

# Journal Pre-proof

Evidence for a health risk by RF on humans living around mobile phone base stations: From radiofrequency sickness to cancer

A. Balmori



PII: S0013-9351(22)01178-1

DOI: <https://doi.org/10.1016/j.envres.2022.113851>

Reference: YENRS 113851

To appear in: *Environmental Research*

Received Date: 15 April 2022

Revised Date: 26 June 2022

Accepted Date: 5 July 2022

Please cite this article as: Balmori, A., Evidence for a health risk by RF on humans living around mobile phone base stations: From radiofrequency sickness to cancer, *Environmental Research* (2022), doi: <https://doi.org/10.1016/j.envres.2022.113851>.

This is a PDF file of an article that has undergone enhancements after acceptance, such as the addition of a cover page and metadata, and formatting for readability, but it is not yet the definitive version of record. This version will undergo additional copyediting, typesetting and review before it is published in its final form, but we are providing this version to give early visibility of the article. Please note that, during the production process, errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

© 2022 Published by Elsevier Inc.

## **Evidence for a health risk by RF on humans living around mobile phone base stations: from radiofrequency sickness to cancer**

A. Balmori

ORCID ID: 0000-0002-4118-0912

**Correspondence:** C/ Navarra, 1 5°B 47007 Valladolid, Spain

[abalmorimartinez@gmail.com](mailto:abalmorimartinez@gmail.com)

### **Abstract**

The objective of this work was to perform a complete review of the existing scientific literature to update the knowledge on the effects of base station antennas on humans. Studies performed in real urban conditions, with mobile phone base stations situated close to apartments, were selected. Overall results of this review show three types of effects by base station antennas on the health of people: radiofrequency sickness (RS), cancer (C) and changes in biochemical parameters (CBP). Considering all the studies reviewed globally (n=38), 73.6% (28/38) showed effects: 73.9% (17/23) for radiofrequency sickness, 76.9% (10/13) for cancer and 75.0% (6/8) for changes in biochemical parameters. Furthermore, studies that did not meet the strict conditions to be included in this review provided important supplementary evidence. The existence of similar effects from studies by different sources (but with RF of similar characteristics), such as radar, radio and television antennas, wireless smart meters and laboratory studies, reinforce the conclusions of this review. Of special importance are the studies performed on animals or trees near base station antennas that cannot be aware of their proximity and to which psychosomatic effects can never be attributed.

### **Key words**

Base station, cell tower, health, mast, RF radiation, microwave syndrome, radar, radio antennas.

**Short title: Health risk by mobile phone base stations**

## Introduction

During the last few decades, hundreds of thousands of mobile phone base stations and other types of wireless communications antennas have been installed around the world, in cities and in nature, including protected natural areas, in addition to pre-existing antennas (television, radio broadcasting, radar, etc.). Only the aesthetic aspects or urban regulations have been generally considered in this deployment, while the biological, environmental and health impacts of the associated non-ionizing electromagnetic radiation emissions have not been assessed so far. Therefore, the effects on humans living around these anthropogenic electromagnetic field sources (antennas) have not been considered.

In France, there is a significant contribution of mobile phone base stations in the exposure to radiofrequency electromagnetic fields (RF-EMF) of urban citizens living nearby (De Giuduci et al., 2021). Some studies from India indicate that more than 15% of people have levels of EMF strength above 12 V/m due to their proximity to antennas (Premial and Eldhose, 2017). Exposure estimates have shown that RF-EMF from mobile telephone systems is stronger in urban than in rural areas. For instance, in Sweden the levels of RF radiation have increased considerably in recent years, both outdoor and indoor, due to new telecommunication technologies, and the median power density measured for RF fields between 30 MHz and 3 GHz was 16  $\mu\text{W}/\text{m}^2$  in rural areas, 270  $\mu\text{W}/\text{m}^2$  in urban areas and 2400  $\mu\text{W}/\text{m}^2$  in city areas (Hardell et al., 2018). Total exposure varies not only between urban and rural areas but also, depending on residential characteristics, between different floors of a building, with a tendency for building exposure to increase at higher floors (Breckenkamp et al., 2012).

Over the past five decades, and more intensively since the beginning of this century, many studies and several reviews have been published on the effects of anthropogenic electromagnetic radiation on humans living around the antennas. The first studies were carried out with radio and television antennas, investigating increases in cancer and leukaemia (Milham 1988; Maskarinec et al., 1994; Hocking et al., 1996; Dolk et al., 1997a,b; Michelozzi et al., 1998; Altpeter et al., 2000), as well as around radars (Kolodynski and Kolodynska, 1996; Goldsmith, 1997).

Regarding base station antennas, there are scientific discrepancies in their effects: some studies concluded that there are no health-related effects (e.g. Augner and Hacker, 2009; Blettner et al., 2009; Rösli et al., 2010; Baliatsas et al., 2016) whereas others found increases in cancer and other health problems in humans living around antennas (e.g. Santini et al., 2002; Navarro et al., 2003; Bortkiewicz et al., 2004; Eger et al., 2004; Wolf and Wolf, 2004; Abdel-Rassoul et al., 2007; Khurana et al., 2010; Dode et al., 2011; Shinjyo and Shinjyo, 2014; Gandhi et al., 2015; López et al., 2021; Rodrigues et al., 2021). There is a specific symptomatology linked to radar and RF exposure at low levels, characterized by functional disturbances of the central nervous system (headache, sleep disturbance, discomfort, irritability, depression, memory loss, dizziness, fatigue, nausea, appetite loss, difficulty in concentration, dizziness, etc.), that has been termed 'RF sickness' (Lilienfeld, 1978; Johnson Liakouris, 1998; Navarro et al., 2003).

The objective of this study was to perform a complete review of the existing scientific literature to update the knowledge on the effects of base stations on humans living around the antennas.

## Methods

A search was performed in the EMF portal, Google Scholar and PubMed databases with the words: “mobile phone base station and health” or “cell tower and health”.

Only studies performed in real urban conditions, with mobile phone base stations situated close to apartments, were selected. Studies conducted in larger regions with numerous antennas, based on surveys and geographic data, were also included.

On the contrary, studies were excluded that considered different sources of electromagnetic radiation, such as mobile phone base stations together with broadcast transmitters (TV and radio), radar, mobile phones, cordless phones, Wi-Fi or wireless smart meters. Also excluded were those that included antennas and powerlines jointly. Studies that only performed measurements or modelling of radiation levels in the environment of the antennas or in the body, but did not deal with health effects, were excluded, as were surveys on risk perception and the nocebo effect, modelled radiofrequency electromagnetic field exposure from mobile-phone base stations or perceived exposure. All experimental laboratory studies, experiments in an exposure chamber or adapted room were also excluded. Finally, the comments or criticism of previously published studies were also excluded. However, due to their importance the conclusions of some of the excluded studies will be discussed in the corresponding section.

## Results

The studies that met the selected criteria are presented in chronological order in Table 1, catalogued as Y/N depending on whether or not they found effects. The selected studies cover three types of effects: radiofrequency sickness (RS) (according to Lilienfeld et al., 1978; Johnson Liakouris, 1998), cancer (C) and changes in biochemical parameters (CBP). Table 1 also includes the authors, year and country, antenna type, study design, diseases and symptoms found/not found and the main conclusions of each study.

**Table 1: Studies that met the selected criteria**

Nº	Reference and country	Antenna type	Study design	Diseases and symptoms found/not found	Main conclusions
<b>1</b> <b>Y</b> <b>RS</b>	Santini et al., 2002 and 2003 a and b France	Base station antennas GSM 900 and 1800 MHz	Questionnaire survey in 530 people	Effects found on: -tiredness -headache -sleep disturbance -discomfort -irritability -depression -memory loss -dizziness -libido decrease -visual perturbations	Effects occur up to a distance of 300 meters from the antenna. Older subjects are more sensitive. Also, hat the facing location is the worst position for some symptoms s tudied, especially for distances till 100m from base stations. The frequency of reported complaints is significantly higher for women in comparison with men
<b>2</b> <b>Y</b> <b>RS</b>	Gómez-Perretta et al., 2013 Spain	Base station antennas GSM 900 and 1800 MHz	Questionnaire survey in 101 people and electric field measurements	Effects found on: -fatigue -irritability -headache -nausea -appetite loss -discomfort -sleep disturbance -depression	Significant correlation between the declared severity of the symptoms and the measured power density. The separation of respondents into two different exposure groups also showed an increase of the declared severity in the group with the higher exposure. The incidence of most of the symptoms was related to exposure levels, independently of

				-difficulty in concentration -dizziness	the demographic variables and some possible risk factors. Health changes related with GSM exposure seem to occur in a manner unrelated with those fears
<b>3 Y RS</b>	Bortkiewicz et al., 2004 Poland	Base station antennas	Review of previous publications	Effects found on: -circulatory system -sleep disturbances -irritability depression -blurred vision -concentration -difficulties nausea -lack of appetite -headache -vertigo	Relationship between the incidence of individual symptoms, the level of exposure, and the distance. This association was observed in both groups of persons, those who linked their complaints with the presence of the base station and those who did not notice such a relation.
<b>4 Y C</b>	Eger et al., 2004 Germany	2 Base station antennas	Number of cancer cases in the selected population (1,045 resident) in Naila to compare results an inner area (within a distance of 400 metres from the base station antennas) and outer area (beyond 400 metres).	The number of newly developed cancer cases in the inner area is more than the expected number taken from the cancer register, which represents the total population being irradiated. The group who had lived during the past five years within a distance of 400 m from the Base station antennas have a two times higher risk of developing cancer than that of the average population. The relative risk of getting cancer in the inner area compared with the Saarland cancer register is 1.7.	The risk of newly developing cancer was three times higher among those patients who had lived during past ten years (1994-2004), within a distance of 400 m. from the cellular transmitter, in comparison to those who had lived further away.
<b>5 Y C</b>	Wolf and Wolf, 2004 Israel	1 Base station antenna	A cancer incidence study to investigate the incidence of cancer cases of individuals (the cohort included 622 people) exposed to a Base station antenna, in comparison to those of a nearby clinic out of that area, to the national incidence rates of the whole country and to the incidence rates in the whole town of Netanya	There were 4.15 times more cases of cancer in area A (breast carcinoma, ovary carcinoma, lung carcinoma, Hodgkin's disease, osteoid osteoma, and hypernephroma) than in the entire population.	The study indicates an association between an increased incidence of cancer and living in proximity to a Base station antenna.
<b>6 Y RS</b>	Hutter et al., 2006 Austria	10 Base station antennas in the 900 MHz band	Questionnaire survey in 365 subjects and exposure measurements	Effects found on: -headache -difficulties to concentrate -Cold hands or feet  No effects found on : -vertigo -palpitations -tremor -hot flushes -sweating -loss of appetite -loss of energy, -exhaustion -tiredness -feeling strained -sleep	Self-reported symptoms like headache and difficulties in concentrating show an association with microwave exposure from base stations, not attributable to subjects' fear of health effects from these sources. Other symptoms, like sleeping problems, seem to be more due to fear of adverse health effects than actual exposure.
<b>7 Y RS</b>	Abdel-Rassoul et al., 2007 Egypt	Base station antennas (GSM)	Questionnaire survey on 85 exposed persons and 80 controls	Effects found on: -headache -memory changes -dizziness -tremors -depressive symptoms	The prevalence of neuropsychiatric complaints were significantly higher among exposed inhabitants than controls. Inhabitants living nearby mobile phone base stations are at risk for developing neuropsychiatric problems and some

