedical and Environmental Sciences*, vol. 28, no. 3, pp. 231–234, 2015.
- [51] C. N. Duong and J. Y. Kim, "Exposure to electromagnetic field attenuates oxygen-glucose deprivation-induced microglial cell death by reducing intracellular Ca(2+) and ROS," *International Journal of Radiation Biology*, vol. 92, no. 4, pp. 195–201, 2016.
- [52] L. Ferroni, G. Bellin, V. Emer et al., "Treatment by Therapeutic Magnetic Resonance (TMR™) increases fibroblastic activity and keratinocyte differentiation in an in vitro model of 3D artificial skin," *Journal of Tissue Engineering and Regenerative Medicine*, vol. 11, no. 5, pp. 1332–1342, 2017.
- [53] B. Poniedzialek, P. Rzymiski, H. Nawrocka-Bogusz, F. Jaroszyk, and K. Wiktorowicz, "The effect of electromagnetic field on reactive oxygen species production in human neutrophils in vitro," *Electromagnetic Biology and Medicine*, vol. 32, no. 3, pp. 333–341, 2013.
- [54] A. G. Cansevan, S. Coskun, and N. Seyhan, "Effects of various extremely low frequency magnetic fields on the free radical processes, natural antioxidant system and respiratory burst system activities in the heart and liver tissues," *Indian Journal of Biochemistry & Biophysics*, vol. 45, no. 5, pp. 326–331, 2008.
- [55] S. Falone, M. R. Grossi, B. Cinque et al., "Fifty hertz extremely low-frequency electromagnetic field causes changes in redox and differentiative status in neuroblastoma cells," *The International Journal of Biochemistry & Cell Biology*, vol. 39, no. 11, pp. 2093–2106, 2007.
- [56] S. Falone, A. Mirabilio, M. C. Carbone et al., "Chronic exposure to 50Hz magnetic fields causes a significant weakening of antioxidant defence systems in aged rat brain," *The International Journal of Biochemistry & Cell Biology*, vol. 40, no. 12, pp. 2762–2770, 2008.
- [57] M. Glinka, A. Sieroń, E. Birkner, and G. Cieślak, "Influence of extremely low-frequency magnetic field on the activity of antioxidant enzymes during skin wound healing in rats," *Electromagnetic Biology and Medicine*, vol. 32, no. 4, pp. 463–470, 2013.
- [58] M. Reale, M. A. Kamal, A. Patrino et al., "Neuronal cellular responses to extremely low frequency electromagnetic field exposure: implications regarding oxidative stress and neurodegeneration," *PLoS One*, vol. 9, no. 8, article e104973, 2014.
- [59] S. Falone, S. Santini, V. Cordone et al., "Power frequency magnetic field promotes a more malignant phenotype in neuroblastoma cells via redox-related mechanisms," *Scientific Reports*, vol. 7, no. 1, article 11470, 2017.
- [60] P. K. Manikonda, P. Rajendra, D. Devendranath et al., "Extremely low frequency magnetic fields induce oxidative stress in rat brain," *General physiology and biophysics*, vol. 33, no. 1, pp. 81–90, 2014.
- [61] M. Z. Akdag, S. Dasdag, E. Ulukaya, A. K. Uzunlar, M. A. Kurt, and A. Taşkin, "Effects of extremely low-frequency magnetic field on caspase activities and oxidative stress values in rat brain," *Biological Trace Element Research*, vol. 138, no. 1–3, pp. 238–249, 2010.
- [62] Y. Cui, Z. Ge, J. D. Rizak et al., "Deficits in water maze performance and oxidative stress in the hippocampus and striatum induced by extremely low frequency magnetic field exposure," *PLoS One*, vol. 7, no. 5, article e32196, 2012.
- [63] J. Martínez-Sámano, P. V. Torres-Durán, M. A. Juárez-Oropeza, and L. Verdugo-Díaz, "Effect of acute extremely low frequency electromagnetic field exposure on the antioxidant status and lipid levels in rat brain," *Archives of Medical Research*, vol. 43, no. 3, pp. 183–189, 2012.
- [64] Y. M. Moustafa, R. M. Moustafa, A. Belacy, S. H. Abou-El-Ela, and F. M. Ali, "Effects of acute exposure to the radiofrequency fields of cellular phones on plasma lipid peroxide and antioxidant activities in human erythrocytes," *Journal of Pharmaceutical and Biomedical Analysis*, vol. 26, no. 4, pp. 605–608, 2001.
- [65] A. R. Ferreira, F. Bonatto, M. A. de Bittencourt Pasquali et al., "Oxidative stress effects on the central nervous system of rats after acute exposure to ultra high frequency electromagnetic fields," *Bioelectromagnetics*, vol. 27, no. 6, pp. 487–493, 2006.
- [66] N. Erdal, S. Gürgül, L. Tamer, and L. Ayaz, "Effects of long-term exposure of extremely low frequency magnetic field on oxidative/nitrosative stress in rat liver," *Journal of Radiation Research*, vol. 49, no. 2, pp. 181–187, 2008.
- [67] A. Agarwal, N. R. Desai, K. Makker et al., "Effects of radiofrequency electromagnetic waves (RF-EMW) from cellular phones on human ejaculated semen: an in vitro pilot study," *Fertility and Sterility*, vol. 92, no. 4, pp. 1318–1325, 2009.
- [68] G. Guler, A. Tomruk, E. Ozgur, and N. Seyha, "The effect of radiofrequency radiation on DNA and lipid damage in non-pregnant and pregnant rabbits and their newborns," *General Physiology and Biophysics*, vol. 29, no. 1, pp. 59–60, 2010.
- [69] S. Dasdag and M. Z. Akdag, "The link between radiofrequencies emitted from wireless technologies and oxidative stress," *Journal of Chemical Neuroanatomy*, vol. 75, pp. 85–93, 2016.
- [70] D. Manna and R. Ghosh, "Effect of radiofrequency radiation in cultured mammalian cells: a review," *Electromagnetic Biology and Medicine*, vol. 35, no. 3, pp. 265–301, 2016.
- [71] H. Wang and X. Zhang, "Magnetic fields and reactive oxygen species," *International Journal of Molecular Sciences*, vol. 18, no. 10, 2017.
- [72] S. Falone, A. Sannino, S. Romeo et al., "Protective effect of 1950 MHz electromagnetic field in human neuroblastoma cells challenged with menadione," *Scientific Reports*, vol. 8, no. 1, article 13234, 2018.

- [73] M. Capri, E. Scarcella, C. Fumelli et al., "In vitro exposure of human lymphocytes to 900 MHz CW and GSM modulated radiofrequency: studies of proliferation, apoptosis and mitochondrial membrane potential," *Radiation Research*, vol. 162, no. 2, pp. 211–218, 2004.
- [74] M. N. Hong, B. C. Kim, Y. G. Ko et al., "Effects of 837 and 1950 MHz radiofrequency radiation exposure alone or combined on oxidative stress in MCF10A cells," *Bioelectromagnetics*, vol. 33, no. 7, pp. 604–611, 2012.
- [75] K. Yao, W. Wu, K. Wang et al., "Electromagnetic noise inhibits radiofrequency radiation-induced DNA damage and reactive oxygen species increase in human lens epithelial cells," *Molecular Vision*, vol. 14, pp. 964–969, 2008.
- [76] A. Campisi, M. Gulino, R. Acquaviva et al., "Reactive oxygen species levels and DNA fragmentation on astrocytes in primary culture after acute exposure to low intensity microwave electromagnetic field," *Neuroscience Letters*, vol. 473, no. 1, pp. 52–55, 2010.
- [77] S. Ni, Y. Yu, Y. Zhang, W. Wu, K. Lai, and K. Yao, "Study of oxidative stress in human lens epithelial cells exposed to 1.8 GHz radiofrequency fields," *PLoS One*, vol. 8, no. 8, article e72370, 2013.
- [78] A. M. Marjanovic Cermak, I. Pavicic, and I. Trosic, "Oxidative stress response in SH-SY5Y cells exposed to short-term 1800 MHz radiofrequency radiation," *Journal of Environmental Science and Health, Part A*, vol. 53, no. 2, pp. 132–138, 2018.
- [79] S. Xu, Z. Zhou, L. Zhang et al., "Exposure to 1800 MHz radiofrequency radiation induces oxidative damage to mitochondrial DNA in primary cultured neurons," *Brain Research*, vol. 1311, pp. 189–196, 2010.
- [80] Y. S. Lu, B. T. Huang, and Y. X. Huang, "Reactive oxygen species formation and apoptosis in human peripheral blood mononuclear cell induced by 900 MHz mobile phone radiation," *Oxidative Medicine and Cellular Longevity*, vol. 2012, Article ID 740280, 8 pages, 2012.
- [81] E. Kazemi, S. M. Mortazavi, A. Ali-Ghanbari et al., "Effect of 900 MHz electromagnetic radiation on the induction of ROS in human peripheral blood mononuclear cells," *Journal of Biomedical Physics and Engineering*, vol. 5, no. 3, pp. 105–114, 2015.
- [82] Y. Sun, L. Zong, Z. Gao, S. Zhu, J. Tong, and Y. Cao, "Mitochondrial DNA damage and oxidative damage in HL-60 cells exposed to 900MHz radiofrequency fields," *Mutation Research/Fundamental and Molecular Mechanisms of Mutagenesis*, vol. 797–799, pp. 7–14, 2017.
- [83] Y. K. Gupta, M. Gupta, and K. Kohli, "Neuroprotective role of melatonin in oxidative stress vulnerable brain," *Indian Journal of Physiology and Pharmacology*, vol. 47, no. 4, pp. 373–386, 2003.
- [84] D. Sokolovic, B. Djindjic, J. Nikolic et al., "Melatonin reduces oxidative stress induced by chronic exposure of microwave radiation from mobile phones in rat brain," *Journal of Radiation Research*, vol. 49, no. 6, pp. 579–586, 2008.
- [85] S. A. Curley, F. Palalon, X. Lu, and N. V. Koshkina, "Noninvasive radiofrequency treatment effect on mitochondria in pancreatic cancer cells," *Cancer*, vol. 120, no. 21, pp. 3418–3425, 2014.
- [86] L. O'Donnell, "Mechanisms of spermiogenesis and spermatiation and how they are disturbed," *Spermatogenesis*, vol. 4, no. 2, article e979623, 2015.
- [87] H. Chen, D. Mruk, X. Xiao, and C. Y. Cheng, "Human spermatogenesis and its regulation," in *Male Hypogonadism*, S. Winters and I. Huhtaniemi, Eds., Contemporary Endocrinology. Humana Press, Cham, 2017.
- [88] J. Ramalho-Santos, S. Varum, S. Amaral, P. C. Mota, A. P. Sousa, and A. Amaral, "Mitochondrial functionality in reproduction: from gonads and gametes to embryos and embryonic stem cells," *Human Reproduction Update*, vol. 15, no. 5, pp. 553–572, 2009.
- [89] H. C. Ho and S. Wey, "Three dimensional rendering of the mitochondrial sheath morphogenesis during mouse spermiogenesis," *Microscopy Research and Technique*, vol. 70, no. 8, pp. 719–723, 2007.
- [90] A. Amaral, B. Lourenço, M. Marques, and J. Ramalho-Santos, "Mitochondria functionality and sperm quality," *Reproduction*, vol. 146, no. 5, pp. R163–R174, 2013.
- [91] B. T. Storey, "Mammalian sperm metabolism: oxygen and sugar, friend and foe," *The International Journal of Developmental Biology*, vol. 52, no. 5-6, pp. 427–437, 2008.
- [92] S. Kothari, A. Thompson, A. Agarwal, and S. S. du Plessis, "Free radicals: their beneficial and detrimental effects on sperm function," *Indian Journal of Experimental Biology*, vol. 48, no. 5, pp. 425–435, 2010.
- [93] R. J. Aitken, Z. Gibb, L. A. Mitchell, S. R. Lambourne, H. S. Connaughton, and G. N. De Iulius, "Sperm motility is lost in vitro as a consequence of mitochondrial free radical production and the generation of electrophilic aldehydes but can be significantly rescued by the presence of nucleophilic thiols," *Biology of Reproduction*, vol. 87, no. 5, p. 110, 2012.
- [94] R. J. Aitken, K. T. Jones, and S. A. Robertson, "Reactive oxygen species and sperm function—in sickness and in health," *Journal of Andrology*, vol. 33, no. 6, pp. 1096–1106, 2012.
- [95] D. W. Deno and D. O. Carpenter, "Sources and characteristics of electric and magnetic fields in the environment," in *Biological Effects of Electric and Magnetic Fields*, D. O. Carpenter and S. Ayrappetyan, Eds., pp. 3–51, Academic Press, San Diego, New York, 1994.
- [96] A. Elbetieha, M.'d.-A. Al-Akhras, and H. Darmani, "Long-term exposure of male and female mice to 50 Hz magnetic field: effects on fertility," *Bioelectromagnetics*, vol. 23, no. 2, pp. 168–172, 2002.
- [97] L. de Bruyn and L. de Jager, "Effect of long-term exposure to a randomly varied 50 Hz power frequency magnetic field on the fertility of the mouse," *Electromagnetic Biology and Medicine*, vol. 29, no. 1-12, pp. 52–61, 2010.
- [98] M.'d.-A. Al-Akhras, A. Elbetieha, M.-K. Hasan, I. Al-Omari, H. Darmani, and B. Albiss, "Effects of extremely low frequency magnetic field on fertility of adult male and female rats," *Bioelectromagnetics*, vol. 22, no. 5, pp. 340–344, 2001.
- [99] C. Sert, M. Z. Akdag, M. Bashan, H. Buyukbayram, and S. Dasdag, "ELF magnetic field effects on fatty acid composition of phospholipid fraction and reproduction of rats' testes," *Electromagnetic Biology and Medicine*, vol. 21, no. 1, pp. 19–29, 2002.
- [100] M.'d.-A. Al-Akhras, H. Darmani, and A. Elbetieha, "Influence of 50 Hz magnetic field on sex hormones and other fertility parameters of adult male rats," *Bioelectromagnetics*, vol. 27, no. 2, pp. 127–131, 2006.
- [101] M. K. Chung, S. J. Lee, Y. B. Kim et al., "Evaluation of spermatogenesis and fertility in F1 male rats after in utero

- and neonatal exposure to extremely low frequency electromagnetic fields," *Asian Journal of Andrology*, vol. 7, no. 2, pp. 189–194, 2005.
- [102] G. Qi, X. Zuo, L. Zhou et al., "Effects of extremely low-frequency electromagnetic fields (ELF-EMF) exposure on B6C3F1 mice," *Environmental Health and Preventive Medicine*, vol. 20, no. 4, pp. 287–293, 2015.
- [103] B. M. Tenorio, G. C. Jimenez, R. N. Morais, S. M. Torres, R. Albuquerque Nogueira, and V. A. Silva Junior, "Testicular development evaluation in rats exposed to 60 Hz and 1 mT electromagnetic field," *Journal of Applied Toxicology*, vol. 31, no. 3, pp. 223–230, 2011.
- [104] B. M. Tenorio, G. C. Jimenez, R. N. Morais, C. A. Peixoto, R. A. Nogueira, and V. A. S. Junior, "Evaluation of testicular degeneration induced by low-frequency electromagnetic fields," *Journal of Applied Toxicology*, vol. 32, no. 3, pp. 210–218, 2012.
- [105] L. Hajhosseini, A. Khaki, E. Merat, and N. Ainehchi, "Effect of rosmarinic acid on sertoli cells apoptosis and serum antioxidant levels in rats after exposure to electromagnetic fields," *African Journal of Traditional, Complementary and Alternative Medicines*, vol. 10, no. 6, pp. 477–480, 2013.
- [106] B. M. Tenorio, M. B. A. F. Filho, G. C. Jimenez et al., "Extremely low-frequency magnetic fields can impair spermatogenesis recovery after reversible testicular damage induced by heat," *Electromagnetic Biology and Medicine*, vol. 33, no. 2, pp. 139–146, 2014.
- [107] J. S. Lee, S. S. Ahn, K. C. Jung, Y. W. Kim, and S. K. Lee, "Effects of 60 Hz electromagnetic field exposure on testicular germ cell apoptosis in mice," *Asian Journal of Andrology*, vol. 6, no. 1, pp. 29–34, 2004.
- [108] Y. W. Kim, H. S. Kim, J. S. Lee et al., "Effects of 60 Hz 14 microT magnetic field on the apoptosis of testicular germ cell in mice," *Bioelectromagnetics*, vol. 30, no. 1, pp. 66–72, 2009.
- [109] W. Duan, C. Liu, H. Wu et al., "Effects of exposure to extremely low frequency magnetic fields on spermatogenesis in adult rats," *Bioelectromagnetics*, vol. 35, no. 1, pp. 58–69, 2014.
- [110] L. A. Ramadan, A. R. A. Abd-Allah, H. A. A. Aly, and A. A. Saad-El-Din, "Testicular toxicity effects of magnetic field exposure and prophylactic role of coenzyme Q10 and L-carnitine in mice," *Pharmacological Research*, vol. 46, no. 4, pp. 363–370, 2002.
- [111] D. K. Li, B. Yan, Z. Li et al., "Exposure to magnetic fields and the risk of poor sperm quality," *Reproductive Toxicology*, vol. 29, no. 1, pp. 86–92, 2010.
- [112] T. Hori, T. Yamsaard, Y. Y. Ueta et al., "Exposure of C57BL/6J male mice to an electric field improves copulation rates with superovulated females," *Journal of Reproduction and Development*, vol. 51, no. 3, pp. 393–397, 2005.
- [113] M. Darbandi, S. Darbandi, A. Agarwal, R. Henkle, and M. R. Sadeghi, "The effects of exposure to low frequency electromagnetic fields on male fertility," *Alternative Therapies in Health and Medicine*, 2017.
- [114] A. M. Sommer, K. Grote, T. Reinhardt, J. Streckert, V. Hansen, and A. Lerchl, "Effects of radiofrequency electromagnetic fields (UMTS) on reproduction and development of mice: a multi-generation study," *Radiation Research*, vol. 171, no. 1, pp. 89–95, 2009.
- [115] S. Takahashi, N. Imai, K. Nabae et al., "Lack of adverse effects of whole-body exposure to a mobile telecommunication electromagnetic field on the rat fetus," *Radiation Research*, vol. 173, no. 3, pp. 362–372, 2010.
- [116] F. Poulietier de Gannes, E. Haro, A. Hurtier et al., "Effect of in utero wi-fi exposure on the pre- and postnatal development of rats," *Birth Defects Research Part B: Developmental and Reproductive Toxicology*, vol. 95, no. 2, pp. 130–136, 2012.
- [117] F. Poulietier de Gannes, B. Billaudel, E. Haro et al., "Rat fertility and embryo fetal development: influence of exposure to the Wi-Fi signal," *Reproductive Toxicology*, vol. 36, pp. 1–5, 2013.
- [118] S. Daşdag*, M. Zülküf Akdag*, O. Ayyıldız, Ö. C. Demirtaş, M. Yayla, and C. Sert, "Do cellular phones alter blood parameters and birth weight of rats?," *Electro- and Magnetobiology*, vol. 19, no. 1, pp. 107–113, 2009.
- [119] K. K. Kesari and J. Behari, "Evidence for mobile phone radiation exposure effects on reproductive pattern of male rats: role of ROS," *Electromagnetic Biology and Medicine*, vol. 31, no. 3, pp. 213–222, 2012.
- [120] K. K. Kesari, S. Kumar, J. Nirala, M. H. Siddiqui, and J. Behari, "Biophysical evaluation of radiofrequency electromagnetic field effects on male reproductive pattern," *Cell Biochemistry and Biophysics*, vol. 65, no. 2, pp. 85–96, 2013.
- [121] R. Meena, K. Kumari, J. Kumar, P. Rajamani, H. N. Verma, and K. K. Kesari, "Therapeutic approaches of melatonin in microwave radiations-induced oxidative stress-mediated toxicity on male fertility pattern of Wistar rats," *Electromagnetic Biology and Medicine*, vol. 33, no. 2, pp. 81–91, 2013.
- [122] M. M. Bin-Meferij and A. F. El-Kott, "The radioprotective effects of Moringa oleifera against mobile phone electromagnetic radiation-induced infertility in rats," *International Journal of Clinical and Experimental Medicine*, vol. 8, no. 8, pp. 12487–12497, 2015.
- [123] S. Dasdag, M. A. Ketani, Z. Akdag et al., "Whole-body microwave exposure emitted by cellular phones and testicular function of rats," *Urological Research*, vol. 27, no. 3, pp. 219–223, 1999.
- [124] M. Mailankot, A. P. Kunnath, H. Jayalekshmi, B. Koduru, and R. Valsalan, "Radio frequency electromagnetic radiation (RF-EMR) from GSM (0.9/1.8GHz) mobile phones induces oxidative stress and reduces sperm motility in rats," *Clinics*, vol. 64, no. 6, pp. 561–565, 2009.
- [125] S. Kumar, J. P. Nirala, J. Behari, and R. Paulraj, "Effect of electromagnetic irradiation produced by 3G mobile phone on male rat reproductive system in a simulated scenario," *Indian Journal of Experimental Biology*, vol. 52, no. 9, pp. 890–897, 2014.
- [126] M. Tas, S. Dasdag, M. Z. Akdag et al., "Long-term effects of 900 MHz radiofrequency radiation emitted from mobile phone on testicular tissue and epididymal semen quality," *Electromagnetic Biology and Medicine*, vol. 33, no. 3, pp. 216–222, 2013.
- [127] S. Dasdag, M. Tas, M. Z. Akdag, and K. Yegin, "Effect of long-term exposure of 2.4 GHz radiofrequency radiation emitted from Wi-Fi equipment on testes functions," *Electromagnetic Biology and Medicine*, vol. 34, no. 1, pp. 37–42, 2013.
- [128] M. Z. Akdag, S. Dasdag, F. Canturk, D. Karabulut, Y. Caner, and N. Adalier, "Does prolonged radiofrequency radiation emitted from Wi-Fi devices induce DNA damage in various tissues of rats?," *Journal of Chemical Neuroanatomy*, vol. 75, no. Part B, pp. 116–122, 2016.

- [129] H. Oguzturk, R. Beytur, O. Ciftci, M. G. Turtay, E. Samdanci, and O. F. Dilek, "Does 3-G mobile phone radiofrequency affect oxidative stress, sperm characteristics and testis histology?," *Fresenius Environmental Bulletin*, vol. 20, no. 3, pp. 646–653, 2011.
- [130] D. Fatehi, M. Anjomshoa, M. Mohammadi, M. Seify, and A. Rostamzadeh, "Biological effects of cell-phone radiofrequency waves exposure on fertilization in mice; an in vivo and in vitro study," *Middle East Fertility Society Journal*, vol. 23, no. 2, pp. 148–153, 2018.
- [131] I. Fejes, Z. Závaczki, J. Szöllosi et al., "Is there a relationship between cell phone use and semen quality?," *Archives of Andrology*, vol. 51, no. 5, pp. 385–393, 2009.
- [132] A. Agarwal, F. Deepinder, R. K. Sharma, G. Ranga, and J. Li, "Effect of cell phone usage on semen analysis in men attending infertility clinic: an observational study," *Fertility and Sterility*, vol. 89, no. 1, pp. 124–128, 2008.
- [133] G. N. De Iuliis, R. J. Newey, B. V. King, and R. J. Aitken, "Mobile phone radiation induces reactive oxygen species production and DNA damage in human spermatozoa in vitro," *PLoS One*, vol. 4, no. 7, article e6446, 2009.
- [134] N. Falzone, C. Huyser, D. R. Franken, and D. Leszczynski, "Mobile phone radiation does not induce pro-apoptosis effects in human spermatozoa," *Radiation Research*, vol. 174, no. 2, pp. 169–176, 2010.
- [135] C. Avendaño, A. Mata, C. A. Sanchez Sarmiento, and G. F. Doncel, "Use of laptop computers connected to internet through Wi-Fi decreases human sperm motility and increases sperm DNA fragmentation," *Fertility and Sterility*, vol. 97, no. 1, pp. 39–45.e2, 2012.
- [136] F. Oktem, F. Ozguner, H. Mollaoglu, A. Koyu, and E. Uz, "Oxidative damage in the kidney induced by 900-MHz-emitted mobile phone: protection by melatonin," *Archives of Medical Research*, vol. 36, no. 4, pp. 350–355, 2005.
- [137] M. Balci, E. Devrim, and I. Durak, "Effects of mobile phones on oxidant/antioxidant balance in cornea and lens of rats," *Current Eye Research*, vol. 32, no. 1, pp. 21–25, 2009.
- [138] I. Meral, H. Mert, N. Mert et al., "Effects of 900-MHz electromagnetic field emitted from cellular phone on brain oxidative stress and some vitamin levels of guinea pigs," *Brain Research*, vol. 1169, pp. 120–124, 2007.
- [139] R. J. Aitken and M. A. Baker, "Oxidative stress and male reproductive biology," *Reproduction, Fertility and Development*, vol. 16, no. 5, p. 581, 2004.
- [140] K. K. Kesari, S. Kumar, and J. Behari, "Effects of radiofrequency electromagnetic wave exposure from cellular phones on the reproductive pattern in male Wistar rats," *Applied Biochemistry and Biotechnology*, vol. 164, no. 4, pp. 546–559, 2011.
- [141] Q. Liu, T. Si, X. Xu, F. Liang, L. Wang, and S. Pan, "Electromagnetic radiation at 900 MHz induces sperm apoptosis through bcl-2, bax and caspase-3 signaling pathways in rats," *Reproductive Health*, vol. 12, no. 1, p. 65, 2015.
- [142] H. Hancı, G. Kerimoğlu, T. Mercantepe, and E. Odacı, "Changes in testicular morphology and oxidative stress biomarkers in 60-day-old Sprague Dawley rats following exposure to continuous 900-MHz electromagnetic field for 1 h a day throughout adolescence," *Reproductive Toxicology*, vol. 81, pp. 71–78, 2018.
- [143] R. Li, M. Ma, L. Li et al., "The protective effect of autophagy on DNA damage in mouse spermatocyte-derived cells exposed to 1800 MHz radiofrequency electromagnetic fields," *Cellular Physiology and Biochemistry*, vol. 48, no. 1, pp. 29–41, 2018.
- [144] S. Kumar, K. K. Kesari, and J. Behari, "Influence of microwave exposure on fertility of male rats," *Fertility and Sterility*, vol. 95, no. 4, pp. 1500–1502, 2011.
- [145] M. A. Al-Damegh, "Rat testicular impairment induced by electromagnetic radiation from a conventional cellular telephone and the protective effects of the antioxidants vitamins C and E," *Clinics*, vol. 67, no. 7, pp. 785–792, 2012.
- [146] N. Pandey and S. Giri, "Melatonin attenuates radiofrequency radiation (900 MHz)-induced oxidative stress, DNA damage and cell cycle arrest in germ cells of male Swiss albino mice," *Toxicology and Industrial Health*, vol. 34, no. 5, pp. 315–327, 2018.
- [147] P. Solek, L. Majchrowicz, D. Bloniarz, E. Krotoszynska, and M. Kozirowski, "Pulsed or continuous electromagnetic field induce p53/p21-mediated apoptotic signaling pathway in mouse spermatogenic cells in vitro and thus may affect male fertility," *Toxicology*, vol. 382, pp. 84–92, 2017.
- [148] P. Solek, L. Majchrowicz, and M. Kozirowski, "Aloe arborescens juice prevents EMF-induced oxidative stress and thus protects from pathophysiology in the male reproductive system in vitro," *Environmental Research*, vol. 166, pp. 141–149, 2018.
- [149] I. M. Saadeldin, A. M. Fadel, M. M. Z. Hamada, and A. A. El-Badry, "Effects of exposure to 50 Hz, 1 Gauss magnetic field on reproductive traits in male albino rats," *Acta Veterinaria Brno*, vol. 80, no. 1, pp. 107–111, 2011.
- [150] M. Z. Akdag, S. Dasdag, A. K. Uzunlar et al., "Can safe and long-term exposure to extremely low frequency (50 Hz) magnetic fields affect apoptosis, reproduction, and oxidative stress?," *International Journal of Radiation Biology*, vol. 89, no. 12, pp. 1053–1060, 2013.
- [151] C. P. Weir and B. Robaire, "Spermatozoa have decreased antioxidant enzymatic capacity and increased reactive oxygen species production during aging in the Brown Norway rat," *Journal of Andrology*, vol. 28, no. 2, pp. 229–240, 2007.
- [152] E. T. Donnelly, M. O'Connell, N. McClure, and S. E. M. Lewis, "Differences in nuclear DNA fragmentation and mitochondrial integrity of semen and prepared human spermatozoa," *Human Reproduction*, vol. 15, no. 7, pp. 1552–1561, 2000.
- [153] M. Piasecka and J. Kawiak, "Sperm mitochondria of patients with normal sperm motility and with asthenozoospermia: morphological and functional study," *Folia Histochemica et Cytobiologica*, vol. 41, no. 3, pp. 125–139, 2003.
- [154] N. Pandey, S. Giri, S. Das, and P. Upadhaya, "Radiofrequency radiation (900 MHz)-induced DNA damage and cell cycle arrest in testicular germ cells in swiss albino mice," *Toxicology and Industrial Health*, vol. 33, no. 4, pp. 373–384, 2016.
- [155] B. J. Houston, B. Nixon, B. V. King, R. J. Aitken, and G. N. De Iuliis, "Probing the origins of 1,800 MHz radio frequency electromagnetic radiation induced damage in mouse immortalized germ cells and spermatozoa in vitro," *Frontiers in Public Health*, vol. 6, p. 270, 2018.
- [156] A. M. Hagraş, E. A. Toraih, and M. S. Fawzy, "Mobile phones electromagnetic radiation and NAD⁺-dependent isocitrate dehydrogenase as a mitochondrial marker in asthenozoospermia," *Biochimie Open*, vol. 3, pp. 19–25, 2016.

- [157] R. J. Aitken, L. E. Bennetts, D. Sawyer, A. M. Wildendit, and B. V. King, "Impact of radio frequency electromagnetic radiation on DNA integrity in the male germline," *International Journal of Andrology*, vol. 28, no. 3, pp. 171–179, 2005.
- [158] N. Falzone, C. Huyser, F. Fourie, T. Toivo, D. Leszczynski, and D. Franken, "In vitro effect of pulsed 900 MHz GSM radiation on mitochondrial membrane potential and motility of human spermatozoa," *Bioelectromagnetics*, vol. 29, no. 4, pp. 268–276, 2008.
- [159] N. Bernabò, E. Tettamanti, M. G. Pistilli et al., "Effects of 50 Hz extremely low frequency magnetic field on the morphology and function of boar spermatozoa capacitated in vitro," *Theriogenology*, vol. 67, no. 4, pp. 801–815, 2007.
- [160] A. A. Khaki, A. Khaki, S. Garachurlou, F. Khorshidi, N. Tajadini, and N. Madinei, "Pre and post natal exposure of 50 Hz electromagnetic fields on prostate glands of rats: an electron microscopy study," *Iranian Journal of Reproductive Medicine*, vol. 6, no. 2, pp. 77–82, 2008.
- [161] R. Iorio, S. Delle Monache, F. Bennato et al., "Involvement of mitochondrial activity in mediating ELF-EMF stimulatory effect on human sperm motility," *Bioelectromagnetics*, vol. 32, no. 1, pp. 15–27, 2011.
- [162] M. A. Aon, S. Cortassa, and B. O'Rourke, "Mitochondrial oscillations in physiology and pathophysiology," *Advances in Experimental Medicine and Biology*, vol. 641, pp. 98–117, 2008.
- [163] O. Oktem and K. Oktay, "The ovary: anatomy and function throughout human life," *Annals of the New York Academy of Sciences*, vol. 1127, no. 1, pp. 1–9, 2008.
- [164] H. Zhang and K. Liu, "Cellular and molecular regulation of the activation of mammalian primordial follicles: somatic cells initiate follicle activation in adulthood," *Human Reproduction Update*, vol. 21, no. 6, pp. 779–786, 2015.
- [165] H. Buckler, "The menopause transition: endocrine changes and clinical symptoms," *British Menopause Society Journal*, vol. 11, no. 2, pp. 61–65, 2005.
- [166] C. Tatone, F. Amicarelli, M. C. Carbone et al., "Cellular and molecular aspects of ovarian follicle ageing," *Human Reproduction Update*, vol. 14, no. 2, pp. 131–142, 2008.
- [167] M. A. Al-Akhras, "Influence of 50 Hz magnetic field on sex hormones and body, uterine, and ovarian weights of adult female rats," *Electromagn Biol Med.*, vol. 27, no. 2, pp. 155–163, 2008.
- [168] M. Aydin, A. Cevik, F. M. Kandemir, M. Yuksel, and A. M. Apaydin, "Evaluation of hormonal change, biochemical parameters, and histopathological status of uterus in rats exposed to 50-Hz electromagnetic field," *Toxicology and Industrial Health*, vol. 25, no. 3, pp. 153–158, 2009.
- [169] B. Dundar, G. Cesur, S. Comlekci et al., "The effect of the prenatal and post-natal long-term exposure to 50 Hz electric field on growth, pubertal development and IGF-1 levels in female Wistar rats," *Toxicology and Industrial Health*, vol. 25, no. 7, pp. 479–487, 2009.
- [170] J. S. Rad, S. Soleimani-Rad, L. Roshangar, B. A. Hamdi, and A. A. Khaki, "Effect of low-frequency electromagnetic field exposure on oocyte differentiation and follicular development," *Advanced Biomedical Research*, vol. 3, no. 1, p. 76, 2014.
- [171] A. A. Khaki, A. Khaki, and S. S. Ahmadi, "The effect of non-ionizing electromagnetic field with a frequency of 50 Hz in Rat ovary: a transmission electron microscopy study," *International Journal of Reproductive BioMedicine*, vol. 14, no. 2, pp. 125–132, 2016.
- [172] S. S. Ahmadi, A. A. Khaki, N. Ainehchi et al., "Effect of non-ionizing electromagnetic field on the alteration of ovarian follicles in rats," *Electronic Physician*, vol. 8, no. 3, pp. 2168–2174, 2016.
- [173] F. Aksen, M. Z. Akdag, A. Ketani, B. Yokus, A. Kaya, and S. Dasdag, "Effect of 50-Hz 1-mT magnetic field on the uterus and ovaries of rats (electron microscopy evaluation)," *Medical Science Monitor*, vol. 12, no. 6, pp. BR215–BR220, 2006.
- [174] S. Cecconi, G. Gualtieri, A. Di Bartolomeo, G. Troiani, M. G. Cifone, and R. Canipari, "Evaluation of the effects of extremely low frequency electromagnetic fields on mammalian follicle development," *Human Reproduction*, vol. 15, no. 11, pp. 2319–2325, 2000.
- [175] L. Hafizi, A. Szargarnia, N. Mousavifar et al., "The effect of extremely low frequency pulsed electromagnetic field on in vitro fertilization success rate in N MRI mice," *Cell Journal*, vol. 15, no. 4, pp. 310–315, 2014.
- [176] N. Borhani, F. Rajaei, Z. Salehi, and A. Javadi, "Analysis of DNA fragmentation in mouse embryos exposed to an extremely low-frequency electromagnetic field," *Electromagnetic Biology and Medicine*, vol. 30, no. 4, pp. 246–252, 2011.
- [177] P. D. Bayat, M. R. Darabi, A. Ghanbari, S. Amiri, and P. Sohoul, "Effects of prenatal exposure to extremely low electro-magnetic field on in vivo derived blastocysts of mice," *Iranian Journal of Reproductive Medicine*, vol. 10, no. 6, pp. 555–560, 2012.
- [178] A. Asghari, A. A. Khaki, A. Rajabzadeh, and A. Khaki, "A review on electromagnetic fields (EMFs) and the reproductive system," *Electronic Physician*, vol. 8, no. 7, pp. 2655–2662, 2016.
- [179] S. Ait-Aïssa, B. Billaudel, F. Poullietier de Gannes et al., "In utero and early-life exposure of rats to a Wi-Fi signal: screening of immune markers in sera and gestational outcome," *Bioelectromagnetics*, vol. 33, no. 5, pp. 410–420, 2012.
- [180] O. Sangum, B. Dundar, H. Darici, S. Comlekci, D. K. Doguc, and S. Celik, "The effects of long-term exposure to a 2450 MHz electromagnetic field on growth and pubertal development in female Wistar rats," *Electromagnetic Biology and Medicine*, vol. 34, no. 1, pp. 63–71, 2013.
- [181] J. A. Flaws, R. Abbud, R. J. Mann, J. H. Nilson, and A. N. Hirshfield, "Chronically elevated luteinizing hormone depletes primordial follicles in the mouse ovary," *Biology of Reproduction*, vol. 57, no. 5, pp. 1233–1237, 1997.
- [182] A. Gul, H. Celebi, and S. Uğraş, "The effects of microwave emitted by cellular phones on ovarian follicles in rats," *Archives of Gynecology and Obstetrics*, vol. 280, no. 5, pp. 729–733, 2009.
- [183] M. Bakacak, M. S. Bostancı, R. Attar et al., "The effects of electromagnetic fields on the number of ovarian primordial follicles: an experimental study," *The Kaohsiung Journal of Medical Sciences*, vol. 31, no. 6, pp. 287–292, 2015.
- [184] S. Türedi, H. Hancı, S. Çolakoğlu, H. Kaya, and E. Odacı, "Disruption of the ovarian follicle reservoir of prepubertal rats following prenatal exposure to a continuous 900-MHz electromagnetic field," *International Journal of Radiation Biology*, vol. 92, no. 6, pp. 329–337, 2016.
- [185] S. Suzuki, M. Okutsu, R. Suganuma et al., "Influence of radiofrequency-electromagnetic waves from 3rd-generation