				-sleep disturbance No effects found on: -Blurred vision -Irritability -Lack of concentration	changes in the performance of neurobehavioral functions either by facilitation or inhibition.
<b>8 N CBP</b>	Augner and Hacker, 2009 Austria	Base station antennas	Questionnaire survey on fifty-seven participants and saliva samples	Self-declared base station neighbors ( $\leq 100$ meters) had significantly higher concentrations of alpha-amylase in their saliva, higher rates in symptoms, somatization, obsessive-compulsive, anxiety, phobic anxiety. There were no differences in EMF-related health concern scales.	Self-declared base station neighbors are more strained than others. EMF-related health concerns cannot explain these findings.
<b>9 N RS</b>	Blettner et al., 2009 Berg-Beckhoff et al., 2009 Germany	Base station antennas (GMS 900 and 1800 and UMTS 2170)	Questionnaire survey on 30047 participants and geo-coding information on the residence distance (less or more than 500 m) to the nearest mobile phone base station. In a second phase RF measurements were conducted for a sub-sample in the households of 1500 persons	The mailed questionnaire included a list of 38 symptoms that have been reported in previous studies to be possibly associated with RF-EMF exposure	Participants who were concerned about or attributed adverse health effects to mobile phone base stations and those living in the vicinity of a mobile phone base station (500 m), reported slightly more health complaints than others. The observed slightly higher prevalence of health complaints near base stations cannot be explained by attributions or concerns alone. The worries and health complaints of people living close to mobile phone base stations need to be taken seriously. Measured RF-EMFs emitted from mobile phone base stations were not associated with health disturbances. However, the study shows that sleep disturbances and health complaints are related to the attribution of adverse health effects to mobile phone base stations.
<b>10 Y RS C</b>	Kundi and Hutter, 2009 Austria	Base station antennas	Review of previous publications	Effects found on: Adverse neurobehavioral symptoms or cancer	There are indications from epidemiology that such exposures affect wellbeing and health weakly supported by human provocation studies and an inconclusive body of evidence from animal and in vitro studies. Cross-sectional investigations of subjective health as a function of distance or measured field strength, despite differences in methods and robustness of study design, found indications for an effect of exposure that is likely independent of concerns and attributions. Two ecological studies of cancer in the vicinity of base stations report both a strong increase of incidence within a radius of 350 and 400m respectively. Due to the limitations inherent in this design no firm conclusions can be drawn, but the results underline the urgent need for a comprehensive investigation of this issue
<b>11 Y C</b>	Eger and Jahn, 2010 Germany	Base station antennas	Questionnaire survey on 255 persons	Effects found on: -sleep problems -depression -headaches -cerebral affections -concentration difficulties -joint problems -infections -skin problems -dizziness -cardiovascular problems -disturbance of equilibrium -visual problems -nosebleed -gastrointestinal problems	A significant relationship between mean exposure levels of the study participants and reported health symptoms. Within the 400-m radius around the transmitter, a higher symptom rate could be documented for 14 out of 19 symptom groups in the highest exposure groups compared to groups further away from the transmitter and the difference is statistically significant. Decreasing symptom scores in relation to decreasing mean exposure levels caused by cell phone transmitter emissions

				No effects found on: -toothaches -hormonal imbalances -weight gain -weight loss	
<b>12</b> <b>N</b> <b>C</b>	Elliott et al., 2010 Great Britain	Base station antennas	Data on all registered cases of cancer in children aged 0-4 in Great Britain and data on mobile phone base stations to investigate the risk of early childhood cancer associated with the mother's exposure to radiofrequency from and proximity to mobile phone base stations during pregnancy.	Of the 1397 cases, there were 251 brain and central nervous system cancers and 527 cases of leukaemia and non-Hodgkin's lymphoma. The study found no association between mobile phone base stations and risk of cancer.	In this systematic national investigation the authors found no association between risk of cancer in young children and estimated exposures to radiofrequency from mobile phone base stations during pregnancy. However there is a research paper limitation on page 5: "our models did not include information on other sources of radiofrequency exposure, such as from microcells or picocells" and the city centers (especially) are full of these kind of antennas.
<b>13</b> <b>Y</b> <b>RS</b> <b>C</b>	Khurana et al., 2010 international	Base station antennas	Review of previous publications	Effects found on: Adverse neurobehavioral symptoms or cancer	<b>The authors identified a total of 10 epidemiological studies that assessed for putative health effects of mobile phone base stations. Seven of these studies explored the association between base station proximity and neurobehavioral effects and three investigated cancer. The authors found that eight of the 10 studies reported increased prevalence of adverse neurobehavioral symptoms or cancer in populations living at distances &lt; 500 meters from base stations.</b>
<b>14</b> <b>N</b> <b>RS</b>	Röösli et al., 2010 Switzerland	Base station antennas (GMS 900 and 1800 and UMTS 2170)	Systematic review	There are no adverse effects	Not indication of an association between any health outcome and RF-EMF exposure from mobile phone base stations at levels typically found in our everyday environment. There is also no evidence that EHS individuals are more susceptible to base station radiation than the rest of the population. The evidence for the absence of long-term effects is limited.
<b>15</b> <b>N</b> <b>CBP</b> <b>C</b>	Yildirim et al., 2010 Turkey	Base station antennas	Blood samples to analyse the micronucleus (MN) frequency and chromosomal aberrations on blood in people living around mobile phone base stations and healthy controls.	There was not a significant difference of MN frequency and chromosomal aberrations between the two study groups.	Mobile phones and their base stations do not produce important carcinogenic changes.
<b>16</b> <b>Y</b> <b>RS</b>	Alazawi., 2011 Iran	8 Base station antennas	Questionnaire survey on 375 subjects. Not measurements	Effects found on: -headaches -sleep disturbances -irritability -depressive -tendencies -feeling of discomfort, -difficulties in concentration -memory loss -lowering of libido	<b>This study shows that inhabitants living nearby mobile phone base stations are at risk for developing non specific health symptoms, the facing position appears to be the worst one for distances from cellular phone base stations &lt; 100 m. It is advisable that cellular phone base stations should not be sited closer than 300 m to populations, as a precautionary measure, siting of base stations should be such as to minimize exposure of neighbors.</b>
<b>17</b> <b>Y</b> <b>C</b>	Dode et al., 2011 Brazil	Base station antennas	This research was conducted in a broad environmental context, aiming to verify if there is a spatial correlation between the Base station antennas and the cases of death by neoplasia during the period between 1996 and 2006 in Belo	<b>The mortality rates and the relative risk were higher for the residents inside a radius of 500 m from the Base station antennas, compared to the average mortality rate of the entire city, and a decreased dose-response gradient was observed for residents who lived farther</b>	The research showed the existence of a spatial correlation between cases of death by neoplasia and the locations of the Base station antennas, in the Belo Horizonte municipality from 1996 to 2006.



			Horizonte municipality (Brazil).	away from these base stations.	
<b>18</b> <b>Y</b> <b>C</b>	Li et al., 2012 Taiwan	Base station antennas	Population-based case-control study in Taiwan considering incident cases aged 15 years or less and admitted in 2003 to 2007 for all neoplasm (n=3481 children). Exposure of each study subject to radio frequency (RF) was indicated by the averaged annual power density within 5 years prior to the neoplasm diagnosis. Controls were randomly selected.	Taiwanese children with higher-than median exposure of RF potentially emitted from Base station antennas were at significantly increased risk of all neoplasms combined. Although there were also positive associations between RF power density and risks of brain neoplasm and leukemia in children, such associations did not reach statistical significance.	This study noted a significantly increased risk of all neoplasms in children with higher-than-median RF exposure to Base station antennas. The slightly elevated risk was seen for leukemia and brain neoplasm, but was not statistically significant.
<b>19</b> <b>N</b> <b>C</b>	Stewart et al., 2012 Great Britain	1 Base station antennas (GMS 1800)	Data on cancer incidence and mortality accessing the medical information of near residents	The study cannot conclude that the base station is responsible for the incidence of cancer in the local residents	Although the age range for local residents with cancer in the suspected cluster was younger than might be generally expected, there was no evidence that their cancer incidence is associated with the mobile phone base station. 10 cancers were registered after installation of the base station. However, the collection of cancers does not fulfil the criteria for a cancer cluster; the cases are a mixed variety of relatively common cancers. No single type of cancer was dominant, all but one were common types of cancer and none were seen in a group not usually affected by that cancer. Data from primary and secondary care also provide evidence that lifestyle and family history factors could have contributed to some individual cases.
<b>20</b> <b>N</b> <b>RS</b>	Islam and Mohammed, 2014 Bangladesh	Base station antennas	Questionnaire survey on 220 adults living near a Base station antenna for at least one year in two selected areas	Half of the respondents experienced problems in sleeping patterns, recent episodes of headache or dizziness and mood change, anxiety, or depression. 11 respondents experienced some generalized burning sensation and 4 reported episodes of shaking or fits. 48 respondents mentioned one or more other health effects, such as mood changes/problem, buzzing in the head, hopelessness, palpitation, tachycardia, heaviness of chest, anorexia, diarrhoea, and skin diseases.	From the results of the study cannot conclude that the health effects are direct results of the base station antennas. However, the complaints were similar to those of other studies, which shows the importance of conducting further research to determine the effects of electromagnetic radiation from base station antennas on human health and should be considered as a public health concern.
<b>21</b> <b>Y</b> <b>RS</b>	Pachua and Pachua, 2014 India	Base station antennas (GSM 900)	Questionnaire survey conducted on 64 adults (31 female, 33 male) and electric field measurements. Health symptoms of RF exposure faced by the inhabitants within 50m and outside 50m from the tower were analysed and compared.	Effects found on: -Muscle pain -Fatigue -Sleep disorder -Nausea -Skin problema -Dizziness -Feeling of discomfort -Difficulty in concentration -Memory loss -Visual disruption	Inhabitants living within 50m had more health complaints than those living outside 50m. It was also found that females had more complaints than males
<b>22</b> <b>Y</b> <b>RS</b>	Shinjyo and Shinjyo, 2014 Japan	2 base station antennas (CDMA 800 MHz and 2 GHz)	Medical examinations and health questionnaires comparing the health of 107 residents during the	Effects found on: -fatigue -eye problems -sleep disturbances -dizziness -headache	A total of 34 residents suffered from health problems after installation of the 800 MHz antennas. Three months after their removal this number decreased to 13. There were 41 residents who had health problems after installation of the 2 GHz antennas, and this