- cellular phones on fertilization and embryo development in mice," *Bioelectromagnetics*, vol. 38, no. 6, pp. 466–473, 2017.
- [186] A. K. Manta, D. Papadopoulou, A. P. Polyzos et al., "Mobile-phone radiation-induced perturbation of gene-expression profiling, redox equilibrium and sporadic-apoptosis control in the ovary of *Drosophila melanogaster*," *Fly*, vol. 11, no. 2, pp. 75–95, 2017.
- [187] A. Burlaka, O. Tsybulin, E. Sidorik et al., "Overproduction of free radical species in embryonal cells exposed to low intensity radiofrequency radiation," *Experimental Oncology*, vol. 35, no. 3, pp. 219–225, 2013.
- [188] N. Esfandiari, R. A. Saleh, A. P. Blaut et al., "Effects of temperature on sperm motion characteristics and reactive oxygen species," *International Journal of Fertility and Women's Medicine*, vol. 47, no. 5, pp. 227–233, 2002.
- [189] T. Gutsch, B. Mohamad Al-Ali, R. Shamloul, K. Pummer, and H. Trummer, "Impact of cell phone use on men's semen parameters," *Andrologia*, vol. 43, no. 5, pp. 312–316, 2011.
- [190] K. Liu, G. Zhang, Z. Wang et al., "The protective effect of autophagy on mouse spermatocyte derived cells exposure to 1800MHz radiofrequency electromagnetic radiation," *Toxicology Letters*, vol. 228, no. 3, pp. 216–224, 2014.
- [191] J. A. Adams, T. S. Galloway, D. Mondal, S. C. Esteves, and F. Mathews, "Effect of mobile telephones on sperm quality: a systematic review and meta-analysis," *Environment International*, vol. 70, pp. 106–112, 2014.
- [192] E. K. Sheiner, E. Sheiner, R. D. Hammel, G. Potashnik, and R. Carel, "Effect of occupational exposures on male fertility: literature review," *Industrial Health*, vol. 41, no. 2, pp. 55–62, 2003.
- [193] N. Bernabò, R. Ciccarelli, L. Greco, A. Ordinelli, M. Mattioli, and B. Barboni, "Scientometric study of the effects of exposure to non-ionizing electromagnetic fields on fertility: a contribution to understanding the reasons of partial failure," *PLoS One*, vol. 12, no. 12, article e0187890, 2017.

- cellular phones on fertilization and embryo development in mice," *Bioelectromagnetics*, vol. 38, no. 6, pp. 466–473, 2017.
- [186] A. K. Manta, D. Papadopoulou, A. P. Polyzos et al., "Mobile-phone radiation-induced perturbation of gene-expression profiling, redox equilibrium and sporadic-apoptosis control in the ovary of *Drosophila melanogaster*," *Fly*, vol. 11, no. 2, pp. 75–95, 2017.
- [187] A. Burlaka, O. Tsybulin, E. Sidorik et al., "Overproduction of free radical species in embryonal cells exposed to low intensity radiofrequency radiation," *Experimental Oncology*, vol. 35, no. 3, pp. 219–225, 2013.
- [188] N. Esfandiari, R. A. Saleh, A. P. Blaut et al., "Effects of temperature on sperm motion characteristics and reactive oxygen species," *International Journal of Fertility and Women's Medicine*, vol. 47, no. 5, pp. 227–233, 2002.
- [189] T. Gutsch, B. Mohamad Al-Ali, R. Shamloul, K. Pummer, and H. Trummer, "Impact of cell phone use on men's semen parameters," *Andrologia*, vol. 43, no. 5, pp. 312–316, 2011.
- [190] K. Liu, G. Zhang, Z. Wang et al., "The protective effect of autophagy on mouse spermatocyte derived cells exposure to 1800MHz radiofrequency electromagnetic radiation," *Toxicology Letters*, vol. 228, no. 3, pp. 216–224, 2014.
- [191] J. A. Adams, T. S. Galloway, D. Mondal, S. C. Esteves, and F. Mathews, "Effect of mobile telephones on sperm quality: a systematic review and meta-analysis," *Environment International*, vol. 70, pp. 106–112, 2014.
- [192] E. K. Sheiner, E. Sheiner, R. D. Hammel, G. Potashnik, and R. Carel, "Effect of occupational exposures on male fertility: literature review," *Industrial Health*, vol. 41, no. 2, pp. 55–62, 2003.
- [193] N. Bernabò, R. Ciccarelli, L. Greco, A. Ordinelli, M. Mattioli, and B. Barboni, "Scientometric study of the effects of exposure to non-ionizing electromagnetic fields on fertility: a contribution to understanding the reasons of partial failure," *PLoS One*, vol. 12, no. 12, article e0187890, 2017.



BioInitiative 2012

A Rationale for Biologically-based Exposure Standards
for Low-Intensity Electromagnetic Radiation



You are here:

[Home](#) / [Media](#) /

[Press Resources](#)

Search ...



[Home](#)

[Editors' Notes](#)

[What's New?](#)

[BioInitiative Report](#)

[Research Summaries](#)

[RF Color Charts](#)

[Participants](#)

[Media](#)

[Contact](#)



[DOWNLOAD PRESS RESOURCES \(PDF\)](#)

PUBLICATION DATE: December 31, 2012

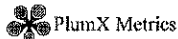
WHERE: The BioInitiative 2012 Report will be published at www.bioinitiative.org. Free download.

WHAT IS IT: A report by 29 independent scientists and health experts from around the world* about possible risks from wireless technologies and electromagnetic fields. It updates the BioInitiative 2007 Report.

WHAT IT COVERS: The science, public health, public policy and global response to the growing health issue of chronic exposure to electromagnetic fields and radiofrequency radiation in the daily life of billions of people around the world. Covers brain tumor risks from cell phones, damage to DNA and genes, effects on memory, learning, behavior, attention; sleep disruption and cancer and neurological diseases like Alzheimer's disease. Effects on sperm and miscarriage (fertility and reproduction), effects of wireless on the brain development of the fetus and infant, and effects of wireless classrooms on children and adolescents is addressed. Mechanisms for biological action and public health responses in other countries are

Use of laptop computers connected to internet through Wi-Fi decreases human sperm motility and increases sperm DNA fragmentation

Conrado Avendaño, M.S.^{a,*}, Ariela Mata, M.S.^a, César A. Sanchez Sarmiento, M.D., Ph.D.^a, Gustavo F. Doncel, M.D., Ph.D.^b



DOI: <https://doi.org/10.1016/j.fertnstert.2011.10.012>

[Article Info](#)

Article Tools

[PDF \(488 KB\)](#)

[Download Images \(.ppt\)](#)
[About Images & Usage](#)

[Email Article](#)

[Add to My Reading List](#)

[Export Citation](#)


[Create Citation Alert](#)

[Cited by in Scopus \(92\)](#)


[Request Permissions](#)

[Order Reprints](#)
(100 minimum order)

Linked Articles

Laptop computers with Wi-Fi decrease human sperm motility and increase sperm DNA fragmentation 

Jean-François Doré, Marie-Christine Chignol
Fertility and Sterility, Vol. 97, Issue 4

Wi-Fi decreases human sperm motility and increases sperm DNA fragmentation 

Thomas Freour, Paul Barriere
Fertility and Sterility, Vol. 97, Issue 4

Related Articles

Sperm DNA fragmentation is correlated with poor embryo

[Abstract](#) | [Full Text](#) | [Images](#) | [References](#) | [Supplemental Materials](#)

Objective

To evaluate the effects of laptop computers connected to local area networks wirelessly (Wi-Fi) on human spermatozoa.

Design

Prospective in vitro study.

Setting

Center for reproductive medicine.

Patient(s)

Semen samples from 29 healthy donors.

Intervention(s)

Motile sperm were selected by swim up. Each sperm suspension was divided into two aliquots. One sperm aliquot (experimental) from each patient was exposed to an internet-connected laptop by Wi-Fi for 4 hours, whereas the second aliquot (unexposed) was used as control, incubated under identical conditions without being exposed to the laptop.

Main Outcome Measure(s)

Evaluation of sperm motility, viability, and DNA fragmentation.

Result(s)

Donor sperm samples, mostly normozoospermic, exposed ex vivo during 4 hours to a wireless internet-connected laptop showed a significant decrease in progressive sperm motility and an increase in sperm DNA fragmentation. Levels of dead sperm showed no significant differences between the two groups.

Conclusion(s)

To our knowledge, this is the first study to evaluate the direct impact of laptop use on human spermatozoa. 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. Further in vitro and in vivo studies are needed to prove this contention.

Key Words:

[Laptop computer](#), [Wi-Fi](#), [sperm quality](#), [fertility](#), [sperm DNA fragmentation](#)

C.A. has nothing to disclose. A.M. has nothing to disclose. C.A.S.S. has nothing to disclose. G.F.D. has nothing to disclose.

© 2012 American Society for Reproductive Medicine. Published by Elsevier Inc. All rights reserved.

development, lower
implantation rate, and higher
miscarriage rate in reproductive
cycles of non-male factor
infertility

Fertility and Sterility, Vol. 112, Issue 3

Selecting the most competent
sperm for assisted reproductive
technologies

Fertility and Sterility, Vol. 111, Issue 5

Use of testicular sperm in
nonazoospermic males

Fertility and Sterility, Vol. 109, Issue 6

Sperm DNA fragmentation
and recurrent pregnancy
loss: a systematic review and
meta-analysis

Fertility and Sterility, Vol. 112, Issue 1

Sperm aneuploidy after
testicular cancer treatment:
data from a prospective
multicenter study performed
within the French Centre
d'Étude et de Conservation des
Oeufs et du Sperme network

Fertility and Sterility, Vol. 107, Issue 3

[View All](#)



Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres

Wi-Fi is an important threat to human health[☆]

Martin L. Pall

Washington State University, 638 NE 41st Avenue, Portland, OR 97232-3312, USA



ARTICLE INFO

Keywords:

Electromagnetic field (EMF)
Brain impact
Testis/sperm count and quality
Impact of pulsation and polarization
Activation of voltage-gated calcium channels
Wi-Fi or WiFi

ABSTRACT

Repeated Wi-Fi studies show that Wi-Fi causes oxidative stress, sperm/testicular damage, neuropsychiatric effects including EEG changes, apoptosis, cellular DNA damage, endocrine changes, and calcium overload. Each of these effects are also caused by exposures to other microwave frequency EMFs, with each such effect being documented in from 10 to 16 reviews. Therefore, each of these seven EMF effects are established effects of Wi-Fi and of other microwave frequency EMFs. Each of these seven is also produced by downstream effects of the main action of such EMFs, voltage-gated calcium channel (VGCC) activation. While VGCC activation via EMF interaction with the VGCC voltage sensor seems to be the predominant mechanism of action of EMFs, other mechanisms appear to have minor roles. Minor roles include activation of other voltage-gated ion channels, calcium cyclotron resonance and the geomagnetic magnetoreception mechanism. Five properties of non-thermal EMF effects are discussed. These are that pulsed EMFs are, in most cases, more active than are non-pulsed EMFs; artificial EMFs are polarized and such polarized EMFs are much more active than non-polarized EMFs; dose-response curves are non-linear and non-monotone; EMF effects are often cumulative; and EMFs may impact young people more than adults. These general findings and data presented earlier on Wi-Fi effects were used to assess the Foster and Moulder (F&M) review of Wi-Fi. The F&M study claimed that there were seven important studies of Wi-Fi that each showed no effect. However, none of these were Wi-Fi studies, with each differing from genuine Wi-Fi in three distinct ways. F&M could, at most conclude that there was no statistically significant evidence of an effect. The tiny numbers studied in each of these seven F&M-linked studies show that each of them lack power to make any substantive conclusions. In conclusion, there are seven repeatedly found Wi-Fi effects which have also been shown to be caused by other similar EMF exposures. Each of the seven should be considered, therefore, as established effects of Wi-Fi.

1. Introduction

Wi-Fi (also known as WiFi or WLAN) is a wireless network involving at least one Wi-Fi antenna connected to the internet and a series of computers, laptops and/or other wireless devices communicating wirelessly with the Wi-Fi antenna. In this way, each such wireless communication device can communicate wirelessly with the internet. All the studies reviewed here were of Wi-Fi using the 2.4 GHz band, although there is also a 5 GHz band reserved for possible Wi-Fi use.

Telecommunications industry-linked individuals and groups have claimed that there are no and cannot possibly be any health impacts of Wi-Fi (Foster and Moulder, 2013; Berezow and Bloom, 2017). However with Wi-Fi exposures becoming more and more common and with many of our exposures being without our consent, there is much concern about possible Wi-Fi health effects. This paper is not focused on anecdotal reports but rather on 23 controlled, scientific studies of such health-related effects in animals, cells including human cells in culture

and in human beings (Table 1).

Each of the effects reported above in from 2 to 11 studies, have an extensive literature for their occurrence in response to various other non-thermal microwave frequency EMFs, discussed in detail below. These include (see Table 1) findings that Wi-Fi exposures produce impacts on the testis leading to lowered male fertility; oxidative stress; apoptosis (a process that has an important causal role in neurodegenerative disease); cellular DNA damage (a process causing cancer and germ line mutations); neuropsychiatric changes including EEG changes; hormonal changes.

The discussion here focuses on those Wi-Fi effects which have been found by multiple Wi-Fi studies and have been previously confirmed by non-thermal exposures to other microwave frequency EMFs. The 1971/72 U.S. Office of Naval Medical Research study (Glaser, 1971) reported the following changes related to testis or sperm: 1. Decreased testosterone leading to lowered testis size. 2. Histological changes in testicular epithelial structure. 3. Gross testicular histological changes. 4.

[☆] For submission to the Wireless Radiation and Health special issue of the Journal Environmental Research.
E-mail address: martin.pall@wsu.edu.

Table 1
Summary of health impacts of Wi-Fi EMF exposures.

Citation(s)	Health Effects
Atasoy et al. (2013); Özorak et al. (2013); Aynali et al. (2013); Çiftçi et al. (2015); Tök et al. (2014); Çiğ and Nazıroğlu (2015); Ghazizadeh and Nazıroğlu (2014); Yüksel et al. (2016); Othman et al. (2017a, 2017b); Topsakal et al. (2017)	Oxidative stress, in some studies effects lowered by antioxidants
Atasoy et al. (2013); Shokri et al. (2015); Dasdag et al. (2015); Avendaño et al. (2012); Yildirim et al. (2015); Özorak et al. (2013); Oni et al. (2011); Akdag et al. (2016)	Sperm/testicular damage, male infertility
Papageorgiou et al. (2011); Maganioti et al. (2010); Othman et al. (2017a, 2017b); Hassanshabhi et al. (2017)	Neuropsychiatric changes including EEG; prenatal Wi-Fi leads to post-natal neural development, increased cholinesterase; decreased special learning; Wi-Fi led to greatly lowered ability to distinguish familiar from novel objects, changes in GABA and cholinergic transmission
Shokri et al. (2015); Dasdag et al. (2015); Çiğ and Nazıroğlu (2015); Topsakal et al. (2017)	Apoptosis (programmed cell death), elevated apoptotic markers
Avendaño et al. (2012); Atasoy et al. (2013); Akdag et al. (2016)	Cellular DNA damage
Salli et al. (2015); Yüksel et al. (2016); Topsakal et al. (2017)	Endocrine changes incl.: Catecholamines, pancreatic endocrine dysfunction, prolactin, progesterone and estrogen
Çiğ and Nazıroğlu (2015); Ghazizadeh and Nazıroğlu (2014)	Calcium overload
Aynali et al. (2013)	Melatonin lowering; sleep disruption
Othman et al. (2017a)	MicroRNA expression (brain)
Othman et al. (2017a)	Abnormal postnatal development
Çiftçi et al. (2015)	Disrupts development of teeth
Salli et al. (2015)	Cardiac changes, blood pressure disruption; erythrocyte damage
Lee et al. (2014)	Growth stimulation of adipose stem cells (role in obesity?)