			base station's operation and after its removal. Measurement of the power density	-tinnitus -nasal bleeding  No effects found on: -tachycardia -tumours -skin problems -rhinitis -angina pectoris -hearing loss	number decreased to 15 after removal of the 2 GHz antennas. In total 49 residents suffered from health problems during operation of both the 800 MHz and the 2 GHz antennas. However, this number decreased to 25 after removal of both sets of antennas. The residents had no prior knowledge about possible adverse health effects of RF-EMFs. Health problems of the residents were associated with the operation of the mobile phone base station and these problems improved after its removal.
<b>23</b> <b>Y</b> <b>CBP</b>	Gandhi et al., 2015 India	Base station antennas	Questionnaire survey and blood samples from 91 individuals, with 70% (63) residing in a populated area with a mobile phone base station (the sample group) and 30% (28) in a sparsely-populated zone without any nearby base stations (the control group). Radiofrequency field measurements	Effects found on: Genetic damage parameters of DNA migration length, damage frequency (DF) and damage index	Genetic damage was significantly increased in the sample group compared to that in the controls. The 2.5–4.5-fold increase in DNA damage in peripheral blood lymphocytes of persons staying near a mobile phone base station is of acute concern given that all neoplasia initiate via unrepaired DNA damage. In the light of the above observations and the statistically significant genetic damage observed in those residing within 300 m of a mobile phone base station in this study, it implies that the effects of radiations from mobile phone base stations cannot be overlooked, as unrepaired DNA damage can lead to cancer, precocious ageing and age-related effects.
<b>24</b> <b>Y</b> <b>CBP</b>	Meo et al., 2015 Saudi Arabia	2 Base station antennas (925 MHz) near two schools	RF-EMF measurements and blood sample collection	Effects found on: -chronic hyperglycemia -increased HbA1c -diabetes mellitus	Students who were exposed to high EMFR generated by MPBS had significantly higher HbA1c and prevalence of pre diabetes mellitus compared to the students who exposed to low EMFR. EMFR appears to be another risk factor contributing to high levels of HbA1c and risk of type 2 diabetes mellitus.
<b>25</b> <b>Y</b> <b>RS</b>	Pachauu et al., 2015 India	Base station antennas (GSM 900)	Questionnaire survey from 50 exposed and 50 control individuals. Power density measurements	Effects found on: -fatigue -sleep disruption -headache -dizziness -muscle pain -cramp  No effects found on: -nausea -discomfort -difficulty in concentration -memory loss -skin problems -visual disruption -hearing problem	Inhabitants living near mobile tower are having more health complaints than those inhabitants living in the area where there is no mobile tower
<b>26</b> <b>Y</b> <b>CBP</b>	Al-Quzwini et al., 2016 Iraq	Base station antennas	Questionnaire survey. Two hundred couples (one hundred subfertile couples as a study group, and one hundred fertile couples as a control group. Semen analysis	Twenty-nine percentage of subfertile couples had exposure to environmental hazards (communication's tower beside their house within fifty meters), and 71% non-hazard. The duration of the exposure to the environmental factor ranged from 2 to 7 years.	The exposure to environmental hazards shows significant difference between the subfertile and the fertile men; as higher percentage of exposure to mobile phone tower among subfertile group, 29% versus 12% for the fertile group,
<b>27</b> <b>N</b> <b>RS</b>	Baliatsas et al., 2016 The Netherlands	Base station antennas (GSM and UMTS)	Health records from 1069 adult participants, All participants were living within 500 m from the nearest bases station. A propagation model combined with a questionnaire was used	Compared to the baseline period, there was a higher prevalence of symptoms theoretically relevant to EMF at T1. A significant increase was observed in the prevalence of ear symptoms and a two-fold (but not	This before-after study found no evidence that RF-EMF exposure from mobile phone base stations is associated with the development of non-specific symptoms in the general population, corroborating recent observational studies. Subgroup analyses among people with self-reported sensitivity to base stations showed a higher prevalence

			to assess indoor exposure to RF-EMF from MPBS at T1. Estimation of exposure at T0 was based on number of antennas at T0 relative to T1.	significant) increase in the prevalence of skin symptoms. Overall, the total prevalence was slightly lower at T1. A consistent association between UMTS exposure and different clusters of GP-registered symptoms, for the self-declared mobile phone base stations-sensitive group.	for most symptoms at T1 compared to baseline and there was some indication for a higher risk of non-specific symptoms for the mobile phone base stations-sensitive group, in relation to exposure.
<b>28 N RS</b>	Klaps et al., 2016 Austria	Base station antennas	Meta-analysis based on the results of 17 studies	The effects of mobile phone base stations seem to be rather unlikely. However, nocebo effects occur.	It is unclear whether electromagnetic fields emitted by mobile phone base stations affect well-being in adults. The existing studies on this topic are highly inconsistent.
<b>29 Y RS CBP</b>	Singh et al., 2016 India	4 Base station antennas	Questionnaire survey and salivary analysis in 20 individuals (case group) and 20 (control group)	Effects found: -sleep disturbances -headache -dizziness -irritability -concentration difficulties -hypertension	A majority of the subjects who were residing near the mobile base station had various complaints. A majority of the study subjects had significantly lesser stimulated salivary secretion as compared to the control subjects. The effects of prolonged exposure to EMRs from mobile phone base stations on the health and well-being of the general population cannot be ruled out.
<b>30 Y RS</b>	Premial and Eldhose, 2017 India	14 Base station antennas	Questionnaire survey (229 persons) and power density measurements	Joint pain, sleep disorders, migraine related headaches and digestive problems	For 32 different diseases, only 4 were found to have obvious relation to the cell tower radiation. Females are more prone to the bad effects of cell tower radiation. The current Indian standard for cell tower exposure is inadequate for the safe living.
<b>31 Y CBP</b>	Taheri et al., 2017 Iran	Base station antennas	45 healthy individuals with their home near BTS antenna (exposed group) and 45 healthy subjects who were away from the antenna	In the exposed group, the whole number of white blood cells, the level of hematocrit, percent of monocytes, eosinophils and basophils were significantly lower than the control group. The number of red blood cells, their average volume and the mean concentration of hemoglobin were notably higher than the controls. There was not observed a significant difference between the two groups in hemoglobin, its mean concentration, platelet count, percent of lymphocytes and neutrophils as well as serum levels of cytokines IL-4, IL-10 and interferon $\gamma$ .	The radiation of base station antennas influenced the blood and immune systems.
<b>32 Y RS C</b>	Vijay and Choudhary, 2017 India	40 Base station antennas (900 - 1800 MHz)	Questionnaire survey	Effects found: - headache - depression - sleep disturbance - nausea - fatigue - asthma - cancer - Alzheimer's disease - multiple sclerosis - brain tumor.	The questionnaires show that people have some kind of physical or mental illness after the installation of mobile towers.
<b>33 Y</b>	Zothansiyama et al., 2017 India	6 Base station antennas (900 - 1800 MHz)	Questionnaire survey. Blood sample collection and lymphocyte culture.	Effects found: -higher frequency of micronuclei	The analyses of data from the exposed group residing within a perimeter of 80 m of mobile base stations, showed significantly higher

<b>CBP</b>			<p>Power density measurement. Exposed group (n = 40) Control group (n=40) The study was envisaged to evaluate the effect of RFR on the DNA damage and antioxidant status in cultured human peripheral blood lymphocytes of individuals residing in the vicinity of mobile phone base stations and comparing it with healthy controls.</p>	-decreased antioxidants	<p>frequency of micronuclei when compared to the control group, residing 300 m away from the mobile base station. The analysis of various antioxidants in the plasma of exposed individuals revealed a significant attrition in glutathione concentration, activities of catalase and superoxide dismutase and rise in lipid peroxidation when compared to controls. Multiple linear regression analyses revealed a significant association among decreased antioxidants and elevated micronuclei frequency with increasing RF power density. The persistence of DNA unrepaired damage leads to genomic instability which may lead to several health disorders including the induction of cancer.</p>
<b>34 Y RS</b>	Meo et al., 2019 Saudi Arabia	Two different schools both situated nearby base station antennas (925 MHz)	Cognitive function, motor screening task and spatial working memory were tested, and also RF measurements were made.	There was a statistically significant impairment in the motor screening task and spatial working memory among students who were exposed to high RF generated by base station antennas (School 2: 10.021 $\mu\text{W}/\text{cm}^2$ ) compared to students who were exposed to lower levels of RF (School 1: 2.010 $\mu\text{W}/\text{cm}^2$ ).	High exposure to RF-EMF produced by base station antennas is associated with a decrease in fine and gross motor skills and spatial working memory and attention in school adolescents compared to students who had been exposed to low RF-EMF.
<b>35 Y RS</b>	Ali et al., 2021 Iraq	Base station antennas (900-1800 MHz.)	Questionnaire survey comparing two groups. The first group (n=79) was located in a town with three cell phone towers with less than a hundred meters apart. The second study group (n=79) was limited to the area almost empty from cell phone towers. Electric field measurements were made.	There was a significant association between health problems (skin problem, hair loss issues, sleeping difficulties, and fertility issues) and distance to towers (less distance, more problems: P-value < 0.05). In regards to health problems (abnormalities, blood pressure issues, tumors cases, and memory and concentration difficulties), the obtained results were not statistically significant.	The results showed an increase in both short- and long-term health problems near base stations antennas in general.
<b>36 Y RS C</b>	López et al., 2021 Spain	9 Base station antennas	Questionnaire survey on 268 persons, 174 in exposed area and 94 in control area, and EMF measurements	<p>Effects found on</p> <ul style="list-style-type: none"> <li>-headache</li> <li>-dizziness</li> <li>-instability</li> <li>-tachycardias</li> <li>-nightmares</li> </ul> <p>No effects found on:</p> <ul style="list-style-type: none"> <li>-fainting</li> </ul>	<p>People who are exposed to higher radiation values present more severe headaches, dizziness and nightmares.</p> <p>5.6% cancer cases in the study population, a percentage 10 times higher than that of the total Spanish population.</p>
<b>37 N RS</b>	Martin et al., 2021 France	Base station antennas	Questionnaire survey in 354 residents from buildings located at a distance of 250 m or less from the base station antennas in the main transmit beam of the antennas and home exposure measurements	<p>No significant association between RF-EMF exposure and the overall symptoms score, nor between RF-EMF exposure from MPBSs and insomnia-like symptoms.</p> <p>There was a significant association between RF-EMF exposure and insomnia-like symptoms only for participants who attributed their symptoms to radiofrequencies.</p>	The findings of the study do not support the hypothesis of an association between RF-EMF exposure and health outcomes, such as self-reported non-specific or insomnia-like symptoms in the general population. However, they may suggest a possible association between such exposure and insomnia-like symptoms among people reporting environmental concerns.
<b>38 Y C</b>	Rodrigues et al., 2021 Brazil	Base station antennas	This is an ecological study using capitals as the unit of analysis. The authors collected information on the	For all cancers and for the specific types investigated (breast, cervix, lung, and esophagus cancers), the higher the exposure to RBS	The results indicate that the exposure to radiofrequency electromagnetic fields from an RBS increases the rate of mortality by all cancers and specifically by breast, cervix, lung, and esophageal cancers. These