Decreased spermatogenesis. Glaser (1971) also reported a total of 35 neurological/neuropsychiatric effects of non-thermal EMF exposures, including 9 central nervous system effects, 4 autonomic system effects, 17 psychological disorders, 4 behavioral changes and EEG changes. It also reported 7 types of chromosomal aberrations several of which are known to be caused by chromosomal double stranded DNA breaks, 8 types of endocrine changes, and cell death (what we now call apoptosis). Glaser (1971) also provided over 1000 different citations each reporting various types of non-thermal microwave frequency EMF effects. Consequently, the existence of 5 types of Wi-Fi effects, each supported by multiple Wi-Fi studies were already well-supported as *general non-thermal EMF effects* back in 1971, 47 years ago: effects on the testis and sperm production, neurological/neuropsychiatric effects, endocrine effects, attacks on cellular DNA and increased apoptosis/cell death.

The 146 page review published by Tolgskaya and Gordon (1973) found that in studies of histological changes in rodents, the three most sensitive organs in the body to non-thermal microwave EMFs were the nervous system (including the brain), followed closely by the heart and the testis. They also reported changes in neuroendocrine tissues and increased cell death in multiple tissues. Thus those pre-1973 rodent studies already showed that other EMFs caused 4 of the repeated, recently documented Wi-Fi effects: changes in testis structure/function, neurological effects, increased cell death (possibly via apoptosis) and endocrine effects. Findings from our longer list of EMF reviews of non-thermal effects are summarized in Table 2.

Each of the 7 Wi-Fi effects found in 2–11 studies (Table 1), have also been found to be caused by other microwave frequency EMFs, in a much larger literature (Table 2). From 10 to 16 reviews extensively document each of these seven effects as general microwave frequency effects (Table 2). These are, therefore, general effects produced by such EMFs. Each of these 7 repeatedly found Wi-Fi effects should, therefore, be considered established Wi-Fi effects. The author is not aware of any genuine Wi-Fi studies on these 7 effects that reported no statistically significant evidence of effect.

Each of these 7 is very serious: Oxidative stress has causal roles in most chronic human diseases; cellular DNA damage can cause cancer, thus producing a partial explanation for EMF cancer causation; because such DNA damage occurs in sperm cells (Atasoy et al., 2013; Avendaño et al., 2012; Akdag et al., 2016; Adams et al., 2014; Liu et al., 2014; Asghari et al., 2016), such damage is highly likely to produce mutations that impact future generations; calcium overload is highly likely to be

the cause of each of these various other effects, as discussed below; apoptosis has central roles in neurodegenerative diseases; the neuropsychiatric effects are almost certainly caused by the impact of EMFs on brain structure which is extensively documented and, in my opinion, produces many impacts (Pall, 2016b). A recent meta-analysis shows major lowering of sperm counts and sperm quality in many countries around the world, with declines of over 50% in all advanced technology countries (Levine et al., 2017). The senior author of this study suggested that this effect alone may lead to human extinction (No authors listed, 2017). Given the major impact of EMF exposures on sperm count and quality in human and in animal studies, the pattern of evidence on male fertility is very worrying.

One thing needs to be clarified, here, however. In the two studies on calcium overload following Wi-Fi exposure, such overload was measured a substantial time period following exposure. Overload was shown to be caused, to a substantial effect, by increased TRPV1 receptor activity (Çiğ and Nazıroğlu, 2015; Ghazizadeh and Nazıroğlu, 2014). The TRPV1 receptor is known to be activated by oxidative stress. It is my view, discussed in detail below, that there is a central mechanism that acts to produce excessive intracellular calcium immediately following EMF exposure and that the oxidative stress/TRPV1 activation is secondary.

We have then, major impacts of non-thermal EMF exposures on both of the most important intercellular regulatory systems in the body, the nervous system and the endocrine systems. We have major impacts on what may be the most important intracellular regulatory system, the calcium regulatory system. And we also have non-thermal EMFs attacking the DNA of our cells, putting our biological inheritance at great risk. As living organisms, EMFs attack each of the most important functions that go to the heart of our human complexities.

Despite all of these clear and important, non-thermal effects, and the fact that there was substantial evidence for many of them already known before 1973, our current U.S. and international safety guidelines are still based on considering only thermal effects.

2. Wi-Fi and other wireless communication EMFs are pulsed, leading to larger biological impacts; These EMFs are also polarized, also producing larger effects; Dose response curves are often both non-linear and non-monotone

There are three patterns of EMF action, each of which is very important and each of which is almost universally ignored by the

Table 2
Reviews of Non-thermal Effects of Microwave Frequency EMFs Similar to Those Found in Multiple Wi-Fi Studies.

Non-thermal effects	Citations
Cellular DNA damage	Glaser (1971); Yakymenko et al. (1999); Aitken and De Iulius (2007); Hardell and Sage (2008); Hazout et al. (2008); Phillips et al. (2009); Ruediger (2009); Makker et al. (2009); Yakymenko and Sidorik (2010); Batista Napotnik et al. (2010); Yakymenko et al. (2011); Pall (2013, 2015b); Asghari et al. (2016); Pall (2018)
Changes in testis structure, lowered sperm count/quality	Glaser (1971); Tolgskaya and Gordon (1973); Aitken and De Iulius (2007); Hazout et al. (2008); Desai et al. (2009); Gye and Park (2012); Nazroglu et al. (2013); Carpenter (2013); Adams et al. (2014); Liu et al. (2014); Houston et al. (2016); La Vignera et al. (2012); Makker et al. (2009)
Neurological/neuropsychiatric effects	Glaser (1971); Tolgskaya and Gordon (1973); Raines (1981); Lai (1994); Grigor'ev (1996); Hardell and Sage (2008); Makker et al. (2009); Khurana et al. (2010); Levitt and Lai (2010); Consales et al. (2012); Carpenter (2013); Pall (2016b); Belyaev et al. (2016); Sangün et al. (2016); Kaplan et al. (2016)
Apoptosis/cell death	Glaser (1971); Tolgskaya and Gordon (1973); Raines (1981); Yakymenko et al. (1999); Batista Napotnik et al. (2010); Yakymenko and Sidorik (2010); Pall (2013, 2016b); Asghari et al. (2016); Sangün et al. (2016)
Calcium overload	Adey (1981, 1988); Walleczek (1992); Yakymenko et al. (1999); Gye and Park (2012); Pall (2013, 2015a, 2015b, 2016a, 2016b); Asghari et al. (2016)
Endocrine effects	Glaser (1971); Tolgskaya and Gordon (1973); Raines (1981); Hardell and Sage (2008); Gye and Park (2012); Hardell and Sage (2008); Makker et al. (2009); Pall (2015b); Sangün et al. (2016); Asghari et al. (2016)
Oxidative stress, free radical damage	Raines (1981); Houston et al. (2016); Hardell and Sage (2008); Hazout et al. (2008); Desai et al. (2009); Yakymenko and Sidorik (2010); Yakymenko et al. (2011); Consales et al. (2012); La Vignera et al. (2012); Nazroglu et al. (2013); Yakymenko et al. (2015); Pall (2013, 2018); Dasdag and Akdag (2016); Wang and Zhang (2017)

telecommunications industry and industry-linked organizations. The most extensively reviewed of these is that pulsed EMFs are usually much more biologically active than are non-pulsed (also known as continuous wave) EMFs of identical frequency and similar average intensity (Osipov, 1965; Pollack and Healer, 1967; Creighton et al., 1987; Grigor'ev, 1996; Belyaev, 2005, 2015; Markov, 2007; Van Boxem et al., 2014; Pall, 2015b; Panagopoulos et al., 2015b). This pattern of action is particularly important because all wireless communication devices, including Wi-Fi (Panagopoulos et al., 2015b; Maret, 2015) communicate via pulsations and are likely to be particularly dangerous as consequence of this. Panagopoulos et al., 2015b have argued that the more pulsed they are, the more damaging EMFs will be and while this may still be questioned, it may well be a roughly applicable generalization.

It is also true that artificial EMFs are polarized and this makes artificial EMFs particularly dangerous (Belyaev, 2005, 2015; Panagopoulos et al., 2015a). Polarized EMFs put much larger forces of electrically charged chemical groups than do non-polarized EMFs (Panagopoulos et al., 2015a), an observation that is relevant to the main mechanism of EMF action in living cells discussed below.

It has often been found that there are windows of exposure where specific intensity ranges produce maximum biological effects, which drop off going to both lower or higher intensities (Belyaev, 2005, 2015; Pall, 2015b). It can be seen from this that dose-response curves are often both non-linear and non-monotone whereas industry linked groups often assume a linear and therefore monotone dose-response curve.

3. EMF effects are often cumulative and irreversible

One question that has been raised about the effects of these low-intensity EMFs producing biological effects is are they cumulative? I am aware of three different types of evidence for cumulative effects. Three of the human occupational exposure studies from the 1970's reviewed in Raines (1981), showed that effects increased substantially with increasing time of exposure to a particular type and intensity of EMF.

The impacts of such EMFs on animal brains were reviewed in Tolgskaya and Gordon (1973) and discussed in Pall (2016b). Initially exposures over period of 1–2 months produced relatively modest changes in structure of the brain and the neurons and when exposures ceased, most of the structural changes disappeared – that is the changes were largely reversible. However more months of exposure produced much more severe impacts on brain and neuronal structure and these were irreversible (Tolgskaya and Gordon, 1973; Pall, 2016b).

Magras and Xenos (1997) put pairs of young mice into cages on the

ground at two locations each with somewhat different exposures within an antenna park. The exposure levels at both sites were well within safety guidelines, so if the safety guidelines have any biological relevance, there should have been no apparent effects. It takes about 30 days for mice to go through gestation. At the higher level exposure, the pairs produced one litter of lower than normal size, and a second litter with lowered numbers of progeny; after that they were completely sterile or had extremely low fertility (Magras and Xenos, 1997). At the other site, the mating pairs produced four litters, with decreasing numbers of progeny over time followed by complete sterility. In both groups, the mating and possible subsequent gestation for the fifth possible litter were performed under conditions of no EMF exposure, but the fertility effects were not reversed; therefore fertility effects may become irreversible, suggesting a similar pattern to the brain related effects of EMFs. It should be noted that Özorak et al (2013) showed that Wi-Fi exposure impacted animal reproduction and that (Atasoy et al., 2013; Shokri et al., 2015; Dasdag et al., 2015; Avendaño et al., 2012; Yildirim et al., 2015; Oni et al., 2011; Akdag et al., 2016) suggest this as well from the Wi-Fi impacts on testis structure and sperm production.

Mutation accumulation produced by cellular DNA damage is likely to be both cumulative and irreversible, as well, because later mutations are highly unlikely to reverse previously occurring mutations.

We have therefore reason to think that such effects as brain damage to animal brains, neuropsychiatric effects in humans, reproductive dysfunction in mice and mutational effects, are each cumulative. Those same effects may be completely or largely irreversible. One thing that this should tell us is that the short-term Wi-Fi studies shown in Table 1 may *greatly underestimate* the damage Wi-Fi may do over much longer time periods. Given the fact that Wi-Fi has been placed in most schools, hotels, restaurants, coffee shops, commercial aircraft and airports as well as in many homes and that Wi-Fi hot spots are becoming increasingly common in cities around the world, we should expect massive cumulative Wi-Fi effects in many people. A second tentative inference is that false assurances of safety on the part of industry are likely to lead to much more severe effects on people exposed to Wi-Fi or other EMFs; rather than leading them to protect themselves or their children by avoiding exposures or demanding that others stop non-voluntary exposures, they are likely to avoid protective changes or be prevented from doing such protective changes. A third inference is that these effects may be among the more difficult ones for us to attribute to EMF exposure. We are much more aware of effects that occur rapidly than those that take months or years before they become readily apparent.

4. Wi-Fi and other EMFs may be particularly damaging to young people

Most arguments that have been made that microwave frequency EMFs may be much more damaging to young children have centered on the much smaller skulls and skull thickness in young children, increasing the exposure of their brains to EMFs (Gandhi and Kang, 2001; Gandhi et al., 2012). However there are other arguments to be made. EMFs have been shown to be particularly active in producing effects on embryonic stem cells (Lee et al., 2014; Belyaev et al., 2009; Marková et al., 2010; Czyn et al., 2004; Xu et al., 2016; Bhargav et al., 2015; Odaci et al., 2008; Uchugonova et al., 2008; Wang et al., 2015; Teven et al., 2012). Because such stem cells occur at much higher cell densities in children, with stem cell densities the highest in the fetus and decreasing with increasing age (Belyaev et al., 2009; Marková et al., 2010), impacts on young children are likely to be much higher than in adults. The decreased DNA repair and increased DNA damage following EMF exposure strongly suggest that young children may be increasingly susceptible to cancer following such exposures (Belyaev et al., 2009; Marková et al., 2010; Czyn et al., 2004). EMF action on stem cells may also cause young children to be particularly susceptible to disruption of brain development (Xu et al., 2016; Bhargav et al., 2015), something that may be relevant to autism causation. These are all very problematic issues and we cannot rule out the possibility that there are other problematic issues as well. Redmayne and Johansson (2015) reviewed the literature showing that there are age-related effects, such that young people are more sensitive to EMF effects. It follows from these various findings that the placement of Wi-Fi into schools around the country may well be a high level threat to the health of our children as well being a threat to teachers and any very sensitive fetuses teachers may be carrying, as well.

5. How do EMF exposures lead to non-thermal health impacts?

The author found the answer to this question in the already published scientific literature (Pall, 2013). That study showed that in 24 different studies [there are now a total of 26 Pall (2015b)], effects of low-intensity EMFs, including microwave frequency and also extremely low frequency EMFs, static electrical fields and static magnetic fields could be blocked by calcium channel blockers, drugs that are specific for blocking voltage-gated calcium channels (VGCCs). There were 5 different types of calcium channel blockers used in these studies, each thought to be highly specific, each structurally distinct and each binding to a different site on the VGCCs. In studies where multiple effects were studied, all studied effects were blocked or greatly lowered by calcium channel blockers. These studies show that EMFs produce diverse non-thermal effects via VGCC activation Pall (2013, 2014, 2015a, 2015b, 2016a, 2016b)) in many human and animal cells. In plant cells, EMFs activate somewhat similar calcium channels and produce somewhat similar effects on oxidative stress, cellular DNA damage and calcium signaling (Pall, 2016a). Furthermore, many different effects shown to be produced in repeated studies by EMF exposures, including the effects discussed above, can be produced by downstream effects of VGCC activation, via increased $[Ca^{2+}]_i$, as discussed in detail below.

Before leaving this issue, it is important to discuss why the VGCCs are so sensitive to activation by these low-intensity EMFs. The VGCCs each have a voltage sensor which is made up of 4 alpha helices in the plasma membrane, with each such helix having 5 positive charges on it, for a total of 20 positive charges (Pall, 2015b). These voltage sensor helices are each called S4 helices because each is the fourth helix in a distinct multi-helix domain. Each of these voltage sensor charges is within the lipid bilayer part of the plasma membrane. The electrical forces on the voltage sensor are very high for three distinct reasons (Pall, 2015b, 2015a, 2016a). 1. The 20 charges on the voltage sensor make the forces on voltage sensor 20 times higher than the forces on a

single charge. 2. Because these charges are within the lipid bilayer section of the membrane where the dielectric constant is about 1/120th of the dielectric constant of the aqueous parts of the cell, the law of physics called Coulomb's law, predicts that the forces on those charges will be approximately 120 times higher than the forces on charges in the aqueous parts of the cell. 3. Because the plasma membrane has a high electrical resistance whereas the aqueous parts of the cell are highly conductive, the electrical gradient across the plasma membrane is estimated to be concentrated about 3000-fold. The combination of these effects means that comparing the forces on the voltage sensor with the forces on singly charged groups in the aqueous parts of the cell, the forces on the voltage sensor are approximately $20 \times 120 \times 3000 = 7.2$ million times higher (Pall, 2015b). The physics predicts, therefore, extraordinarily strong forces activating the VGCCs via the voltage sensor. It follows that the biology tells us that the VGCCs are the main target of the EMFs and the physics tells us why they are the main target. Thus the physics and biology are pointing in the same direction.

There are also additional findings pointing to the voltage sensor as the direct target of the EMFs. In addition to the VGCCs, there are also voltage-gated sodium, potassium and chloride channels, with each of these having a voltage sensor similar to those found in the VGCCs. Lu et al. (2015) reported that voltage gated sodium channels, in addition to the VGCCs were activated by EMFs. Tabor et al. (2014) found that Mauthner cells, specialized neurons with special roles in triggering rapid escape mechanisms in fish, were almost instantaneously activated by electrical pulses, which acted via voltage-gated sodium channel activation to subsequently produce large $[Ca^{2+}]_i$ increases. Zhang et al. (2016) reported that in addition to the VGCCs, potassium and chloride channels were each activated by EMFs, although these other voltage-gated ion channels had relatively modest roles compared with the VGCCs in producing biological effects. Each of these three studies, the Lu et al. (2015) study, the Tabor et al. (2014) study and the Zhang et al. (2016) study used specific blockers for these other voltage-gated ion channels to determine their roles. The Tabor et al. (2014) study also used genetic probing to determine the role of the voltage-gated sodium channels. Lu et al. (2015) also used whole cell patch clamp measurements to measure the rapid influx of both sodium and calcium into the cell via the voltage-gated channels following EMF exposure. Sodium influx, particularly in electrically active cells, act in the normal physiology to depolarize the plasma membrane, leading to VGCC activation such that the voltage-gated sodium channels may act primarily via indirect activation of the VGCCs. In summary then, we have evidence that in animal including human cells, seven distinct classes of voltage-gated ion channels are each activated by EMF exposures: From the Pall (2013) review, four classes of voltage-gated ion channels were shown from calcium channel blocker studies, to be activated by EMFs, L-type, T-type, N-type and P/Q-type VGCCs. In this paragraph we have evidence that three other channels are also activated, voltage-gated sodium channels, voltage-gated potassium channels and voltage-gated chloride channels. Furthermore the plant studies strongly suggest that the so called TPC channels, which contain a similar voltage sensor, are activated in plants allowing calcium influx into plants to produce similar EMF-induced responses (Pall, 2016a). One can put those observations together with the powerful findings from the physics, that the electrical forces on the voltage-sensor are stunningly strong, something like 7.2 million times stronger than the forces on the singly charged groups in the aqueous phases of the cell. Now you have a stunningly powerful argument that the voltage sensor is the predominant direct target of the EMFs.

There is one additional finding that should be discussed here. In a study published by Pilla (2012), it was found that pulsed EMFs produced an "instantaneous" increase in calcium/calmodulin-dependent nitric oxide synthesis in cells in culture. What Pilla (2012) showed was that following EMF exposure, the cells in culture, must have produced a large increase in $[Ca^{2+}]_i$, this in turn produced a large increase in

nitric oxide synthesis, the nitric oxide diffused out of the cells and out of the aqueous medium above the cells into the gas phase, where the nitric oxide was detected by a nitric oxide electrode. This entire sequence occurred in less than 5 s. This eliminates almost any conceivable indirect effect, except possibly via plasma membrane depolarization. Therefore that the pulsed EMFs are acting directly on the voltage sensors of the VGCCs and possibly the voltage-gated sodium channels, to produce the $[Ca^{2+}]_i$ increase.

Why is it that the VGCCs, acting via calcium influx, seem to be much more important in producing EMF effects than are the other voltage-gated ion channels? Probably for three reasons: 1. Ca^{2+} ions under resting conditions in cells have about a 10,000-fold concentration gradient driving them into the cell, and over a million-fold electrochemical gradient also driving them into the cell. Because of this, one can have huge calcium influxes upon channel activation. 2. $[Ca^{2+}]_i$ produces many important regulatory effects, such that over activation of those effects can have very large pathophysiological consequences. 3. Sustained elevation of $[Ca^{2+}]_i$ produces major cell damage.

6. How can the Wi-Fi effects be produced by EMF triggered VGCC activation?

Can the various effects produced by Wi-Fi and by other microwave frequency EMFs be produced by the downstream effects of VGCC activation? In order to determine that, one needs to consider the various downstream effects of VGCC activation, summarized in Fig. 1 and how these are likely to produce each of the effects of Wi-Fi and other microwave frequency EMFs. Let's consider Fig. 1.

As shown in the top left section of Fig. 1, microwave and lower frequency EMFs act via VGCC activation to produce increases in intracellular calcium $[Ca^{2+}]_i$. All of the downstream effects of VGCC activation considered in Fig. 1 are produced by elevated (often excessive) $[Ca^{2+}]_i$.

Just to the right of $[Ca^{2+}]_i$ in Fig. 1, you will see that elevated $[Ca^{2+}]_i$ produced increases in nitric oxide (NO) synthesis. This is because two of the three types of enzymes producing NO are calcium-dependent. There is an NO signaling pathway that goes through increased cGMP and increased protein kinase G activity. Protein kinase G can act by raising the activity of the transcriptional regulatory factor, Nrf2, to produce the therapeutic effects produced by EMF exposures (Pilla, 2013; Pall, 2014; Pall and Levine, 2015).

High levels of NO can bind to heme groups on cytochromes (uppermost section, Fig. 1) inhibiting cytochrome oxidase, the terminal oxidase in the mitochondria, inhibiting ATP synthesis. NO can also

inhibit cytochrome P450s involved in steroid hormone synthesis, lowering levels of estrogen, progesterone and testosterone (sex hormones).

The main pathophysiological effects of EMF exposures are produced via excessive calcium signaling (lower left) and the peroxynitrite pathway (lower right). Peroxynitrite levels are elevated because both NO and superoxide are elevated by increased $[Ca^{2+}]_i$ with NO and superoxide reacting with each other to form peroxynitrite. Peroxynitrite and its CO_2 adduct, can break down to produce reactive free radicals, hydroxyl radical, carbonate radical and NO_2 radical which produce oxidative stress. These various oxidants act to produce greatly elevated NF-kappaB activity, leading to inflammation. All of this biochemistry and physiology is well-accepted and widely known with a single exception: The role of protein kinase G in raising Nrf2 has only recently been reviewed (Pall and Levine, 2015).

The ways in which these mechanisms can produce each of the seven effects produced by Wi-Fi, as well as other microwave frequency EMFs, are described in Table 3.

It can be seen from Table 3, that there are plausible mechanisms by which each of those seven effects can be produced by VGCC activation via known pathways. Given the complexities of biology, the mechanisms described in Table 3 may, in some cases, be over simplified.

There is one other finding, not related to the Wi-Fi findings, that is included in Table 3. A question that was raised in review of the paper was whether the heat shock stress elevation found following EMF exposure in many studies, could be produced by VGCC activation. As you can see from Table 3, it can be.

7. Other proposed biophysical mechanisms

One question that can be asked is how the VGCC activation mechanism compares with other biophysical models of non-thermal EMF effects. Belyaev (2015) has discussed a number of what he describes as biophysical models which are, therefore considered here. These models are basically theoretical models of how the weak electrical forces of the EMFs can interact with biologically plausible structures to produce non-thermal effects.

The first of these Belyaev considers is Fröhlich's theory. This is where there are "coherent longitudinal vibrations of electrically polar structures." The mechanism of Fröhlich's theory will not be considered here (the reader is referred to Belyaev, 2015). The author considers this to be a plausible mechanism for possible production of some non-thermal EMF effects. However, there are no specific testable predictions made by the theory that suggest how it could be tested, given the fact that there may be multiple possible targets of the EMFs according to

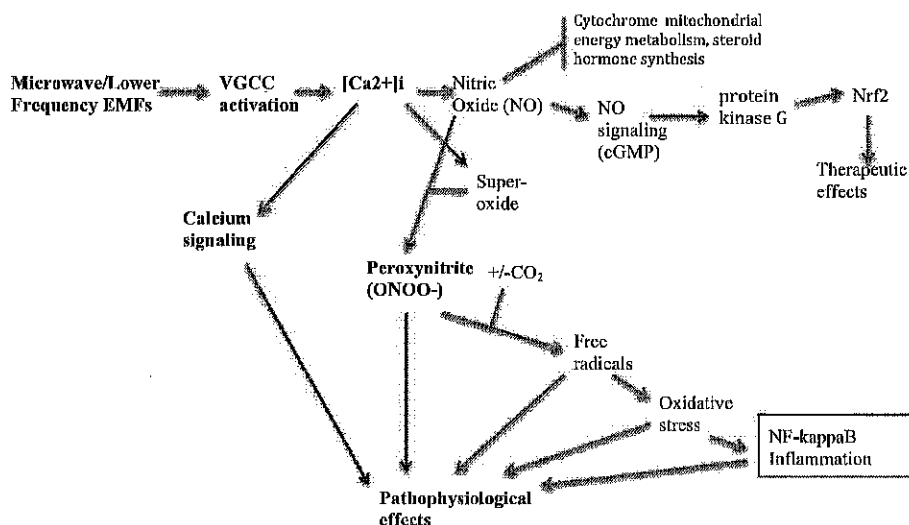


Fig. 1. Various pathways of action by which EMF VGCC activation can produce effects produced by EMF exposure (modified, with permission from Pall, 2015b).

Table 3
How Bight Established Effects of Wi-Fi and Other EMFs Can Be Produced by VGCC Activation.

EMF effect	Probable mechanism(s)
Oxidative stress	Produced by elevated levels of peroxynitrite and the free radical breakdown products of peroxynitrite and its CO ₂ adduct. Four studies of EMF exposure, cited in Pall (2013) showed that oxidative stress following exposure was associated with major elevation of 3-nitrotyrosine, a marker of peroxynitrite, thus confirming this interpretation. Two other studies each found 3-nitrotyrosine elevation, both following 35 GHz exposures (Sypniewska et al. (2010); Kalns et al., 2000).
Lowered male/female fertility, elevated spontaneous abortion, lowered libido	Both the lowered male fertility and lowered female fertility are associated with and presumably caused by the oxidative stress in the male and female reproductive organs. Spontaneous abortion is often caused by chromosomal mutations, so the germ line mutations may have a causal role. Lowered libido may be caused by lowered estrogen, progesterone and testosterone levels. It seems likely that these explanations may be greatly oversimplified. One mechanism that may be important in lowered fertility is that VGCC activation and consequent high [Ca ²⁺] _i levels is known to have a key role in avoiding polyspermy. Consequently, if this is triggered before any fertilization of an egg has occurred, it may prevent any sperm from fertilizing and egg.
Neurological/ neuropsychiatric effects	Of all cells in the body, the neurons have the highest densities of VGCCs, due in part to the VGCC role and [Ca ²⁺] _i role in the release of every neurotransmitter in the nervous system. Calcium signaling regulates synaptic structure and function in 5 different ways, each likely to be involved here. Oxidative stress and apoptosis are both thought to have important roles. Lowered sleep and increased fatigue are likely to involve lowered nocturnal melatonin and increased nocturnal norepinephrine.
Apoptosis	Apoptosis can be produced by excessive Ca ²⁺ levels in the mitochondria and by double strand breaks in cellular DNA; it seems likely that both are involved following EMF exposure. A third mechanism for triggering apoptosis, endoplasmic reticulum stress (see bottom row in this Table), may also be involved.
Cellular DNA damage	Cellular DNA damage is produced by the free radical breakdown products of peroxynitrite directly attacking the DNA [see Pall (2018) for discussion].
Changes in non-steroid hormone levels	The release of non-steroid hormones is produced by VGCC activation and [Ca ²⁺] _i elevation. The immediate effects of EMF exposures is to increase hormone release and to raise, therefore, hormone levels. However many hormone systems become "exhausted" as a consequence of chronic EMF exposures. The mechanism of exhaustion is still uncertain, but it may involve oxidative stress and inflammation.
Lowered steroid hormone	Steroid hormones are synthesized through the action of cytochrome P450 enzymes; activity of these hormones is inhibited by binding of high levels of nitric oxide (NO) leading to lowered hormone synthesis.
Calcium overload	Produced by excessive activity of the VGCCs; secondary calcium overload is produced by oxidative stress activation of TRPV1, TRPM2 and possibly some other TRP receptors, opening the calcium channel of these receptors.
Heat shock protein induction	There is a large literature showing that excessive [Ca ²⁺] _i induces very large increases in heat shock proteins. This is thought to be produced by complex calcium signaling changes involving the endoplasmic reticulum, mitochondria and the cytosol and also involving excessive [Ca ²⁺] _i producing increasing protein misfolding (Garbez, 2017; Park et al., 2014; Krebs et al., 2011). It should be noted that some calcium is essential for proper protein folding in the endoplasmic reticulum such that only excessive calcium leads to misfolding and consequent endoplasmic reticulum stress.

Fröhlich's theory.

A second possible mechanism involves the spin state of radical pairs. When radical pairs are generated from the breakdown of a non-radical molecule, these radical pairs often react back with each other to form another non-radical molecule, not necessarily identical to the original non-radical. What is postulated by this theory is that EMFs can interact with one or both radicals, changing their spin state and greatly lowering their ability to react back with each other, thus generating increased free radicals and therefore increased oxidative stress. The potential strong point of this theory is that it provides an explanation for the oxidative stress found following EMF exposure. However, as noted under oxidative stress in Table 3, there are 6 studies where oxidative stress following EMF exposure was associated with very high levels of 3-nitrotyrosine, a specific marker of peroxynitrite elevation. These studies argue, therefore, that oxidative stress following EMF exposure is produced by peroxynitrite elevation and is not primarily produced by this radical pair mechanism. It follows from this that the proposed radical pair mechanism cannot even explain the properties of oxidative stress production, let alone the various consequences of non-thermal EMF exposure that do not involve oxidative stress. Does that mean that the radical pair mechanism has no possible role in producing non-thermal EMF effects? No, but it does argue there is no evidence for any such role.

A third mechanism discussed in Belyaev (2015) is the electrosoliton theory proposed by Brizhik and colleagues, involving a "self reinforcing solitary wave packet." Brizhik and her colleagues discussed this in the context of reaching a threshold minimum energy state where both charged molecules and the EMF is in a coherent state, such that charge movement can ratchet from one state to another. This concept shows

substantial similarity to what is thought to occur in the activation of the voltage sensor, that is discussed above. There we have four alpha helices, each designated an S4 helix and with each S4 helix having 5 positive charges, with the 4 S4 helices together making up the voltage sensor. Most of those positive charges are 3 amino acid residues apart from each other, such that the closest charged residues stick out from the helix pretty much on the same side of the helix. Three of those positive charges are electrostatically attracted to negative residues on other helices thought to be in fixed positions. What is thought to happen in activation is that there a ratcheting of the S4 helices toward the extracellular space, ratcheting such that the negative charges are now bound to a positive charge 3 residues away from the one that was previously bound. The ratcheting also produces some turning of the S4 helix. This needs to occur several times on each of the four S4 helices to open the channel and allow calcium ions to flow. While I don't completely understand the Brizhik electrosoliton model, it may well be relevant to our understanding the VGCC activation, because the mechanism of the voltage sensor is similar to what Brizhik and her colleagues propose to occur in the electrosoliton model. Both the electrosoliton model and the voltage sensor activation mechanism involve both charge movements and ratcheting. In order to test these biophysical models one needs to have a specific mechanism where it may apply and where such tests can be done. In the case of the voltage sensor of the VGCCs, these tests have already been done.

These models are basically theoretical models of how the weak electrical forces of the EMFs can interact with biologically plausible structures to produce non-thermal effects. Their theoretical support is their strong point. They are weak, however, in providing any compelling evidence that they have causal roles in producing non-thermal

changes in cells in culture or in whole animal (or human) studies. They are also weak because they do not provide stated explanations for the range of EMF effects that have been documented.

Belyaev (2015) discusses microwave hearing in this context. He discusses the findings showing that people can hear microwave fields that are pulsed, including pulsed low intensity EMFs. While there is no doubt that these are very interesting observations on what are clearly non-thermal effects, they do not provide a biophysical model explaining how microwave hearing may occur. It is important, therefore to ask whether such microwave hearing could be caused by VGCC activation. It has been shown that hearing involves the activation of the VGCCs (Joiner and Lee, 2015). Furthermore, various otolaryngological conditions, including tinnitus, involve excessive VGCC activity, such that the calcium channel blocker, nimodipine is useful in their treatment (Monzani et al., 2015). These findings tell us that microwave hearing may be produced by VGCC activation. Consequently, microwave hearing may be interpreted as providing further support for the VGCC mechanism.

Following microwave hearing, Dr. Belyaev (2015) discusses plasma membrane and ion models. Here the VGCC mechanisms fit into the scheme, as do the other voltage-gated ion channels and the plant TPC channels, all discussed above as being activated by their voltage sensor following EMF exposures.

Finally, Dr. Belyaev (2015) discusses possible direct effects of EMFs on DNA, possibly leading to changes in chromatin structure and/or nuclear structure. There is a literature showing that aqueous solutions of DNA absorb microwave EMFs much more efficiently than do identical solutions not containing DNA. This clearly shows that DNA has a high absorbance of the EMFs. Furthermore, there are studies showing such dissolved DNA, when it absorbs such EMFs, undergoes structural changes as measured by biophysical techniques. All of this suggests that DNA is a plausible potential target for the EMFs. The problem is what are the predicted effects of such changes in DNA structure in living cells and organisms? Dr. Belyaev spends almost a page and a half in his paper discussing various possible models of interactions of DNA or of chromatin with EMFs. But again, how do we test any of these in living cells to demonstrate a role of such DNA or chromatin changes in producing any specific or general biological effects? Given the extraordinary complexity of living cells and organisms, there are only two powerful ways of demonstrating causal roles in such living cells and organisms. These are to use genetics or to use specific pharmacological agents. The extraordinary power of each of these approaches comes from the fact that these approaches allow researchers to vary one variable at a time out of the thousands of interacting variables in a living cell, allowing us to ask does that specific variable have a causal role in determining a specific response. But these two approaches can be used when specific proteins have specific roles, not when you are looking at the role of DNA structural changes, Fröhlich's theory, radical pair mechanisms or electrosoliton models. Fortunately the VGCC mechanism does allow this approach by studying various classes of calcium channel blockers, so here we do have hard data on widespread causal roles of VGCC activation in producing EMF effects.

8. Two other models for producing non-thermal effects

With the possible exception of the electrosoliton model, the author does not find any of the models discussed by Dr. Belyaev (2015) to have substantial evidence for roles in producing EMF effects. There are two other models which may be more compelling, each of which either produces increased $[Ca^{2+}]_i$.

Six studies have supported the view that calcium cyclotron resonance, has a role in producing biological effects produced by *certain specific frequencies* which can interact with Ca^{2+} ions to produce a cyclotron-like resonance (Foletti et al., 2010; Gaetani et al., 2009; De Carlo et al., 2012; Lisi et al., 2008; Pazur and Rassadina, 2009; Pazur et al., 2006). In each case, the effects involved a very specific frequency

which produces the calcium cyclotron resonance and in three studies, these frequencies were shown to produce increases in $[Ca^{2+}]_i$ levels. In the De Carlo et al. (2012) study, the calcium channel blocker nifedipine was shown to greatly lower the apparent calcium cyclotron resonance effect. This finding strongly suggests that the calcium cyclotron resonance can feed Ca^{2+} ions into the VGCCs, thus increasing the flow of Ca^{2+} ions through the VGCCs into the cell following EMF exposure. The frequencies studied here for cyclotron resonance, one was close to 7 Hz and the other was close to 50 Hz, are both in the extremely low frequency range and consequently are not relevant to microwave frequency effects. The finding that only very specific calcium cyclotron resonance frequencies produce these effects is the main evidence for this mechanism.

It is now well established that there is a magnetoreception mechanism found in many animals that can detect and respond to the very low intensity geomagnetic field. This has been most studied in bees and in birds, both of whom use it for navigation. This has been suggested to involve tiny particles of magnetite which occur in bacterial, animal and plant cells, including human cells. Kirschvink (1992) first proposed a model of how such a mechanism might act. He proposed that magnetite particles may be tethered through a microtubule and/or microfilament or perhaps other fibers to a mechanosensitive channel, such that tiny magnetic forces could open the mechanosensitive channels, allowing cation flow into the cells. It is still uncertain what mechanosensitive channel or channels might be involved, but most of the candidates are channels that allow both sodium and calcium to flow into cells. Hsu et al. (2007) suggested that such magnetite particles were linked in honeybees to an undefined calcium channel, such that magnetic field exposure produces increases in $[Ca^{2+}]_i$. The worm *Caenorhabditis elegans* had been shown to have a geomagnetic orientation system. Vidal-Gadea et al. (2015) found that certain specific neurons in *C. elegans* which may be geomagnetic sensory neurons, very low intensity geomagnetic fields could produce increases in $[Ca^{2+}]_i$ in those specific neurons, even when they had no synaptic inputs, suggesting that these neurons themselves acted as geomagnetic sensors.