number of deaths by cancer, gender, age group, gross domestic product per capita, death year, and the amount of exposure over a lifetime and investigated all cancer types and some specific types (breast, cervix, lung, and esophagus cancers).

radiofrequency, the higher the median of mortality rate.

conclusions are based on the fact that the findings of the study indicate that, the higher the RBS radiofrequency exposure, the higher the cancer mortality rate, especially for cervix cancer. The spatial analysis showed that the highest radiofrequency exposure was observed in a city located in the southern region of Brazil, which also showed the highest mortality rate for all types of cancer and specifically for lung and breast cancers.

Considering all the selected studies (n=38), 73.6% (28/38) showed effects: 73.9% (17/23) for radiofrequency sickness, 76.9% (10/13) for cancer and 75.0% (6/8) for changes in biochemical parameters (Figure 1). Therefore, most of the studies carried by research groups from twenty different countries reach the same conclusions.

For the reasons previously explained, the following studies (n=85) were not considered in this review, even though the conclusions of some of these studies will be discussed later due to their importance regarding the similarities of the electromagnetic radiation types involved and the effects found in many cases. Several studies only performed measurements or modelling of radiation levels in the environment of the antennas or in the body, but did not deal with the effects on health (e.g. Aniołczyk, 1999; Henderson et al., 2006; Keow et al., 2006; Neitzke et al., 2007; Burgi et al., 2008; Augner et al., 2009; Chen and Chuang, 2009; Schmiedel et al., 2009; Viel et al., 2009; Hansson et al., 2011; Alhekail et al., 2012; Breckenkamp et al., 2012; Beekhuizen et al., 2013; Bürgi et al., 2014; Iyare et al., 2014; Urbinello et al., 2014; Lemaire et al., 2016; Admawi, 2021; De Giudici et al., 2021; Kazaure et al., 2021; Yetiş and Kayili, 2021). Some were surveys on risk perception and the placebo effect, modelled RF-EMF exposure from mobile-phone base stations or perceived exposure (Wiedemann et al., 2006; Dohle et al., 2012; Kowall et al., 2012; Freudenstein et al., 2015; Dieudonné, 2016; Klaps et al., 2016; Martens et al., 2017; Koh et al., 2020). Others jointly considered various sources of electromagnetic fields such as telephone antennas, mobile phones, cordless phones, Wi-Fi, powerlines or wireless smart meters (Seitz et al., 2005; Baliatsas et al., 2011; Atzmon et al., 2012; Eskander et al., 2012; Frei et al., 2012; Lamech, 2014; Singh and Pati, 2016; Boehmert et al., 2020; Akkam et al., 2020). Some studied the effects of radio or television antennas (Milham 1988; Maskarinec et al., 1994; Hocking et al., 1996; Dolk et al., 1997 a and b; McKenzie et al., 1998; Michelozzi et al., 1998; Altpeter et al., 2000; Hocking and Gordon, 2000; Boscolo et al., 2001; Cooper et al., 2001; Michelozzi et al., 2002; Hallberg and Johansson, 2002; Elwood, 2003; Ha et al., 2003; Park et al., 2004; Abelin et al., 2005; Altpeter et al., 2006; Ha et al., 2007; Satta et al., 2018). Others were radar studies (Kolodynski and Kolodynska, 1996; Goldsmith, 1997; Szmigielski et al., 2001; Yakymenko et al., 2011; Schoeni et al., 2016; Martens et al., 2018). Some studies performed experiments in a laboratory, exposure chamber or adapted room, with simulated or real electromagnetic radiation from base station antennas (e.g. Zwamborn et al., 2003; Hinrichs et al., 2005; Regel et al., 2006 and 2007; Eltiti et al., 2007; Leitgeb et al., 2008; Riddervold et al., 2008; Augner et al., 2009; Augner et al., 2010; Wallace et al., 2010; Danker-Hopfe et al., 2010; Falcioni et al., 2018; Azimzadehand Jelodar, 2019; Smith-Roe et al., 2020). Some reports were comments or criticisms of previously published studies (e.g. Coggon, 2006; Rössli and Huss, 2008; Bithell, 2010; Dode and Leão, 2012; Foster and Trotter, 2012; Mortazavi, 2014 and 2017).

## Discussion

The results of this review show three types of effects by base station antennas on the health of humans: radiofrequency sickness, cancer and changes in biochemical parameters (Figure 1). From among all these studies, most of them found effects (73.6%). Thus, despite some limitations and differences in study design, statistical measures, risk estimates and exposure categories (Khurana et al., 2010), together they provide a consistent view of the effects on the health of people living in the vicinity of base station antennas.

Studies conducted in large regions with numerous antennas, based on surveys and geographic data (e.g. Augner and Hacker, 2009; Dode et al., 2011; Baliatsas et al., 2016; Martens et al., 2017; Dode et al. al., 2021), have the limitation that there may be many factors other than the base station antennas affecting the health of the population (environmental and occupational determinants of diseases and symptoms, individual characteristics such as food and life habits, activity level, smoking, self-medication, individual pathologies or genetic factors) that can act as confounding factors. It is important to mention here that the meters used for power density measurements in research papers should have more high quality equipment and better measurement methods.

On the other hand, some studies did not meet the strict conditions to be considered in this review, but due to their importance regarding the similarities of the electromagnetic radiation types involved and the effects found in many cases, they provide important supplementary evidence, as we will see in the next paragraphs.

For example, mobile phone users had an increased risk of headache (one of the typical symptoms for RF sickness near base station antennas) compared with non-users, and the risk of headache was also increased in those who had a longer daily call duration and higher daily call frequency (Wang et al., 2017). The same was also seen with cancer (Hardell et al., 2007). On the other hand, the symptoms caused by wireless smart meters were similar to those reported by people exposed to RF fields emitted by mobile phones (Lamech, 2014).

### Investigations with radar and radio/television antennas

In studies carried out in the last century, occupational exposure of people to microwave radiation (RF) related to military, industrial and radio uses, as well as radio waves, showed several types of effects: an increase in spontaneous abortions, changes in red and white blood cell counts and an increase in childhood, testicular and other cancers. These findings suggest that RF exposures are potentially carcinogenic and have other health effects; the author recommends precautionary measures to avoid unnecessary exposure (Goldsmith, 1997). An analysis of particular locations of diagnosed neoplasms indicates significantly higher morbidity rates in the military exposed to RF for alimentary tract cancers, skin tumours, neoplasms and cerebral and haematological/lymphatic malignancies. For haematological/lymphatic malignancies, the difference in morbidity between exposed and unexposed military was the largest. This may suggest that spontaneous neoplasms develop faster in the exposed group, with a shorter latency period than in those not exposed. In fact, in exposed subjects, the disease occurs 5–10 years earlier (Szmigielski et al., 2001). On the other hand, children exposed to radar electromagnetic radiation had less developed memory and attention, their reaction time was slower and their neuromuscular apparatus endurance was decreased (Kolodynski and Kolodynska, 1996).

In several studies performed around radio and television antennas, there was a significant decrease in the risk of cancer and leukaemia with increasing distance to the antennas (Maskarinec et al., 1994; Dolk et al., 1997; Hocking and Gordon, 2000; Michelozzi et al., 2002; Park et al., 2004). People exposed to a radio antenna shortwave broadcasting station

in Schwarzenburg (Switzerland) had sleep disturbances, which were more frequent in exposed than in unexposed subjects (Altpeter et al., 2000).

Thus, the coincidences of similar effects from studies with different sources of electromagnetic radiation (but with similar pulsed, polarized and modulated radiation), such as radar or radio/television antennas, reinforce the conclusions of this review. Non-ionizing EMF are among the fastest growing forms of environmental pollution, its increase around the world in recent years has been exponential (Bandara and Carpenter, 2018) and symptoms reported today may be classic microwave/RF sickness (Levitt and Lai, 2010).

### **RF exposure incidents among diplomats (Havanna Syndrome)**

From late 2016 through August 2017, US government personnel on a diplomatic mission in Havana, Cuba, reported neurological symptoms, including cognitive, balance, visual and hearing disturbances, sleep disturbances and headaches. These individuals appeared to have sustained injuries to generalized brain networks with no associated history of head trauma (Swanson et al., 2018). They complained of cognitive decline, fatigue and headache, especially after cognitive exertion, and in some cases tinnitus, nausea and balance problems (Dyer, 2018). This mysterious disease that affected US and Canadian diplomats in Cuba (and later also in China) has confused the FBI, the State Department and US intelligence agencies.

The reported facts seem consistent with pulsed RF/microwave as the source of injuries to the affected diplomats (Golomb, 2018). The same conclusion was later reached by the National Academy of Sciences (2020), who reported that many of the chronic or non-specific symptoms were consistent with known effects of RF, such as dizziness, headache, fatigue, nausea, anxiety, cognitive deficits and memory loss. In general, directed pulsed RF energy appears to be the most plausible mechanism to explain these cases. Such symptoms had already been described much earlier at the Moscow embassy (Lilienfeld et al., 1978; Johnson Lyakouris, 1998).

There are objective pathophysiological changes and health effects induced by EMF exposure that can biologically damage the organism and are noxious agents in healthy people (Belpomme and Irigaray, 2022).

### **Important laboratory studies**

The United States National Toxicology Program (NTP) tested the two main modulation types used for mobile phones worldwide for GSM (2G) and UMTS (3G/4G), in a two-year rodent cancer bioassay under near-field exposure conditions; the experiments included additional assays for genotoxicity endpoints (Smith-Roe et al., 2020). They found clear evidence of carcinogenic activity, and more specifically malignant schwannomas of the heart, malignant gliomas of the brain and benign, malignant or complex pheochromocytomas (combined) of the adrenal medulla. They also found increased DNA damage (measured by the comet assay) in the frontal cortex of male mice, in the leukocytes of female mice and in the hippocampus of male rats, indicating that mobile phone EMF could cause DNA damage and consequent carcinogenesis. In a similar large carcinogenicity study by the Ramazzini Institute, Falcioni et al. (2018) examined far-field exposure to GSM 1800 MHz EMF and reported very similar results to the NTP study. Specifically, they also found increased incidence of tumours of the brain and heart in the mobile phone EMF-exposed Sprague-Dawley rats. Furthermore, these tumours are of the same histotype as those observed in some epidemiological studies on mobile phone users (Hardell et al., 2007).

Kostoff et al. (2020) emphasizes that most of the laboratory experiments conducted to date were not designed to identify the more severe adverse effects reflective of the real-life



operating environment in which wireless radiation systems operate, as many experiments do not include pulsing and modulation of the carrier signal and the majority do not account for synergistic adverse effects of other toxic stimuli.

### **Importance of studies with biological parameters and those performed on animals and plants**

Despite the scientific evidence shown in the studies carried out in many countries by different teams of researchers that we have reviewed, several studies conclude that no effects are found and blame it on risk perception and the placebo effect (Wiedemann et al., 2006; Kowall et al., 2012; Freudenstein et al., 2015; Dieudonné, 2016; Klaps et al., 2016; Koh et al., 2020). However, the placebo effect is not supported by objective data (Belpomme and Irigaray, 2022), by the results of cancer studies (Eger et al., 2004; Wolf and Wolf, 2004; Dode et al., 2011; Li et al., 2012; Rodrigues et al., 2021), by studies on changes in haematological parameters (Gandhi et al., 2015; Meo et al., 2015; Taheri et al., 2017; Zothansiana et al., 2017), by hormonal changes after long-term exposure (Eskander et al., 2012), by salivary secretion (Singh et al., 2016) and by effects on fertility (Al-Quzwini et al., 2016). Many reviews on the health effects of mobile phones have reached the same conclusions regarding their effects on male infertility (El-Hamd and Aboeldahab, 2018). Unfortunately, the studies that allude to the placebo effect seem to be the ones taken into account by the World Health Organization (WHO, 2015).

On the other hand, studies performed on animals or trees near base station antennas are especially important, because animals and plants cannot be aware of their proximity and therefore placebo or psychosomatic effects cannot be attributed (Balmori, 2005, 2010; Balmori and Hallberg, 2007; Hässig et al., 2012; Lázaro et al., 2016; Waldmann-Selsam et al., 2016; Levitt et al., 2021).

Moreover, for these effects, perfectly plausible mechanisms of action have already been proposed. Plasma membrane calcium channels and other voltage-gated ion channels are irregularly activated/inactivated by man-made EMF in both animals and plants, increasing intracellular  $[Ca^{2+}]$  and altering intracellular ion concentrations (Panagopoulos et al., 2002; 2021; Pall, 2016).

Under the influence of non-thermal intensities of microwave radiation, often there are important signals of some hazardous changes in cell metabolism. A significant increase of reactive oxygen species and nitrogen oxide generation in cells under non-thermal intensities has been detected both in vivo and in vitro (Yakimenko et al., 2011; Belpomme and Irigaray, 2022). Thus, the different findings clearly argue for a causal role of EMF in inducing free radical species, including overproduction of reactive oxygen and nitrogen species or suppression of antioxidant defence in cells (Belpomme and Irigaray, 2022). Furthermore, this exposure can result in DNA damage through oxidative stress with reactive oxygen species/free radical overproduction (Yakymenko et al., 2011; Kivrak et al., 2017; Panagopoulos et al., 2021).

### **The Precautionary Principle**

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) is a private organization that issues exposure guidelines that are then adopted by governments, but it has been accused of having conflicts of interest (Hardell & Carlberg 2020; Hardell et al. 2021). The ICNIRP (2010, 2020) limits are thousands of times above the levels where effects are recorded for both extremely low frequency and RF man-made EMF and account only for thermal effects, whereas the vast majority of recorded effects are non-thermal. These existing guidelines for public health protection only consider the effects of acute intense (thermal) exposures and do not protect from lower level long-term exposures (Israel et al., 2011;



Yakimenko et al., 2011; Blank et al., 2015; Starkey, 2016; Belpomme and Irigaray, 2022). The exposure duration is crucial to assess the induced effects.

The Precautionary Principle is one of the fundamental principles of the European Union, governing policies related to the environment, health and food safety (Harremoes et al., 2013). This principle enables decision-makers to adopt precautionary measures when the scientific evidence regarding an environmental or human health factor is not certain regarding its safety. Therefore, despite the existing ample and rapidly increasing scientific evidence, no significant progress has been made over all these years, at least at the level of guidelines issued by the responsible authorities and official regulatory bodies. Some authors have pointed out that the source of funding correlates with study findings, and many systematic reviews and meta-analyses in this field have failed to correct for this source of funding bias, which has likely underestimated the evidence for causation (Carpenter, 2019). A growing number of scientists have been calling internationally on governments to raise their safety standards for RF-EMF (Blank et al., 2015; Hardell and Nyberg, 2020; Frank, 2021). Thus, there is an urgent need to adopt the Precautionary Principle and impose more restrictive levels (Zinelis, 2010, Yakymenko et al., 2011; Blank et al., 2015; Starkey, 2016).

### **Conclusion**

In the current circumstances, it seems that the scientific experts in the field are very clear about the serious problems we are facing and have expressed this through important appeals (Blank et al., 2015; Hardell and Nyberg, 2020). However, the media, the responsible organizations (World Health Organization, 2015) and the governments are not transmitting this crucial information to the population, who remain uninformed. For these reasons, the current situation will probably end in a crisis not only for health but also for the technology itself, as it is unsustainable and harmful to the environment and the people.