Cadiou and McNaughton (2010) reviewed the literature on a magnetite-based magnetoreception system in birds and its role in avian migration. They also reviewed findings on neurons found in the trigeminal nerve of birds, where magnetic fields as low as 200 nT can activate specific neurons. Trains of action potentials are produced by magnetic fields, plateauing in the region of 20–100 mT. Latency in a study presented by Cadiou and McNaughton (2010) was about 4 s, but other studies have reported latencies of about 2.5 s. Therefore these are rapid effects. Cadiou and McNaughton (2010) also discuss possible roles mechanosensitive channels, including a model similar to that proposed by Kirschvink (1992) and also three other models, each involving different ways of coupling forces on magnetite to opening of a channel. Magnetoreception has also been reported to occur in a mammal, the mole-rat (Wegner et al., 2006). There are also studies of magnetic compass orientation in salmonids, newts, sea turtles and other rodents. There is evidence in *Drosophila*, that a magnetic structure attached to cryptochrome is involved in magnetoreception, as opposed to magnetite.

The two mechanisms described in this section have minor roles, only acting, as far as we can tell, in very specific situations. The calcium cyclotron resonance mechanism only acts with a few specific frequencies in the extremely low frequency range. The magnetoreception mechanism only acts, as far as one can tell, on detecting the weak geomagnetic fields and only acts, as far as one can tell, in certain specific neurons. It is possible that this view may change with regard to the magnetoreception mechanism but what is clear is that the VGCC mechanism is vastly more important than either of these mechanisms, acting in diverse cell types and acting to provide responses to a very wide frequency range and even to static electrical fields and static magnetic fields. Because static magnetic fields only place forces on moving electric charges, this produced a puzzle on how they can

activate the VGCCs. Pall (2013) suggested that the solution to that puzzle is that the plasma membrane of animal cells is often moving, such that the charges in the voltage sensor are also moving and can, therefore, have forces placed on them by the static magnetic fields. These static magnetic fields, activating the VGCCs can be relative low intensity but probably must be much higher intensity than the extraordinarily weak geomagnetic fields. The reader is referred to Lu et al. (2015) for empirical information from an important static magnetic field study, where those static magnetic fields activate both VGCCs and voltage-gated sodium channels.

9. Foster and Moulder on Wi-Fi

The Foster and Moulder (2013) paper argues that there are no and cannot be any health effects of Wi-Fi. The first 7½ pages of the paper are, however, largely irrelevant to that issue. These pages discuss such issues as predicted peak power output, incident power density and the FCC and international safety guidelines. They also discuss specific absorption rate (SAR) values, a measure of heating. Because it is now established, as discussed above that thermal effects are not the relevant mechanism of non-thermal effects and that VGCC activation is the main mechanism of such effects, this whole section is irrelevant. Foster and Moulder (2013) discuss the issue of biological effects, praising 7 studies listed in table 4 of their paper as having “well-characterized exposure systems” of well defined SARS values, reporting that there were no effects in the rats or mice in those 7 studies. Those 7 studies are Laudisi et al. (2012), Sambucci et al. (2010), Ait-Aïssa et al. (2010, 2012, 2013) and Poullétiér de Gannes et al. (2012, 2013). The first two studies come from one research group and the other five from another, albeit with some shared personnel.

Six or those seven studies (Sambucci et al., 2010; Ait-Aïssa et al., 2010, 2012, 2013; Poullétiér de Gannes et al., 2012, 2013) used an exposure system described by Wu et al. (2009) that is important here and that was claimed to produce a near uniform exposure. Laudisi et al. (2012) used a somewhat similar exposure system of Ardoïno et al. (2005), albeit another one that is also claimed to produce near uniform exposures. The important features here of the Wu et al. (2009) exposure system need to be examined in the light of the fact that, as discussed above, artificial EMFs are polarized with the polarization producing much larger biological effects than natural non-polarized EMFs (Belyaev, 2005, 2015; Panagopoulos et al., 2015a). The probable important feature of these polarized EMFs is that they put much larger forces on electrically charged groups (Panagopoulos et al., 2015a); since such forces are central to VGCC activation via the voltage sensor, as discussed above, they are likely to be central to the production of most biological effects. Let's examine Wu et al. (2009) with that issue in mind. It uses a large chamber surrounded by 1 mm aluminum mesh wire mesh to provide reflections of the EMFs. The chamber in which animals are exposed on a platform at its center, is also surrounded by antennae in all 6 directions (up, down, all four horizontal directions) such that each antenna is broadcasting with one polarization is opposed (at 180°) by another broadcasting with the 180° opposite polarization, as well as by four other antennae, broadcasting with 90° different polarization in each of the four possible directions. This produces a field that is more like a non-polarized EMF rather than the usual polarized artificial EMF. This move toward non-polarization is further exacerbated by the aluminum wire reverberation system whose reflections will generate vast numbers of reflections of different polarity, like a non-polarized EMF. The consequences of this is that the structure of this exposure system is clearly very different from that seen in Wi-Fi or any other artificially produced EMF that we may be exposed to, with biological effects produced via electrical forces being vastly less. Consequently this exposure system is not only inherently different from genuine Wi-Fi, it is predicted to be inherently less active than genuine Wi-Fi, regardless of what EMFs are being fed into the 6 antennae.

There is a second type of consequence of using such reverberation

exposure systems. Because of the many reverberations occurring, the path lengths of different photons reaching a specific point in the exposed tissue, will often be quite different from each other, such that the phase of the EMFs produced will also be quite different from each other. This leads to the possibility of destructive interference and thus a second mechanism which is predicted to lead to substantial decreases in the intensity of the exposures. Because exposures are usually predicted by groups using such exposure chambers without considering such destructive interference, rather than being measured, the actual exposures may be substantially lower than are the predicted exposures. Both the polarization effect and the possible difference between predicted exposure and actual exposure were considered in an earlier study.

Vian et al. (2006), using a different reverberation exposure chamber, discussed in Fig. 1 of that paper, how the various reverberations lead to the initial polarized EMF being converted to a non-polarized or at least, less polarized EMF. They also on p. 69 of that paper compared the predicted with the measured amplitude and found that the measured amplitude was only 78% of the predicted amplitude. These findings suggest that both of the lowered polarization and destructive interference discussed in the previous two paragraphs can have substantial roles in lowering biological responses produced when using such reverberation exposure chambers.

Laudisi et al. (2012) used a different exposure system, that of Ardoïno et al. (2005) where the vast majority of the exposure is produced from reflections off a long cylindrical surface in a TEM cell, where the curvature of the cylinder will also produce a largely non-polarized EMF and different reverberation paths and consequent destructive interference, may both be expected to occur. Consequently the predicted low biological activity of EMFs produced by the Wu et al. (2009) system may be expected to also occur from this TEM exposure system Ardoïno et al. (2005). It is not possible to study biological effects of EMFs from Wi-Fi, cell phones or any other important exposures using such exposure systems because of the polarization changes they produce from the original polarized EMFs and because of destructive interference.

Let's now shift to the issue of the important role of pulsations in producing biological effects and ask whether the EMFs fed into the antennae have pulsation patterns similar or different from genuine Wi-Fi. Poullétiér de Gannes et al. (2012) used a non-pulsed (continuous wave) as did Wu et al. (2009), an EMF which will have, therefore, much lower biological effects than genuine Wi-Fi with its myriad of pulsations (Maret, 2015). The other 6 studies (Laudisi et al., 2012; Sambucci et al., 2010; Ait-Aïssa et al., 2010, 2012, 2013; Poullétiér de Gannes et al., 2013) used computers with Wi-Fi cards. Such Wi-Fi cards are designed to communicate with genuine Wi-Fi antennae, but are used here to communicate with each other, using two such computers to generate “Wi-Fi”. How the EMFs so generated compare with the pulsations of genuine Wi-Fi is a complete mystery and none of these papers provide any information to allow the reader to make such a comparison. It follows that these studies (Laudisi et al., 2012; Sambucci et al., 2010; Ait-Aïssa et al., 2010, 2012, 2013; Poullétiér de Gannes et al., 2013) are not studying genuine Wi-Fi, even before the effects of the reverberation chamber and the reader is left with no evidence to compare these original EMFs with genuine Wi-Fi. In summary, then none of the EMFs used in these studies are genuine Wi-Fi, with them differing from genuine Wi-Fi in three different ways: the antenna locations produce a substantial difference from genuine Wi-Fi regarding EMF polarization and this is further exacerbated by the effects of the aluminum mesh reverberation producing further lowering of any polarization; differences in path lengths of different photons produce substantial destructive interference; the initial EMF fed into the antennae differs substantially from genuine Wi-Fi, with the main concern here being due to the issue of pulsation patterns and biological effects.

Let's shift now to the claim made by Foster and Moulder (2013) that there were no effects found in any of these 7 studies. Rothman et al.,

Modern Epidemiology, 3rd Edition is a highly respected source of information, cited over 18,500 times according to the Google Scholar database. It states (p. 151, bottom) that: "A common misinterpretation of significance tests is that there no difference between two observed groups because the null test is not statistically significant, in that P is greater than the cutoff for declaring statistical significance (again, usually .05). This interpretation confuses a descriptive issue (whether two observed groups differ) with an inference about the superpopulation. The significance test refers only to the superpopulation, not the observed groups. To say that the difference is not statistically significant means only that one cannot reject the null hypothesis that the superpopulation groups are the same; it does not imply that the two groups are the same." It follows that the claim of "no effect" that Foster and Moulder (2013) make about each of these 7 studies in Table 4 of their paper is false because one can never legitimately make such a claim; one can at most claim that there were no statistically significant differences.

However there are other reasons to reject those claims that need to be considered for each of these 7 studies. Each of these 7 studies fails to provide raw numerical data, the lack of which is problematic, given the other flaws that follow. 1). Laudisi et al. (2012) finds in Table 2, that two T cell populations are statistically significantly different in prenatally exposed mice vs sham controls: DP and CD4SP cells are significantly affected by exposure in mice at 26 weeks after birth; CD4SP cells are affected in female mice at 5 weeks after birth ($P < .02$ in each case). Furthermore in each of the measurements in Laudisi et al. (2012), only 11 or 12 mice were studied, tiny numbers. It follows that claims in Foster and Moulder (2013) that there were no effects are false or misleading for 3 distinct reasons: You can never make such claims even in large studies; there were 3 comparisons each of which showed statistically significant effects; this study was done with tiny numbers of animals being compared and thus had extremely low statistical power. 2). Sambucci et al. (2010) also had a tiny numbers, with 11 or 12 per group studied in Table 2, from 6 to 35 studied in Table 3 and 6 to 12 studied in Table 4. The claims of no statistically significant effects in Figs. 2, 3, 4 and 5 are based on the tiny numbers in Table 3, are therefore, based on studies with very low statistical power. 3). The first part of the Ait-Aïssa et al. (2010) paper focused on GFAP values, a measure of gliosis, which is a risk factor for glioma formation. The groups studied in Fig. 4 of Ait-Aïssa et al. (2010) range from 3 to 10, so again we have tiny numbers and the authors report that none of the exposures, SAR = .08, = .4. or = 4 W/Kg produced statistically significant changes according to their statistical calculations. As in the other studies, no raw data are provided but Fig. 4 provides bar graph information which includes median values for each of the 10 different regions of the brain in these rats, control rats and also rats exposed either pre-natally or both pre-natally and post-natally. For 5 of those brain regions, M4, CA1, CA2, CA3 and DG, the median values are high enough that one can see which are higher and which are lower from the graph. It appears to this author that the median values go up from the sham exposures to the lowest intensity (= .08), that they drop going to the next intensity (= .4) and that they go up going to the highest intensity studies (= 4). You may recall (see above) that there are certain windows of exposure that give the highest biological response but with both lower and higher intensities giving lower responses. It follows that the complex apparent dose-response curve of Ait-Aïssa et al. (2010), can be explained by these window effects. The question is whether any such apparent changes are statistically significant? I did, therefore a Chi-square analysis of these data, to determine statistical significance, using both the only prenatal and both prenatal and postnatal exposures (see Fig. 4 in Ait-Aïssa et al., 2010). Those data show that in 10 out of 10 cases, the median value increased going from sham to .08 ($P < .002$). Similarly, in 10 out of 10 cases, the median value drops going from .08 to .4 ($P < .002$). However in 8 out of 10 cases, the median value increases going from .4 to 4 ($P < .07$), falling just short of statistical significance. The median values increased with exposure,

comparing the sham values with the values at 4 ($P < .02$). It follows from this, that three of the comparisons show statistically significant changes, and the fourth falls just short of statistical significance. Does this mean that that we should conclude that Wi-Fi can cause gliosis and thus possibly gliomas? No, but only because they did not study Wi-Fi. It should be noted, however that the long-term effects on the brain from pre-natal exposures may be relevant to autism causation.

4). Pouilletier de Gannes et al. (2012) also suffered from tiny numbers in their study, with 12 to 15 rats studied in each group in Fig. 1, only 5 females in each group in Table 1, 12 to 15 rats in each group in both Table 2 and Table 3. 5). Ait-Aïssa et al. (2012) also suffers from tiny numbers of rats in the various studies. It used from 9 to 12 pregnant female rats in each group to attempt to assess EMFs impact of reproduction; it used 9 to 12 juvenile rats to determine if EMFs act to change antibody production; it used 9 to 12 young rats to determine whether EMFs impact growth over time. These tiny numbers mean that failure to find statistical significant changes has very low power to support any inferences. 6). Ait-Aïssa et al. (2013) had similar problems with tiny numbers, 6 to 12 in Fig. 5, 5 to 11 in Fig. 8 and 6 to 12 in Fig. 9. 7). Pouilletier de Gannes et al. (2013) also suffers from tiny numbers. Fig. 1 groups each had 12 males or females and there were also groups of 12 studied in Table 1, Fig. 2 and Table 2. Regarding, the authors give no information regarding statistical significance or lack thereof; rather they only state that the values of these groups were "similar", without providing a definition of "similar". However in comparing the values of testis weight and epididymis weight at 4 W/Kg exposure vs sham control, they provided values for the mean and standard error of the mean (SEM). It is usually the case that when the mean values differ by more than 2.4 times the SEM, the difference is statistically significant. Here the testis weight, comparing sham with 4 W/Kg, values differed by 3.18 times the SEM and the epididymis weight differed by 3.40 times the SEM, each arguing strongly for statistical significance. This raises the question of why the authors failed to provide their P values?

An additional flaw of these 7 supposed Wi-Fi studies is that they each studied exposures of 2 h per day, 5 days per week except for one that only studied one hour per week, 5 days per day. Given that many people are exposed to Wi-Fi fields for 5, 6, 8 or more hours per day, this is another factor which argues that these studies may have been set up to minimize any effects seen.

To sum up the other flaws:

1. The 6 antennae of the reverberation chamber used in 6 out of 7 studies, minimized probable effects produced through the arrangement of the antennae in such a way as to greatly lower the polarization of the EMFs.
2. The use of 1 mm aluminum wires to produce the reverberation reflections, further decreases such polarization, again lowering probable effects. These structures are clearly very different from those found in genuine Wi-Fi, emphasizing the point that these are not genuine Wi-Fi studies, because of 1 and 2 here.
3. Differences in path lengths for different photons, produced by reverberation produce substantial destructive interference.
4. Furthermore the EMFs fed into the antennae are not genuine Wi-Fi either. It follows from this that claims that these are studies of genuine Wi-Fi made by both the authors of these individual studies and by Foster and Moulder (2013) are false.
5. The claims made by Foster and Moulder (2013) that there are no effects produced are also false; the most that may be legitimately concluded is that there is no statistically significant evidence of effects.
6. Each of the 7 studies used only tiny numbers of animals in each group studied, such that lack of statistical significance, because of the low power of these studies, drastically limits the drawing of inferences.
7. Finally, 3 out of 7 had evidence of statistically significant effects,

with each of these being ignored by Foster and Moulder.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial or not-for-profit sectors.