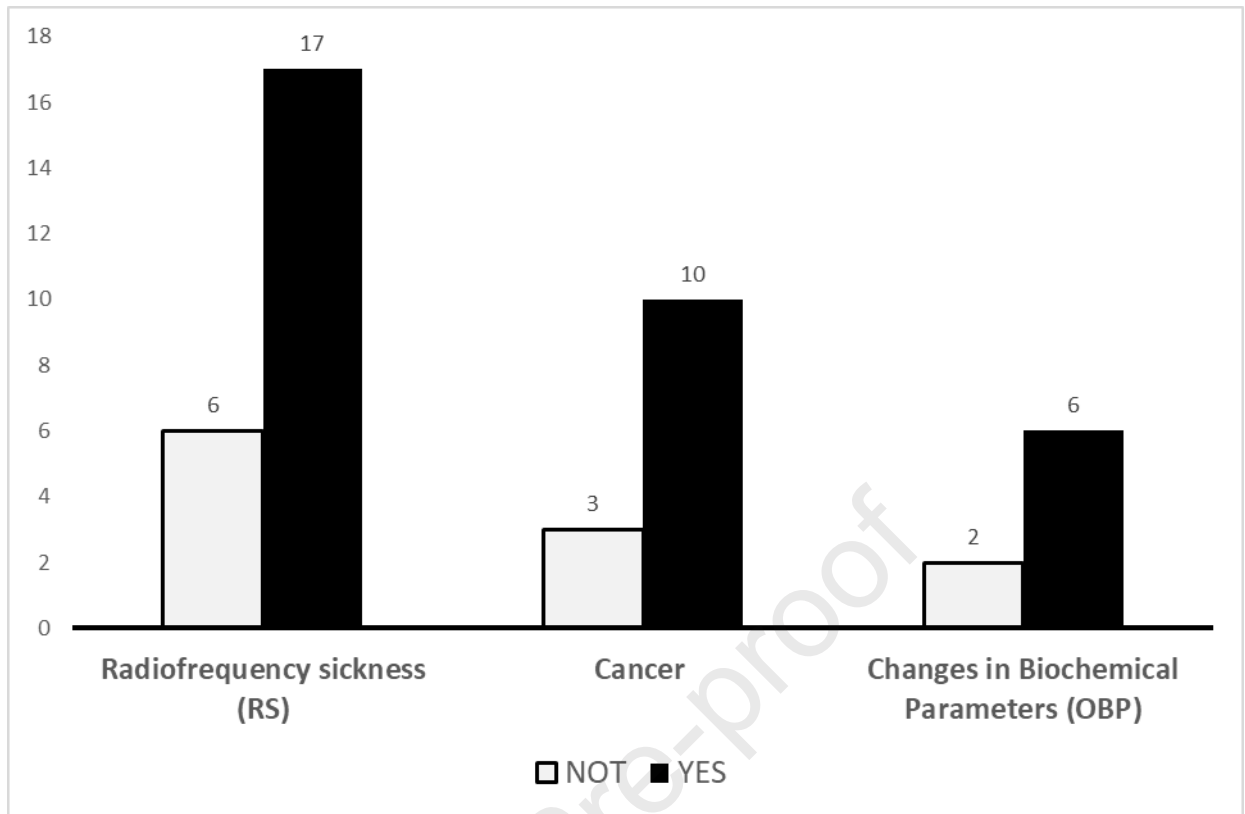


Figure 1. Results on effects according to the study type considered

## References

- Abelin, T., Altpeter, E., & Rösli, M. (2005). Sleep disturbances in the vicinity of the short-wave broadcast transmitter Schwarzenburg. *Somnologie-Schlafforschung und Schlafmedizin*, 9(4), 203-209.
- Akkam, Y., Al-Taani, A., Ayasreh, S., Almutairi, A., & Akkam, N. (2020). Correlation of blood oxidative stress parameters to indoor radiofrequency radiation: A cross sectional study in Jordan. *International Journal of Environmental Research and Public Health*, 17(13), 4673.
- Alazawi, S.A. (2011) Mobile Phone Base Stations Health Effects, *Diyala Journal of Medicine*, 1:1, 44–52.
- Alhekail, Z. O., Hadi, M. A., & Alkanhal, M. A. (2012). Public safety assessment of electromagnetic radiation exposure from mobile base stations. *Journal of Radiological Protection*, 32(3), 325.
- Altpeter, E., Battaglia, M., Bader, A., Pfluger, D., Minder, C. E., & Abelin, T. (2000, June). Ten years experience with epidemiological research in the vicinity of the short-wave broadcasting area Schwarzenburg: what does the story tell us. In *Proceedings of the International Conference on Cell Tower Siting*. Salzburg, Austria (pp. 7-8).
- Altpeter, E. S., Rösli, M., Battaglia, M., Pfluger, D., Minder, C. E., & Abelin, T. (2006). Effect of short-wave (6–22 MHz) magnetic fields on sleep quality and melatonin cycle in humans: the Schwarzenburg shut-down study. *Bioelectromagnetics*, 27(2), 142-150.
- Abdel-Rassoul, G., Abou El-Fateh, O., Abou Salem, M., Michael, A., Farahat, F., El-Batanouny, M., & Salem, E. (2007). Neurobehavioral effects among inhabitants around mobile phone base stations. *Neurotoxicology*, 28(2), 434-440.
- Admawi, H. K. (2021). Assessment of Electromagnetic Pollution in Some Hospitals and Schools in Al-Najaf City. *Journal of Engineering*, 27(3), 1-14.
- Ali, M. T., Muhsen, Y. R., Chisab, R. F., & Abed, S. N. (2021). Evaluation Study of Radio Frequency Radiation Effects from Cell Phone Towers on Human Health. *Radioelectronics and Communications Systems*, 64(3), 155-164.
- Al-Quzwini, O. F., Al-Taee, H. A., & Al-Shaikh, S. F. (2016). Male fertility and its association with occupational and mobile phone towers hazards: an analytic study. *Middle East Fertility Society Journal*, 21(4), 236-240.
- Altpeter, E., Battaglia, M., Bader, A., Pfluger, D., Minder, C. E., & Abelin, T. (2000). Ten years experience with epidemiological research in the vicinity of the short-wave broadcasting area Schwarzenburg: what does the story tell us. In *Proceedings of the International Conference on Cell Tower Siting*, Salzburg, Austria (Vol. 78, pp. 127-132).

- Aniolczyk, H. (1999). Electromagnetic field pattern in the environment of GSM base stations. *Int. J. Occup. Med. Environ. Health*, 12(1), 47-58.
- Atzmon, I., Linn, S., Richter, E., & Portnov, B. A. (2012). Cancer risks in the Druze Isifya Village: Reasons and RF/MW antennas. *Pathophysiology*, 19(1), 21-28.
- Augner, C., & Hacker, G. W. (2009). Are people living next to mobile phone base stations more strained? Relationship of health concerns, self-estimated distance to base station, and psychological parameters. *Indian Journal of Occupational and Environmental Medicine*, 13(3), 141.
- Augner, C., Florian, M., Pauser, G., Oberfeld, G., & Hacker, G. W. (2009). GSM base stations: Short-term effects on well-being. *Bioelectromagnetics*, 30(1), 73-80.
- Augner, C., Hacker, G. W., Oberfeld, G., Florian, M., Hitzl, W., Hutter, J., & Pauser, G. (2010). Effects of exposure to GSM mobile phone base station signals on salivary cortisol, alpha-amylase, and immunoglobulin A. *Biomedical and Environmental Sciences*, 23(3), 199-207.
- Azimzadeh, M., & Jelodar, G. (2019). Alteration of testicular regulatory and functional molecules following long-time exposure to 900 MHz RFW emitted from BTS. *Andrologia*, 51(9), e13372.
- Baliatsas, C., van Kamp, I., Kelfkens, G., Schipper, M., Bolte, J., Yzermans, J., & Lebrecht, E. (2011). Non-specific physical symptoms in relation to actual and perceived proximity to mobile phone base stations and powerlines. *BMC Public Health*, 11(1), 1-12.
- Baliatsas, C., van Kamp, I., Bolte, J., Kelfkens, G., van Dijk, C., Spreeuwenberg, P., ... & Yzermans, J. (2016). Clinically defined non-specific symptoms in the vicinity of mobile phone base stations: A retrospective before-after study. *Science of the Total Environment*, 565, 714-720.
- Balmori, A. (2005). Possible effects of electromagnetic fields from phone masts on a population of white stork (*Ciconia ciconia*). *Electromagnetic Biology and Medicine*, 24(2), 109-119.
- Balmori, A., and Hallberg, Ö. (2007). The urban decline of the house sparrow (*Passer domesticus*): a possible link with electromagnetic radiation. *Electromagnetic Biology and Medicine*, 26(2), 141-151.
- Balmori, A. (2010). Mobile phone mast effects on common frog (*Rana temporaria*) tadpoles: the city turned into a laboratory. *Electromagnetic Biology and Medicine*, 29(1-12), 31-35.
- Bandara, P., & Carpenter, D. O. (2018). Planetary electromagnetic pollution: it is time to assess its impact. *The Lancet Planetary Health*, 2(12), e512-e514.

- Beekhuizen, J., Vermeulen, R., Kromhout, H., Bürgi, A., & Huss, A. (2013). Geospatial modelling of electromagnetic fields from mobile phone base stations. *Science of the total environment*, 445, 202-209.
- Belpomme, D., and Irigaray, P. (2022). Why electrohypersensitivity and related symptoms are caused by non-ionizing man-made electromagnetic fields: An overview and medical assessment. *Environmental Research*, 113374.
- Berg-Beckhoff, G., Blettner, M., Kowall, B., Breckenkamp, J., Schlehofer, B., Schmiedel, S., ... & Schüz, J. (2009). Mobile phone base stations and adverse health effects: phase 2 of a cross-sectional study with measured radio frequency electromagnetic fields. *Occupational and environmental medicine*, 66(2), 124-130.
- Bithell, J. F. (2010). Childhood cancer and proximity to mobile phone masts. *Bmj*, 340.
- Blank, M., Havas, M., Kelley, E., Lai, H., & Moskowitz, J. (2015). International Appeal: Scientists call for protection from non-ionizing electromagnetic field exposure. *Eur. J. Oncol*, 20(3/4), 180-2.
- Blettner, M., Schlehofer, B., Breckenkamp, J., Kowall, B., Schmiedel, S., Reis, U., ... & Berg-Beckhoff, G. (2009). Mobile phone base stations and adverse health effects: phase 1 of a population-based, cross-sectional study in Germany. *Occupational and environmental medicine*, 66(2), 118-123.
- Boehmert, C., Freudenstein, F., & Wiedemann, P. (2020). A systematic review of health risk communication about EMFs from wireless technologies. *Journal of Risk Research*, 23(5), 571-597.
- Bortkiewicz, A., Zmyślony, M., Szyjowska, A., & Gadzicka, E. (2004). Subjective symptoms reported by people living in the vicinity of cellular phone base stations: review. *Medycyna pracy*, 55(4), 345-351.
- Boscolo, P., Di Sciascio, M. B., D'ostilio, S., Del Signore, A., Reale, M., Conti, P., ... & Di Gioacchino, M. (2001). Effects of electromagnetic fields produced by radiotelevision broadcasting stations on the immune system of women. *Science of the Total Environment*, 273(1-3), 1-10.
- Breckenkamp, J., Blettner, M., Schüz, J., Bornkessel, C., Schmiedel, S., Schlehofer, B., & Berg-Beckhoff, G. (2012). Residential characteristics and radiofrequency electromagnetic field exposures from bedroom measurements in Germany. *Radiation and environmental biophysics*, 51(1), 85-92.
- Bürgi, A., Theis, G., Siegenthaler, A., & Rösli, M. (2008). Exposure modeling of high-frequency electromagnetic fields. *Journal of exposure science & environmental epidemiology*, 18(2), 183-191.

- Bürge, A., Scanferla, D., & Lehmann, H. (2014). Time averaged transmitter power and exposure to electromagnetic fields from mobile phone base stations. *International journal of environmental research and public health*, 11(8), 8025-8037.
- Carpenter, D. O. (2019). Extremely low frequency electromagnetic fields and cancer: how source of funding affects results. *Environmental research*, 178, 108688.
- Chen, H. Y., & Chuang, C. Y. (2009). Currents induced in human bodies during radiofrequency exposure near a cellular phone base station. *Electromagnetics*, 29(1), 13-23.
- Coggon, D. (2006). Health risks from mobile phone base stations. *Occupational and Environmental Medicine*, 63(5), 298-299.
- Cooper D, Hemmings K, Saunders P. Re: "Cancer incidence near radio and television transmitters in Great Britain. I. Sutton Coldfield transmitter"; II. All high power transmitters. *Am J Epidemiol*. 2001;153: 202–204
- Danker-Hopfe, H., Dorn, H., Bornkessel, C., & Sauter, C. (2010). Do mobile phone base stations affect sleep of residents? Results from an experimental double-blind sham-controlled field study. *American Journal of Human Biology*, 22(5), 613-618.
- De Giudici, P., Genier, J. C., Martin, S., Doré, J. F., Ducimetiere, P., Evrard, A. S., ... & Ségala, C. (2021). Radiofrequency exposure of people living near mobile-phone base stations in France. *Environmental Research*, 194, 110500.
- Dieudonné, M. (2016). Does electromagnetic hypersensitivity originate from nocebo responses? Indications from a qualitative study. *Bioelectromagnetics*, 37(1), 14-24.
- Dode, A. C., & Leao, M. M. (2011). Tjo Fde A, Gomes AC, Dode DC, Dode MC, Moreira CW, Condessa VA, Albinatti C, and Caiaffa WT. Mortality by neoplasia and cellular telephone base stations in the Belo Horizonte municipality, Minas Gerais state, Brazil. *Science of the Total Environment*, 409, 3649-65.
- Dode, A. C., & Leão, M. M. (2012). Comments on" Foster KR, Trottier L, comments on" mortality by neoplasia and cellular telephone base stations in the Belo Horizonte municipality, Minas Gerais state,...," *Sci Total Environ* (2012. The Science of the total environment, 442, 553-556.
- Dohle, S., Keller, C., & Siegrist, M. (2012). Mobile communication in the public mind: Insights from free associations related to mobile phone base stations. *Human and Ecological Risk Assessment: An International Journal*, 18(3), 649-668.
- Dolk, H., Shaddick, G., Walls, P., Grundy, C., Thakrar, B., Kleinschmidt, I., & Elliott, P. (1997). Cancer incidence near radio and television transmitters in Great Britain I. Sutton Coldfield transmitter. *American journal of epidemiology*, 145(1), 1-9.

- Dolk, H., Elliot, G., Shaddick, G., Walls, P. & B. Thakrar (1997): Cancer Incidence Near Radio and Television Transmitters in Great Britain, Part 2. All High Tower Transmitters, *Am. J. Epidemiol.* 145: 10-17.
- Dyer, O. (2018). Microwave weapon caused syndrome in diplomats in Cuba, US medical team believes. *BMJ: British Medical Journal (Online)*, 362.
- Eger, H., Hagen, K. U., Lucas, B., Vogel, P., & Voit, H. (2004). Einfluss der räumlichen Nähe von Mobilfunkseanlagen auf die Krebsinzidenz. *Umwelt-Medizin-Gesellschaft*, 17(4), 326-35.
- Eger, H., and Jahn, M. (2010). Specific health symptoms and cell phone radiation in Selbitz (Bavaria, Germany)—Evidence of a dose-response relationship. *umwelt-medizin-gesellschaft*, 23: 130-139.
- El-Hamd, M. A., & Aboeldahab, S. (2018). Cell phone and male infertility: An update. *Journal of Integrative Nephrology and Andrology*, 5(1), 1.
- Elliott, P., Toledano, M. B., Bennett, J., Beale, L., De Hoogh, K., Best, N., & Briggs, D. J. (2010). Mobile phone base stations and early childhood cancers: case-control study. *Bmj*, 340.
- Eltiti, S., Wallace, D., Ridgewell, A., Zougkou, K., Russo, R., Sepulveda, F., ... & Fox, E. (2007). Does short-term exposure to mobile phone base station signals increase symptoms in individuals who report sensitivity to electromagnetic fields? A double-blind randomized provocation study. *Environmental health perspectives*, 115(11), 1603-1608.
- Elwood, J. M. (2003). Epidemiological studies of radio frequency exposures and human cancer. *Bioelectromagnetics*, 24(S6), S63-S73.
- Eskander, E. F., Estefan, S. F., & Abd-Rabou, A. A. (2012). How does long term exposure to base stations and mobile phones affect human hormone profiles?. *Clinical biochemistry*, 45(1-2), 157-161.
- Falcioni, L., Bua, L., Tibaldi, E., Lauriola, M., De Angelis, L., Gnudi, F., & Belpoggi, F. (2018). Report of final results regarding brain and heart tumors in Sprague-Dawley rats exposed from prenatal life until natural death to mobile phone radiofrequency field representative of a 1.8 GHz GSM base station environmental emission. *Environmental research*, 165, 496-503.
- Foster, K. R., & Trottier, L. (2012). Comments on " Mortality by neoplasia and cellular telephone base stations in the Belo Horizonte municipality, Minas Gerais state, Brazil" by AC Dode et al. *Science of the Total Environment* 409 (2011) 3649-3665. *The Science of the total environment*, 450, 366-368.
- Frank, J. W. (2021). Electromagnetic fields, 5G and health: what about the precautionary principle?. *J Epidemiol Community Health*, 75(6), 562-566.



- Frei, P., Mohler, E., Braun-Fahrlander, C., Fröhlich, J., Neubauer, G., & Rösli, M. (2012). Cohort study on the effects of everyday life radio frequency electromagnetic field exposure on non-specific symptoms and tinnitus. *Environment international*, 38(1), 29-36.
- Freudenstein, F., Wiedemann, P. M., & Brown, T. W. (2015). Exposure perception as a key indicator of risk perception and acceptance of sources of radio frequency electromagnetic fields. *Journal of environmental and public health*, 2015.
- Gandhi, G., Kaur, G., & Nisar, U. (2015). A cross-sectional case control study on genetic damage in individuals residing in the vicinity of a mobile phone base station. *Electromagnetic biology and medicine*, 34(4), 344-354.
- Goldsmith, J. R. (1997). Epidemiologic evidence relevant to radar (microwave) effects. *Environmental Health Perspectives*, 105(suppl 6), 1579-1587.
- Golomb, B. A. (2018). Diplomats' mystery illness and pulsed radiofrequency/microwave radiation. *Neural computation*, 30(11), 2882-2985.
- Gómez-Perretta, C., Navarro, E. A., Segura, J., & Portolés, M. (2013). Subjective symptoms related to GSM radiation from mobile phone base stations: a cross-sectional study. *BMJ open*, 3(12), e003836.
- Ha, M., Lim, H. J., Cho, S. H., Choi, H. D., & Cho, K. Y. (2003). Incidence of cancer in the vicinity of Korean AM radio transmitters. *Archives of Environmental Health*, 58(12), 756-762.
- Ha, M., Im, H., Lee, M., Kim, H. J., Kim, B. C., Gimm, Y. M., & Pack, J. K. (2007). Radio-frequency radiation exposure from AM radio transmitters and childhood leukemia and brain cancer. *American journal of epidemiology*, 166(3), 270-279.
- Hansson, B., Thors, B., & Törnevik, C. (2011). Analysis of the effect of mobile phone base station antenna loading on localized SAR and its consequences for measurements. *Bioelectromagnetics*, 32(8), 664-672.
- Hallberg, Ö., & Johansson, O. (2002). Melanoma incidence and frequency modulation (FM) broadcasting. *Archives of Environmental Health*, 57(1), 32-40.
- Hardell L., Carlberg M., Söderqvist F., Mild K. H., Morgan L. L. (2007). Long-term use of cellular phones and brain tumours: increased risk associated with use for > or =10 years. *Occup Environ Med*. 64(9):626-32. Review.
- Hardell, L., Carlberg, M., & Hedendahl, L. K. (2018). Radiofrequency radiation from nearby base stations gives high levels in an apartment in Stockholm, Sweden: A case report. *Oncology letters*, 15(5), 7871-7883.

- Hardell, L., and Carlberg, M. (2020). [Comment] Health risks from radiofrequency radiation, including 5G, should be assessed by experts with no conflicts of interest. *Oncology Letters*, 20(4), 1-1.
- Hardell, L., and Nyberg, R. (2020). [Comment] Appeals that matter or not on a moratorium on the deployment of the fifth generation, 5G, for microwave radiation. *Molecular and Clinical Oncology*, 12(3), 247-257.
- Hardell, L., Nilsson, M., Koppel, T., and Carlberg, M. (2021). Aspects on the International Commission on Non-Ionizing Radiation Protection (ICNIRP) 2020 Guidelines on Radiofrequency Radiation. *Journal of Cancer Science and Clinical Therapeutics*, 5(2), 250-285.
- Harremoës, P., Gee, D., MacGarvin, M., Stirling, A., Keys, J., Wynne, B., and Vaz, S. G. (Eds.). (2013). *The precautionary principle in the 20th century: Late lessons from early warnings*. Routledge. London.
- Hässig, M., Jud, F., & Spiess, B. (2012). Increased occurrence of nuclear cataract in the calf after erection of a mobile phone base station. *Schweizer Archiv Fur Tierheilkunde*, 154(2), 82-86.
- Henderson, S. I., & Bangay, M. J. (2006). Survey of RF exposure levels from mobile telephone base stations in Australia. *Bioelectromagnetics: Journal of the Bioelectromagnetics Society, The Society for Physical Regulation in Biology and Medicine, The European Bioelectromagnetics Association*, 27(1), 73-76.
- Hinrichs, H., Heinze, H. J., & Rotte, M. (2005). Human sleep under the influence of a GSM 1800 electromagnetic far field. *Somnologie-Schlafforschung und Schlafmedizin*, 9(4), 185-191.
- Hocking, B., Gordon, I. R., Grain, H. L., & Hatfield, G. E. (1996). Cancer incidence and mortality and proximity to TV towers. *Medical Journal of Australia*, 165(11-12), 601-605.
- Hocking, B., & Gordon, I. (2000). Decreased survival for childhood leukemia in proximity to TV towers. In Poster presented at the annual scientific meeting of the Royal Australian College of Physicians in Adelaide, SA, Australia.
- Hutter, H. P., Moshhammer, H., Wallner, P., & Kundi, M. (2006). Subjective symptoms, sleeping problems, and cognitive performance in subjects living near mobile phone base stations. *Occupational and Environmental medicine*, 63(5), 307-313.
- Hutter, H. P., Moshhammer, H., & Kundi, M. (2002, October). Mobile Telephone base-stations: Effects on health and wellbeing. In *2nd Workshop on Biological Effects of EMFs* (Vol. 7, No. 11).

- ICNIRP, (2010). "Guidelines for limiting exposure to time-varying electric and magnetic fields (1Hz to 100 kHz)", *Health Phys.* 99(6):818-836.
- ICNIRP, (2020). "Guidelines for limiting exposure to electromagnetic fields (100 kHz to 300 GHz)", *Health Phys.* 118(5):483-524.
- Islam, S., & Mohammed, S. (2014). Awareness and self-reported health hazards of electromagnetic waves from mobile phone towers in Dhaka, Bangladesh: A pilot study. *Advances in Public Health*, 2014.
- Johnson Lyakouris, A. G. 1998. "Radiofrequency (RF) Sickness in the Lilienfeld Study: An Effect of Modulated Microwaves?" *Archives of Environmental Health*, 53, No. 3 (1998).
- Kazaure, J. S., Matthew, U. O., Okafor, N. U., & Okey, O. D. (2021). Telecommunication Network Performances and Evaluation of Radio Frequency Electromagnetic Radiation: Health Effects of the RF-EMR GSM Base Stations. *International Journal of Information Communication Technologies and Human Development (IJICTHD)*, 13(3), 16-37.
- Keow, M. A., & Radiman, S. (2006). Assessment of radiofrequency/microwave radiation emitted by the antennas of rooftop-mounted mobile phone base stations. *Radiation protection dosimetry*, 121(2), 122-127.
- 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. *International journal of occupational and environmental health*, 16(3), 263-267.
- Kivrak, E. G., Yurt, K. K., Kaplan, A. A., Alkan, I., & Altun, G. (2017). Effects of electromagnetic fields exposure on the antioxidant defense system. *Journal of Microscopy and Ultrastructure*, 5(4), 167-176.
- Klaps, A., Ponocny, I., Winker, R., Kundi, M., Auersperg, F., & Barth, A. (2016). Mobile phone base stations and well-being—A meta-analysis. *Science of the Total Environment*, 544, 24-30.
- Koh, T. H., Choi, J. W., Seo, M., Choi, H. D., & Kim, K. (2020). Factors Affecting Risk Perception of Electromagnetic Waves From 5G Network Base Stations. *Bioelectromagnetics*, 41(7), 491-499.
- Kolodynski, A. A., & Kolodynska, V. V. (1996). Motor and psychological functions of school children living in the area of the Skrunnda Radio Location Station in Latvia. *Science of the Total Environment*, 180(1), 87-93.
- Kostoff, R. N., Heroux, P., Aschner, M., & Tsatsakis, A. (2020). Adverse health effects of 5G mobile networking technology under real-life conditions. *Toxicology Letters*, 323, 35-40.
- Kundi, M., & Hutter, H. P. (2009). Mobile phone base stations—Effects on wellbeing and health. *Pathophysiology*, 16(2-3), 123-135.