References

- Adams, J.A., Galloway, T.S., Mondal, D., Esteves, S.C., 2014. Effect of mobile telephones on sperm quality: a systematic review and meta-analysis. *Environ. Int.* 70, 106–112. <http://dx.doi.org/10.1016/j.envint.2014.04.015>.
- Adey, W.R., 1981. Tissue interactions with nonionizing electromagnetic fields. *Physiol. Rev.* 61, 435–514.
- Adey, W.R., 1988. Cell membranes: the electromagnetic environment and cancer promotion. *Neurochem. Res.* 13, 671–677.
- Ait-Aïssa, S., Billaudel, B., Poulletier De Gannes, F., Hurtier, A., Haro, E., Taxile, M., Ruffie, G., Athané, A., Veyret, B., Lagroye, I., 2010. In situ detection of gliosis and apoptosis in the brains of young rats exposed in utero to a Wi-Fi signal. *C. R. Phys.* 11, 592–601. <http://dx.doi.org/10.1016/j.crhy.2010.10.005>.
- Ait-Aïssa, S., Billaudel, B., Poulletier de Gannes, F., Ruffié, G., Dulen, S., Hurtier, A., Haro, E., Taxile, M., Athané, A., Geffard, M., Wu, T., Wiart, J., Bodet, D., Veyret, B., Lagroye, I., 2012. In utero and early-life exposure of rats to a Wi-Fi signal: screening of immune markers in sera and gestational outcome. *Bioelectromagnetics* 33, 410–420. <http://dx.doi.org/10.1002/bem.21699>.
- Ait-Aïssa, S., de Gannes, F.P., Taxile, M., Billaudel, B., Hurtier, A., Haro, E., Ruffié, G., Athané, A., Veyret, B., Lagroye, I., 2013. In situ expression of heat-shock proteins and 3-nitrotyrosine in brains of young rats exposed to a WiFi signal in utero and in early life. *Radiat. Res.* 179, 707–716. <http://dx.doi.org/10.1667/RR2995.1>.
- Aitken, R.J., De Iulius, G.N., 2007. Origins and consequences of DNA damage in male germ cells. *Reprod. Biomed. Online* 14, 727–733.
- Akdag, M.Z., Dasdag, S., Canturk, P., Karabulut, D., Caner, Y., Adalier, N., 2016. Does prolonged radiofrequency radiation emitted from Wi-Fi devices induce DNA damage in various tissues of rats? *J. Chem. Neuroanat.* 75 (Pt B), 116–122. <http://dx.doi.org/10.1016/j.jchemneu.2016.01.003>.
- Arduino, L., Lopresto, V., Mancini, S., Marino, C., Pinto, R., Lovisolò, G.A., 2005. A radio-frequency system for in vivo pilot experiments aimed at the studies on biological effects of electromagnetic fields. *Phys. Med. Biol.* 50, 3643–3654.
- Asghari, A., Khaki, A.A., Rajabzadeh, A., Khaki, A., 2016. A review on electromagnetic fields (EMFs) and the reproductive system. *Electron. Physician* 8, 2655–2662. <http://dx.doi.org/10.19082/2655>.
- Atasoy, H., Gunal, M.Y., Atasoy, P., Elgund, S., Bugdayci, G., 2013. Immunopathologic demonstration of deleterious effects on growing rat testes of radiofrequency waves emitted from conventional Wi-Fi devices. *J. Pediatr. Urol.* 9, 223–229. <http://dx.doi.org/10.1016/j.jpuro.2012.02.015>.
- Avendaño, C., Mata, A., Sanchez Sarmiento, C.A., Doncel, G.F., 2012. Use of laptop computers connected to the internet through Wi-Fi decreases human sperm motility and increases sperm DNA fragmentation. *Fertil. Steril.* 97, 39–45. <http://dx.doi.org/10.1016/j.fertnstert.2011.10.012>.
- Aynali, G., Naziroglu, M., Celik, O., Dogan, M., Yariktas, M., Yasun, H., 2013. Modulation of wireless (2.45 GHz)-induced oxidative toxicity in laryngotracheal mucosa of rat by melatonin. *Eur. Arch. Otorhinolaryngol.* 270, 1695–1700. <http://dx.doi.org/10.1007/s00405-013-2425-0>.
- Batišta Napotnik, T., Reberšek, M., Vernier, P.T., Mali, B., Miklavčič, D., 2010. Effects of high voltage nanosecond electric pulses on eukaryotic cells (in vitro): a systematic review. *Bioelectrochemistry* 110, 1–12. <http://dx.doi.org/10.1016/j.bioelechem.2016.02.011>.
- Belyaev, I., 2005. Non-thermal biological effects of microwaves. *Microw. Rev.* 11, 13–29.
- Belyaev, I., 2015. Biophysical mechanisms for nonthermal microwave effects. In: Markov, M.S. (Ed.), *Electromagnetic Fields in Biology and Medicine*. CRC Press, New York, pp. 49–67.
- Belyaev, I.Y., Marková, E., Hillert, L., Malmgren, L.O., Persson, B.R., 2009. Microwaves from UMTS/GSM mobile phones induce long-lasting inhibition of 53BP1/gamma-H2AX DNA repair foci in human lymphocytes. *Bioelectromagnetics* 30, 129–141. <http://dx.doi.org/10.1002/bem.20445>.
- Belyaev, I., Dean, A., Eger, H., Hubmann, G., Jandrisovits, R., Kern, M., Kundi, M., Moshhammer, H., Lercher, P., Müller, K., Oberfeld, G., Olmsorge, P., Pelzmann, P., Scheingraber, C., Thill, R., 2016. EUROPAEM EMF Guideline 2016 for the prevention, diagnosis and treatment of EMF-related health problems and illnesses. *Rev. Environ. Health.* <http://dx.doi.org/10.1515/revheh-2016-0011>.
- Berezow, A., Bloom, A., 2017. Recommendation to limit Md. School Wi-Fi based on 'junk science'. Baltimore Sun op-ed piece, March 12. <http://www.baltimoresun.com/news/opinion/oped/bs-ed-wifi-school-20170312-story.html> (accessed 10 October 2017).
- Bhargava, H., Srinivasan, T.M., Varambally, S., Gangadhar, B.N., Koka, P., 2015. Effect of mobile phone-induced electromagnetic field on brain hemodynamics and human stem cell functioning: Possible mechanistic link to cancer risk and early diagnostic value of electrophotonic imaging. *J. Stem Cells* 10, 287–294 (doi: jsc.2015.10.4.287).
- Cadiou, H., McNaughton, P.A., 2010. Avian magnetite-based magnetoreception: a physiologist's perspective. *J. R. Soc. Interface* 7, S193–S205. <http://dx.doi.org/10.1098/rsif.2009.0423.focus>.
- Carpenter, D.O., 2013. Human disease resulting from exposure to electromagnetic fields. *Rev. Environ. Health* 28, 159–172. <http://dx.doi.org/10.1515/revheh-2013-0016>.
- Çiftçi, Z.Z., Kirzioğlu, Z., Naziroğlu, M., Özmen, Ö., 2015. Effects of prenatal and post-natal exposure of Wi-Fi on development of teeth and changes in teeth element concentration in rats. [corrected]. *Biol. Trace Elem. Res.* 163, 193–201. <http://dx.doi.org/10.1007/s12011-014-0175-5>.
- Çiğ, B., Naziroğlu, M., 2015. Investigation of the effects of distance from sources on apoptosis, oxidative stress and cytosolic calcium accumulation via TRPV1 channels induced by mobile phones and Wi-Fi in breast cancer cells. *Biochim. Biophys. Acta* 1848 (10 Pt B), 2756–2765. <http://dx.doi.org/10.1016/j.bbamen.2015.02.013>.
- Consales, C., Merla, C., Marino, C., Benassi, B., 2012. Electromagnetic fields, oxidative stress, and neurodegeneration. *Int. J. Cell Biol.* 2012, 683897. <http://dx.doi.org/10.1155/2012/683897>.
- Creighton, M.O., Larsen, L.E., Stewart-DeHaan, P.J., Jacobi, J.H., Sanwal, M., Baskerville, J.C., Bassin, H.E., Brown, D.O., Trevithick, J.R., 1987. In vitro studies of microwave-induced cataract. II. Comparison of damage observed for continuous wave and pulsed microwaves. *Exp. Eye Res.* 45, 357–373.
- Czyz, J., Guan, K., Zeng, Q., Nikolova, T., Meister, A., Schönborn, F., Schuderer, J., Kuster, N., Wobus, A.M., 2004. High frequency electromagnetic fields (GSM signals) affect gene expression levels in tumor suppressor p53-deficient embryonic stem cells. *Bioelectromagnetics* 25, 296–307. <http://dx.doi.org/10.1002/bem.10199>.
- Dasdag, S., Tas, M., Akdag, M.Z., Yegin, K., 2015. Effect of long-term exposure of 2.4 GHz radiofrequency radiation emitted from Wi-Fi equipment on testes functions. *Electromagn. Biol. Med.* 34, 37–42. <http://dx.doi.org/10.3109/15368378.2013.869752>.
- Dasdag, S., Akdag, M.Z., 2016. The link between radiofrequencies emitted from wireless technologies and oxidative stress. *J. Chem. Neuroanat.* 75 (Pt B), 85–93. <http://dx.doi.org/10.1016/j.jchemneu.2015.09.001>.
- De Carlo, F., Ledda, M., Pozzi, D., Piermarchi, P., Zonfrillo, M., Giulliani, L., D'Emilia, E., Foletti, A., Scorretti, R., Grimaldi, S., Lisi, A., 2012. Nonionizing radiation as a noninvasive strategy in regenerative medicine: the effect of Ca(2+) -ICR on mouse skeletal muscle cell growth and differentiation. *Tissue Eng. Part A* 18 (21–22), 2248–2258. <http://dx.doi.org/10.1089/ten.TKA.2012.0113>. Epub 2012 Jul 23.
- Desai, N.R., Kesari, K.K., Agarwal, A., 2009. Pathophysiology of cell phone radiation: oxidative stress and carcinogenesis with focus on the male reproductive system. *Reprod. Biol. Endocrinol.* 7, 114. <http://dx.doi.org/10.1186/1477-7875-7-114>.
- Foletti, A., Ledda, M., De Carlo, F., Grimaldi, S., Lisi, A., 2010. Calcium ion cyclotron resonance (ICR), 7.0 Hz, 9.2 microT magnetic field exposure initiates differentiation of pituitary corticotrope-derived ATT20 D16V cells. *Electromagn. Biol. Med.* 29 (3), 63–71. <http://dx.doi.org/10.3109/15368378.2010.482480>.
- Foster, K.R., Moulder, J.E., 2013. Wi-Fi and health: review of current status of research. *Health Phys.* 105, 561–565. <http://dx.doi.org/10.1097/HP.0b013e31829b49bb>.
- Gaetani, R., Ledda, M., Barile, L., Chimenti, I., De Carlo, F., Forte, E., Ionta, V., Giulliani, L., D'Emilia, E., Frati, G., Miraldi, F., Pozzi, D., Messina, E., Grimaldi, S., Giacomello, A., Lisi, A., 2009. Differentiation of human adult cardiac stem cells exposed to extremely low-frequency electromagnetic fields. *Cardiovasc. Res.* 82 (3), 411–420. <http://dx.doi.org/10.1093/cvr/cvp067>. Epub 2009 Feb 19.
- Gandhi, O.P., Kang, G., 2001. Calculation of induced current densities for humans by magnetic fields from electronic article surveillance devices. *Phys. Med. Biol.* 46, 2759–2771.
- Gandhi, O.P., Morgan, L.L., de Salles, A.A., Han, Y.Y., Herberman, R.B., Davis, D.L., 2012. Exposure Limits: the underestimation of absorbed cell phone radiation, especially in children. *Electromagn. Biol. Med.* 31, 34–51. <http://dx.doi.org/10.3109/15368378.2011.622827>.
- Garbez, D.G., 2017. Regulation of heat shock gene expression in response to stress. *Mol. Biol.* 51, 352–367. <http://dx.doi.org/10.1134/S0026893317020108>.
- Ghazizadeh, V., Naziroğlu, 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. *Metab. Brain Dis.* 29, 787–799. <http://dx.doi.org/10.1007/s10073-014-9549-9>.
- Glaser, Z.R., PhD., 1971. Naval Medical Research Institute Research Report, June 1971. Bibliography of Reported Biological Phenomena ("Effects") and Clinical Manifestations Attributed to Microwave and Radio-Frequency Radiation. Report No. 2 Revised. http://scholar.google.com/scholar?c=Glaser+naval+medical+microwave+radio-frequency+1972&btnG=&hl=en&as_sdt=0%2C38 (accessed 9 September 2017).
- Grigor'ev, Iu.G., 1996. Role of modulation in biological effects of electromagnetic radiation. *Radiat. Biol. Radioecol.* 36, 659–670.
- Gye, M.C., Park, C.J., 2012. Effect of electromagnetic field exposure on the reproductive system. *Clin. Exp. Reprod. Med.* 39, 1–9. <http://dx.doi.org/10.5653/cerm.2012.39.1.1>.
- Hardell, L., Sage, C., 2008. Biological effects from electromagnetic field exposure and public exposure standards. *Biomed. Pharmacother.* 62, 104–109. <http://dx.doi.org/10.1016/j.biopha.2007.12.004>.
- Hassanshahi, A., Shafeie, S.A., Fatemi, I., Hassanshahi, E., Allahtavakoli, M., Shabani, M., Roohbakhsh, A., Shamsizadeh, A., 2017. The effect of Wi-Fi electromagnetic waves in unimodal and multimodal object recognition tasks in male rats. *Neurol. Sci.* 38, 1069–1076. <http://dx.doi.org/10.1007/s10072-017-2920-y>.
- Hazout, A., Monezo, Y., Madelenat, P., Yazbeck, C., Selva, J., Cohen-Bacrie, P., 2008. Causes and clinical implications of sperm DNA damages. *Gynecol. Obstet. Fertil.* 36, 1109–1117. <http://dx.doi.org/10.1016/j.gyobfe.2008.07.017>.
- Houston, B.J., Nixon, B., King, B.V., De Iulius, G.N., Aitken, R.J., 2016. The effects of radiofrequency electromagnetic radiation on sperm function. *Reproduction* 152, R263–R276. <http://dx.doi.org/10.1530/REP-16-0126>.
- Hsu, C.Y., Ko, P.Y., Li, C.W., Fann, K., Lue, J.T., 2007. Magnetoreception system in honeybees (*Apis mellifera*). *PLoS One* 2 (4), e395. <http://dx.doi.org/10.1371/journal.pone.0000395>.

- Joiner, M.L., Lee, A., 2015. Voltage-gated Cav1 channels in disorders of vision and hearing. *Curr. Mol. Pharmacol.* 8, 143–148.
- Kalms, J., Ryan, K.L., Mason, P.A., Bruno, J.G., Gooden, R., Kiel, J.L., 2000. Oxidative stress precedes circulatory failure induced by 35-GHz microwave heating. *Shock* 13, 52–59.
- Kaplan, S., Deniz, C.G., Önger, M.E., Türkmen, A.P., Yurt, K.K., Aydın, I., Altunkaynak, B.Z., Davis, D., 2016. Electromagnetic field and brain development. *J. Chem. Neuroanat.* 75 (Pt B), 52–61. <http://dx.doi.org/10.1016/j.jchemneu.2015.11.005>.
- 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, 263–267. <http://dx.doi.org/10.1179/107735210799160192>.
- Kirschvink, J.L., 1992. Comment on "constraints on biological effects of weak extremely-low-frequency electromagnetic fields". *Phys. Rev. A* 46, 2178–2183.
- Krebs, J., Groenendyk, J., Michalek, M., 2011. Ca²⁺-signaling, alternative splicing and endoplasmic reticulum stress responses. *Neurochem. Res.* 36, 1198–1211. <http://dx.doi.org/10.1007/s11064-011-0431-4>.
- Lai, H., 1994. Neurological effects of radiofrequency electromagnetic radiation. In: Lin, J.C. (Ed.), *Advances in Electromagnetic Fields in Living Systems Vol. 1*. Plenum Press, New York, pp. 27–88.
- La Vignera, S., Condorelli, R.A., Vicari, E., D'Agata, R., Calogero, A.E., 2012. Effects of the exposure to mobile phones on male reproduction: a review of the literature. *J. Androl.* 33, 350–356. <http://dx.doi.org/10.2164/jandrol.111.014373>.
- Laudisi, F., Sambucci, M., Nasta, F., Pinto, R., Lodato, R., Altavista, P., Lovisolio, G.A., Marino, C., Pioli, C., 2012. Prenatal exposure to radiofrequencies: effects of WiFi signals on thymocyte development and peripheral T cell compartment in an animal model. *Bioelectromagnetics* 33, 652–661. <http://dx.doi.org/10.1002/bem.21733>.
- Lee, S.S., Kim, H.R., Kim, M.S., Park, S.H., Kim, D.W., 2014. Influence of smart phone Wi-Fi signals on adipose-derived stem cells. *J. Craniofac. Surg.* 25, 1902–1907. <http://dx.doi.org/10.1097/SCS.0000000000000939>.
- Levine, H., Jorgensen, N., Martino-Andrade, A., Mendiola, J., Weksler-Derri, D., Mindlis, I., Pinotti, R., Swan, S.H., 2017. Temporal trends in sperm count: a systematic review and meta-analysis. *Hum. Reprod. Update.* <http://dx.doi.org/10.1093/humupd/dmx022>.
- 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. <http://dx.doi.org/10.1139/A10-018>.
- Lisi, A., Ledda, M., De Carlo, F., Poletti, A., Giuliani, L., D'Emilia, E., Grimaldi, S., 2008. Calcium ion cyclotron resonance (ICR) transfers information to living systems: effects on human epithelial cell differentiation. *Electromagn. Biol. Med.* 27 (3), 230–240. <http://dx.doi.org/10.1080/15368370802269135>.
- Liu, K., Li, Y., Zhang, G., Liu, J., Cao, J., Ao, L., Zhang, S., 2014. Association between mobile phone use and semen quality: a systematic review and meta-analysis. *Andrology* 2, 491–501. <http://dx.doi.org/10.1111/j.2047-2927.2014.00205.x>.
- Liu, X.W., Du, L., Kou, L., Song, N., Zhang, Y.J., Wu, M.K., Shen, J.F., 2015. Effects of moderate static magnetic fields on the voltage-gated sodium and calcium channels currents in trigeminal ganglion neurons. *Electromagn. Biol. Med.* 34, 285–292. <http://dx.doi.org/10.3109/15368378.2014.906448>.
- Maganioti, A.E., Papageorgiou C.C., Hountala, C.D., Kiprianou, M.A., Rabavilas, A.D., Papademitriou, G.N., Capalis, C.N., 2010. Wi-Fi electromagnetic fields exert gender related alterations on EEG. 6th International Workshop on Biological Effects of Electromagnetic Fields. (https://www.researchgate.net/profile/Miltiades_Kyrianoou3/publication/267816859_WIFI_ELECTROMAGNETIC_FIELDS_EXERT_GENDER_RELATED ALTERATIONS_ON_EEG/links/550ab8670cf265693eed8e9c.pdf) (accessed 7 September 2017).
- Magras, I.N., Xenos, T.D., 1997. RF radiation-induced changes in the prenatal development of mice. *Bioelectromagnetics* 18, 455–461.
- Makker, K., Varghese, A., Desai, N.R., Mouradi, R., Agarwal, A., 2009. Cell phones: modern man's nemesis? *Reprod. Biomed. Online* 18, 148–157.
- Maret, K., 2015. Expert Forum on Cell Phone and Wireless Risks, June 22, 2015. (<https://vimeo.com/132039697>).
- Markov, M.S., 2007. Pulsed electromagnetic field therapy: history, state of the art and future. *Environmentalist* 27, 465–475.
- Marková, E., Malmgren, L.O., Belyaev, I.Y., 2010. Microwaves from mobile phones inhibit 53BP1 focus formation in human stem cells more strongly than in differentiated cells: possible mechanistic link to cancer risk. *Environ. Health Perspect.* 118, 394–399. <http://dx.doi.org/10.1289/ehp.0900781>.
- Monzani, D., Genovese, E., Pini, L.A., Di Berardino, F., Alicandri Clufelli, M., Galeazzi, G.M., Presutti, L., 2015. Nimodipine in otolaryngology: from past evidence to clinical perspectives. *Acta Otorhinolaryngol. Ital.* 35, 135–145.
- Naziroglu, M., Yüksel, M., Kösen, S.A., Özkaya, M.O., 2013. Recent reports of Wi-Fi and mobile phone-induced radiation on oxidative stress and reproductive signaling pathways in females and males. *J. Membr. Biol.* 246, 869–875. <http://dx.doi.org/10.1007/s00232-013-9597-9>.
- No authors listed, 2017. Scientists warn plunging sperm counts could lead to human extinction. *Geobase article.* (<https://www.aol.com/article/news/2017/07/26/scientists-sound-the-alarm-about-declining-sperm-counts/23049397/0>) (accessed 7 September 2017).
- Odaei, E., Bas, O., Kaplan, S., 2008. Effects of prenatal exposure to a 900 MHz electromagnetic field on the dentate gyrus of rats: a stereological and histopathological study. *Brain Res.* 1238, 224–229. <http://dx.doi.org/10.1016/j.brainres.2008.08.013>.
- Oni, O.M., Amuda, D.B., Gilbert, C.E., 2011. Effects of radiofrequency radiation from WiFi devices on human ejaculated sperm. *Int. J. Res. Rev. Appl. Sci.* 9 (Article 13).
- Ospov, Yu.A., 1965. Labor Hygiene and the Effect of Radiofrequency Electromagnetic Fields on Workers. Leningrad Meditsina Publishing House (220 pp.).
- Othman, H., Ammar, M., Rihl, K., Bensaid, N., Sakly, M., Abdelmelek, H., 2017a. Postnatal development and behavior effects of in-utero exposure of rats to radio-frequency waves emitted from conventional WiFi devices. *Environ. Toxicol. Pharmacol.* 52, 239–247. <http://dx.doi.org/10.1016/j.etep.2017.04.016>.
- Othman, H., Ammar, M., Sakly, M., Abdelmelek, H., 2017b. Effects of repeated restraint stress and WiFi signal exposure on behavior and oxidative stress in rats. *Metab. Brain Dis.* <http://dx.doi.org/10.1007/s11011-017-0016-2>.
- Özörak, A., Naziroglu, M., Çelik, Ö., Yüke, I.M., Özçelik, D., Özkaya, M.O., Çetin, H., Kahya, M.C., Kose, S.A., 2013. Wi-Fi (2.45 GHz)- and mobile phone (900 and 1800 MHz)-induced risks on oxidative stress and elements in kidney and testis of rats during pregnancy and the development of offspring. *Biol. Trace Elem. Res.* 156, 221–229. <http://dx.doi.org/10.1007/s12011-013-9836-z>.
- Pall, M.L., 2013. Electromagnetic fields act via activation of voltage-gated calcium channels to produce beneficial or adverse effects. *J. Cell. Mol. Med.* 17, 958–965. <http://dx.doi.org/10.1111/jcmm.12088>.
- Pall, M.L., 2014. Electromagnetic field activation of voltage-gated calcium channels: role in therapeutic effects. *Electromagn. Biol. Med.* <http://dx.doi.org/10.3109/15368378.2014.906447>.
- Pall, M.L., 2015a. How to approach the challenge of minimizing non-thermal health effects of microwave radiation from electrical devices. *Int. J. Innov. Res. Eng. Manag (IJIREM)* 2 (5), 71–76.
- Pall, M.L., 2015b. Scientific evidence contradicts findings and assumptions of Canadian Safety Panel 6: microwaves act through voltage-gated calcium channel activation to induce biological impacts at non-thermal levels, supporting a paradigm shift for microwave/lower frequency electromagnetic field action. *Rev. Environ. Health* 3, 99–116. <http://dx.doi.org/10.1515/revch-2015-0001>.
- Pall, M.L., 2016a. Electromagnetic fields act similarly in plants as in animals: Probable activation of calcium channels via their voltage sensor. *Curr. Chem. Biol.* 10, 74–82.
- Pall, M.L., 2016b. Microwave frequency electromagnetic fields (EMFs) produce widespread neuropsychiatric effects including depression. *J. Chem. Neuroanat.* 75 (Pt B), 43–51. <http://dx.doi.org/10.1016/j.jchemneu.2015.08.001>.
- Pall, M.L., 2018. How cancer can be caused by microwave frequency electromagnetic field (EMF) exposures: EMF activation of voltage-gated calcium channels (VGCCs) can cause cancer including tumor promotion, tissue invasion and metastasis via 15 mechanisms. In: Markov, M.S. (Ed.), *Mobile Communications and Public Health*. CRC Press, Boca Raton, FL (in press).
- Pall, M.L., Levine, S., 2015. Nrf2, a master regulator of detoxification and also anti-oxidant, anti-inflammatory and other cytoprotective mechanisms, is raised by health promoting factors. *Acta Physiol. Sin.* 67, 1–18.
- Panagopoulos, D.J., Johansson, O., Carlo, G.L., 2015a. Polarization: a key difference between man-made and natural electromagnetic fields, in regard to biological activity. *Sci. Rep.* 5, 14914. <http://dx.doi.org/10.1038/srep14914>.
- Panagopoulos, D.J., Johansson, O., Carlo, G.L., 2015b. Real versus simulated mobile phone exposures in experimental studies (article ID 607053, 8 pages). *BioMed. Res. Int.* <http://dx.doi.org/10.1155/2015/607053>.
- Papageorgiou, C.C., Hountala, C.D., Maganoti, A.E., Kiprianou, M.A., Rabavilas, A.S.D., Papademitriou, G.N., Capalis, C.N., 2011. Effects of Wi-Fi signals on the P300 component or event-related potentials during an auditory haying task. *J. Integr. Neurosci.* 10, 189–202. <http://dx.doi.org/10.1142/S0219635211002695>.
- Parf, H.K., Lee, J.E., Lim, J.F., Kang, B.H., 2014. Mitochondrial Hsp90s suppress calcium-mediated stress signals propagating from the mitochondria to the ER in cancer cells (Article Number: 148). *Mol. Cancer* 13. <http://dx.doi.org/10.1186/1476-4598-13-148>.
- Pazar, A., Rassadina, V., 2009. Transient effect of weak electromagnetic fields on calcium ion concentration in *Arabidopsis thaliana*. *BMC Plant Biol.* 9, 47.
- Pazar, A., Rassadina, V., Dandler, J., Zoller, J., 2006. Growth of etiolated barley plants in weak static and 50 Hz electromagnetic fields tuned to calcium ion cyclotron resonance. *Biomagn. Res. Technol.* 4, 1.
- Phillips, J.L., Singh, N.P., Lai, H., 2009. Electromagnetic fields and DNA damage. *Pathophysiology* 16, 79–88. <http://dx.doi.org/10.1016/j.pathophys.2008.11.005>.
- Pilla, A.A., 2012. Electromagnetic fields instantaneously modulate nitric oxide signaling in challenged biological systems. *Biochem. Biophys. Res. Commun.* 28 (426), 330–333. <http://dx.doi.org/10.1016/j.bbrc.2012.08.078>.
- Pilla, A.A., 2013. Nonthermal electromagnetic fields: from first messenger to therapeutic applications. *Electromagn. Biol. Med.* 32, 123–136. <http://dx.doi.org/10.3109/15368378.2013.776335>.
- Pollack, H., Healer, J., 1967. Review of Information on Hazards to Personnel from High-Frequency Electromagnetic Radiation. Institute for Defense Analyses; Research and Engineering Support Division, IDA/IHQ 67-6211, Series B, May 1967.
- Pouletier de Gannes, F., Haro, E., Hurtier, A., Taxile, M., Athane, A., Ait-Aissa, S., Masuda, H., Percheron, Y., Ruffié, G., Billandier, B., Dufour, P., Veyret, B., Lagroye, L., 2012. Effect of in utero wi-fi exposure on the pre- and postnatal development of rats. *Birth Defects Res. B Dev. Reprod. Toxicol.* 95, 130–136. <http://dx.doi.org/10.1002/bdrb.20346>.
- Pouletier de Gannes, F., Billandier, B., Haro, E., Taxile, M., Le Montagner, L., Hurtier, A., Ait-Aissa, S., Masuda, H., Percheron, Y., Ruffié, G., Dufour, P., Veyret, B., Lagroye, L., 2013. Rat fertility and embryo fetal development: influence of exposure to the Wi-Fi signal. *Reprod. Toxicol.* 36, 1–5. <http://dx.doi.org/10.1016/j.reprotox.2012.11.003>.
- Raines, J.K., 1981. Electromagnetic Field Interactions with the Human Body: Observed Effects and Theories. National Aeronautics and Space Administration, Greenbelt, Maryland (116 p).
- Redmayne, M., Johansson, O., 2015. Radiofrequency exposure in young and old: different sensitivities in the light of age-relevant natural differences. *Rev. Environ. Health* 30, 323–335. <http://dx.doi.org/10.1515/revch-2015-0030>.
- Ruediger, H.W., 2009. Genotoxic effects of radiofrequency electromagnetic fields. *Pathophysiology* 16, 89–102. <http://dx.doi.org/10.1016/j.pathophys.2008.11.004>.

- Saifi, L., Hanif, A., Smirani, C., Azzouz, I., Azzouz, A., Sakly, M., Abdelmelek, H., Bouslama, Z., 2015. Effects of acute WiFi signals (2.45 GHz) on heart variability and blood pressure in albino rabbits. *Environ. Toxicol. Pharmacol.* 40, 600–605. <http://dx.doi.org/10.1016/j.etap.2015.08.015>.
- Sambucci, M., Laudisi, F., Nasta, F., Pinto, R., Lodato, R., Altavista, P., Lovisolo, G.A., Marino, C., Pioli, C., 2010. Prenatal exposure to non-ionizing radiation: effects of WiFi signals on pregnancy outcome, peripheral B-cell compartment and antibody production. *Radiat. Res.* 174, 732–740. <http://dx.doi.org/10.1667/RR2255.1>.
- Sangün, Ö., Dündar, B., Çömlekçi, S., Büyükgöbüz, A., 2016. The effects of electromagnetic fields on the endocrine system in children and adolescents. *Pediatr. Endocrinol. Rev.* 13, 531–545.
- Shokri, S., Soltani, A., Kazemi, M., Sardari, D., Mofrad, F.B., 2015. Effects of Wi-Fi (2.45 GHz) exposure on apoptosis, sperm parameters and testicular histomorphology in rats: a time course study. *Cell J.* 17, 322–331. <http://dx.doi.org/10.22074/cellj.2016.3740>.
- Sypniewska, R.K., Millenbaugh, N.J., Kiel, J.L., Blystone, R.V., Ringham, H.N., Mason, P.A., Witzmann, F.A., 2010. Protein changes in macrophages induced by plasma from rats exposed to 35 GHz millimeter waves. *Bioelectromagnetics* 3, 656–663 (doi: 0.1002/bem.20598).
- Tabor, K.M., Bergeron, S.A., Horstick, E.J., Jordan, D.C., Aho, V., Porkka-Heiskanen, T., Haspel, G., Burgess, H.A., 2014. Direct activation of the Mauthner cell by electric field pulses drives ultrarapid escape responses. *J. Neurophysiol.* 112, 834–844. <http://dx.doi.org/10.1152/jn.00228.2014>.
- Teven, C.M., Greives, M., Natale, R.B., Su, Y., Luo, Q., He, B.C., Shenaq, D., He, T.C., Reid, R.R., 2012. Differentiation of osteoprogenitor cells is induced by high-frequency pulsed electromagnetic fields. *J. Craniofac. Surg.* 23, 586–593. <http://dx.doi.org/10.1097/SCS.0b013e31824cd6de>.
- Tök, L., Naziroğlu, M., Doğan, S., Kahya, M.C., Tök, O., 2014. Effects of melatonin on Wi-Fi-induced oxidative stress in lens of rats. *Indian J. Ophthalmol.* 62, 12–15. <http://dx.doi.org/10.4103/0301-4738.126166>.
- Toltskaya, M.S., Gordon, Z.V., 1973. *Pathological Effects of Radio Waves*, Translated from Russian by B Haigh, Consultants Bureau, New York/London (146 pp).
- Topsakal, S., Ozmen, O., Cicek, R., Conlekci, S., 2017. The ameliorative effect of gallic acid on pancreas lesions induced by 2.45 GHz electromagnetic radiation (Wi-Fi) in young rats. *J. Rad. Res. Appl. Sci.* 10, 233–240. <http://dx.doi.org/10.1016/j.jrras.2017.04.009>.
- Uchugonova, A., Isemann, A., Gorjup, E., Tempea, G., Bückle, R., Watanabe, W., König, K., 2008. Optical knock out of stem cells with extremely ultrashort femtosecond laser pulses. *J. Biophotonics* 1, 463–469. <http://dx.doi.org/10.1002/jbio.200810047>.
- Van Boxem, K., Huntoon, M., Van Zundert, J., Patijn, J., van Kleef, M., Joosten, E.A., 2014. Pulsed radiofrequency: a review of the basic science as applied to the pathophysiology of radicular pain: a call for clinical translation. *Reg. Anesth. Pain Med.* 39, 149–159. <http://dx.doi.org/10.1097/AAP.0000000000000063>.
- Viant, A., Roux, D., Girard, S., Bonnet, P., Paladian, E., Davies, E., Ledoigt, G., 2006. Microwave irradiation affects gene expression in plants. *Plant Signal. Behav.* 1, 67–70. <http://dx.doi.org/10.4161/psb.1.2.2434>.
- Vidal-Gadea, A., Ward, K., Beron, C., Ghorashlan, N., Gokce, S., Russell, J., Truong, N., Parikh, A., Gadea, O., Ben-Yakar, A., Pierce-Shimomura, J., 2015. Magnetosensitive neurons mediate geomagnetic orientation in *Caenorhabditis elegans*. *Neuroscience* 4, e07493. <http://dx.doi.org/10.7554/eLife.07493>.
- Walleczek, J., 1992. Electromagnetic field effects on cells of the immune system: the role of calcium signaling. *FASEB J.* 6, 3177–3185.
- Wang, C., Wang, X., Zhou, H., Dong, G., Guan, X., Wang, L., Xu, X., Wang, S., Chen, P., Peng, R., Hu, X., 2015. Effects of pulsed 2.856 GHz microwave exposure on BM-MSCs isolated from C57BL/6 mice. *PLoS One* 10 (2), e0117550. <http://dx.doi.org/10.1371/journal.pone.0117550>. (eCollection 2015).
- Wang, H., Zhang, X., 2017. Magnetic fields and reactive oxygen species. *Int. J. Mol. Sci.* 18 (10), E2175. <http://dx.doi.org/10.3390/ijms18102175>.
- Wegner, R.E., Begall, S., Burda, H., 2006. Magnetic compass in the cornea: local anesthesia impairs orientation in a mammal. *J. Exp. Biol.* 209, 4747–4750. <http://dx.doi.org/10.1242/jeb.02573>.
- Wu, G.W., Liu, X.X., Wu, M.X., Zhao, J.Y., Chen, W.L., Lin, R.H., Lin, J.M., 2009. Experimental study of millimeter wave-induced differentiation of bone marrow mesenchymal stem cells into chondrocytes. *Int. J. Mol. Med.* 23, 461–467.
- Xu, F., Bai, Q., Zhou, K., Ma, L., Duan, J., Zhuang, F., Xie, C., Li, W., Zou, P., Zhu, C., 2016. Age-dependent acute interference with stem and progenitor cell proliferation in the hippocampus after exposure to 1800 MHz electromagnetic radiation. *Electromagn. Biol. Med.* 3, 1–9. <http://dx.doi.org/10.1080/15368378.2016.1043557>. (Early Online 1–16. ISSN: 1536-8378).
- Yakymenko, I.L., Sidorik, E.P., Tsybulin, A.S., 1999. Metabolic changes in cells under electromagnetic radiation of mobile communication systems. *Ukr. Biokhim. Zh.* (1999) 20–28 (2011 Mar-Apr).
- Yakymenko, I., Sidorik, E., 2010. Risks of carcinogenesis from electromagnetic radiation and mobile telephony devices. *Exp. Oncol.* 32, 729–736.
- Yakymenko, I., Sidorik, E., Kyrylenko, S., Chekhun, V., 2011. Long-term exposure to microwave radiation provokes cancer growth: evidences from radars and mobile communication systems. *Exp. Oncol.* 33, 62–70.
- Yakymenko, I., Tsybulin, O., Sidorik, E., Henshel, D., Kyrylenko, O., Kyrylenko, S., 2015. Oxidative mechanisms of biological activity of low-intensity radiofrequency radiation. *Electromagn. Biol. Med.* <http://dx.doi.org/10.3109/15368378.2015.1043557>. (Early Online 1–16. ISSN: 1536-8378).
- Yildirim, M.E., Kaynar, M., Badem, H., Cavlis, M., Karatus, O.F., Cimentepe, E., 2015. What is harmful for male fertility: cell phone or wireless internet? *Kaosiung J. Med. Sci.* 31, 480–484. <http://dx.doi.org/10.1016/j.kjms.2015.06.006>.
- Yüleşel, M., Naziroğlu, M., Özkaya, M.O., 2016. Long-term exposure to electromagnetic radiation from mobile phones and Wi-Fi devices decreases plasma prolactin, progesterone, and estrogen levels but increases uterine oxidative stress in pregnant rats and their offspring. *Endocrine* 52, 352–362. <http://dx.doi.org/10.1007/s12020-015-0795-3>.
- Zhang, J., Li, M., Kang, E.T., Neoh, K.G., 2016. Electrical stimulation of adipose-derived mesenchymal stem cells in conductive scaffolds and the roles of voltage-gated ion channels. *Acta Biomater.* 32, 46–56. <http://dx.doi.org/10.1016/j.actbio.2015.12.024>.