- Kowall, B., Breckenkamp, J., Blettner, M., Schlehofer, B., Schüz, J., & Berg-Beckhoff, G. (2012). Determinants and stability over time of perception of health risks related to mobile phone base stations. *International journal of public health*, 57(4), 735-743.
- Lamech, F. (2014). Self-reporting of symptom development from exposure to radiofrequency fields of wireless smart meters in Victoria, Australia: a case series. *Alternative therapies in health and medicine*, 20(6), 28.
- Lázaro, A., Chroni, A., Tscheulin, T., Devalez, J., Matsoukas, C., and Petanidou, T. (2016). Electromagnetic radiation of mobile telecommunication antennas affects the abundance and composition of wild pollinators. *Journal of Insect Conservation*, 20(2), 315-324.
- Lemaire, T., Wiart, J., & De Doncker, P. (2016). Variographic analysis of public exposure to electromagnetic radiation due to cellular base stations. *Bioelectromagnetics*, 37(8), 557-562.
- Leitgeb, N., Schröttner, J., Cech, R., & Kerbl, R. (2008). EMF-protection sleep study near mobile phone base stations. *Somnologie-Schlafforschung und Schlafmedizin*, 12(3), 234-243.
- Levitt, B. B., & Lai, H. (2010). Biological effects from exposure to electromagnetic radiation emitted by cell tower base stations and other antenna arrays. *Environmental Reviews*, 18(NA), 369-395.
- Levitt, B. B., Lai, H. C., and Manville, A. M. (2021). Effects of non-ionizing electromagnetic fields on flora and fauna, Part 2 impacts: how species interact with natural and man-made EMF. *Reviews on Environmental Health*.
- Li, C. Y., Liu, C. C., Chang, Y. H., Chou, L. P., & Ko, M. C. (2012). A population-based case-control study of radiofrequency exposure in relation to childhood neoplasm. *Science of the Total Environment*, 435, 472-478.
- Lilienfeld AM, Tonascia J. Tonascia S. et al. (1978). Foreign Service Health Status Study. Final report contract no. 6025-619037 (NTS publication PB-288163). Washington, DC.: Department of State.
- Lyare, R. N., Volskiy, V., & Vandenbosch, G. A. (2019). Study of the correlation between outdoor and indoor electromagnetic exposure near cellular base stations in Leuven, Belgium. *Environmental research*, 168, 428-438.
- Martens, A. L., Slottje, P., Smid, T., Kromhout, H., Vermeulen, R. C., & Timmermans, D. R. (2018). Longitudinal associations between risk appraisal of base stations for mobile phones, radio or television and non-specific symptoms. *Journal of psychosomatic research*, 112, 81-89.
- Martens, A. L., Slottje, P., Timmermans, D. R., Kromhout, H., Reedijk, M., Vermeulen, R. C., & Smid, T. (2017). Modeled and perceived exposure to radiofrequency electromagnetic

- fields from mobile-phone base stations and the development of symptoms over time in a general population cohort. *American journal of epidemiology*, 186(2), 210-219.
- Martin, S., De Giudici, P., Genier, J. C., Cassagne, E., Doré, J. F., Ducimetière, P., ... & Ségala, C. (2021). Health disturbances and exposure to radiofrequency electromagnetic fields from mobile-phone base stations in French urban areas. *Environmental Research*, 193, 110583.
- Maskarinec, G., Cooper, J., & Swygert, L. (1994). Investigation of increased incidence in childhood leukemia near radio towers in Hawaii: preliminary observations. *Journal of environmental pathology, toxicology and oncology*, 13(1), 33-37.
- McKenzie DR, Yin Y, Morrell S. (1998) Childhood incidence of acute lymphoblastic leukemia and exposure to broadcast radiation in Sydney—a second look. *Aust N Z J Public Health*. 22(3 suppl):360–367
- Meo, S. A., Alsubaie, Y., Almubarak, Z., Almutawa, H., AlQasem, Y., & Hasanato, R. M. (2015). Association of exposure to radio-frequency electromagnetic field radiation (RF-EMFR) generated by mobile phone base stations with glycated hemoglobin (HbA1c) and risk of type 2 diabetes mellitus. *International journal of environmental research and public health*, 12(11), 14519-14528.
- Meo, S. A., Almahmoud, M., Alsultan, Q., Alotaibi, N., Alnajashi, I., & Hajjar, W. M. (2019). Mobile phone base station tower settings adjacent to school buildings: impact on students' cognitive health. *American journal of men's health*, 13(1), 1557988318816914.
- Michelozzi, P., Ancona, C., Fusco, D., Forastiere, F., & Perucci, C. A. (1998). Risk of leukemia and residence near a radio transmitter in Italy. *Epidemiology*, 9(4), S111.
- Michelozzi, P., Capon, A., Kirchmayer, U., Forastiere, F., Biggeri, A., Barca, A., & Perucci, C. A. (2002). Adult and childhood leukemia near a high-power radio station in Rome, Italy. *American journal of epidemiology*, 155(12), 1096-1103.
- Milham Jr, S. (1988). Increased mortality in amateur radio operators due to lymphatic and hematopoietic malignancies. *American journal of epidemiology*, 127(1), 50-54.
- Mortazavi, S. M. J. (2014). Subjective symptoms related to GSM radiation from mobile phone base stations: a cross-sectional study. *Journal of Biomedical Physics and Engineering*, 4(1).
- Mortazavi, S. M. J. (2017). RE:“Modeled and perceived exposure to radiofrequency electromagnetic fields from mobile-phone base stations and the development of symptoms over time in a general population cohort”. *American journal of epidemiology*, 186(10), 1217-1217.

- National Academies of Sciences, Engineering, and Medicine (2020). An assessment of illness in US government employees and their families at overseas embassies.
- Navarro, E. A., Segura, J., Portolés, M., & Gómez-Perretta de Mateo, C. (2003). The microwave syndrome: a preliminary study in Spain. *Electromagnetic biology and medicine*, 22(2-3), 161-169.
- Neitzke, H. P., Osterhoff, J., Peklo, K., & Voigt, H. (2007). Determination of exposure due to mobile phone base stations in an epidemiological study. *Radiation protection dosimetry*, 124(1), 35-39.
- Pachau, L., & Pachau, Z. (2014). Study of Cell Tower Radiation and its Health Hazards on human body. *IOSR Journal of Applied Physics (IOSR-JAP)*, e-ISSN, 2278-4861.
- Pachau, L., Pachau, Z., & Zothansiam. (2015). Comparisons of Non specific Health Symptoms Faced by Inhabitants Exposed to High and Low Power Density from Mobile Phone Tower Radiation. *International Journal on Recent and Innovation Trends in Computing and Communication*, 3(2), 094-098.
- Pall, M. (2016). Electromagnetic fields act similarly in plants as in animals: Probable activation of calcium channels via their voltage sensor. *Current Chemical Biology*, 10(1), 74-82.
- Panagopoulos, D. J., Karabarbounis, A., Margaritis, L.H. (2002). Mechanism for action of electromagnetic fields on cells. *Biochem. Biophys. Res. Commun.* 298, 95–102.
- Panagopoulos, D. J., Karabarbounis, A., Yakymenko, I., and Chrousos, G. P. (2021). Human-made electromagnetic fields: Ion forced-oscillation and voltage-gated ion channel dysfunction, oxidative stress and DNA damage. *International Journal of Oncology*, 59(5), 1-16.
- Park, S. K., Ha, M., & Im, H. J. (2004). Ecological study on residences in the vicinity of AM radio broadcasting towers and cancer death: preliminary observations in Korea. *International archives of occupational and environmental health*, 77(6), 387-394.
- Premlal, P. D., & Eldhose, N. V. (2017). Mobile tower radiation-an assessment of radiation level and its health implications in the residential areas of western ghats in idukki, Kerala. *Int. J. Appl. Eng. Res.* 12(20), 9548-9554.
- Regel, S. J., Negovetic, S., Rössli, M., Berdiñas, V., Schuderer, J., Huss, A., ... & Achermann, P. (2006). UMTS base station-like exposure, well-being, and cognitive performance. *Environmental health perspectives*, 114(8), 1270-1275.
- Regel, S. J., Tinguely, G., Schuderer, J., Adam, M., Kuster, N., LANDOLT, H. P., & Achermann, P. (2007). Pulsed radio-frequency electromagnetic fields: dose-dependent effects on sleep, the sleep EEG and cognitive performance. *Journal of sleep research*, 16(3), 253-258.

- Riddervold, I. S., Pedersen, G. F., Andersen, N. T., Pedersen, A. D., Andersen, J. B., Zachariae, R., ... & Kjærgaard, S. K. (2008). Cognitive function and symptoms in adults and adolescents in relation to rf radiation from UMTS base stations. *Bioelectromagnetics: Journal of the Bioelectromagnetics Society, The Society for Physical Regulation in Biology and Medicine, The European Bioelectromagnetics Association*, 29(4), 257-267.
- Rodrigues, N. C. P., Dode, A. C., Andrade, M. K. D. N., O'Dwyer, G., Monteiro, D. L. M., Reis, I. N. C., ... & Lino, V. T. S. (2021). The Effect of Continuous Low-Intensity Exposure to Electromagnetic Fields from Radio Base Stations to Cancer Mortality in Brazil. *International journal of environmental research and public health*, 18(3), 1229.
- Röösl, M., & Huss, A. (2008). Mobile phone base station exposure and symptoms. *Environmental health perspectives*, 116(2), A62-A63.
- Röösl, M., Frei, P., Mohler, E., & Hug, K. (2010). Systematic review on the health effects of exposure to radiofrequency electromagnetic fields from mobile phone base stations. *Bulletin of the World Health Organization*, 88, 887-896.
- Santini, R., Seigne, M., & Bonhomme-Faivre, L. (2000). Danger des téléphones cellulaires et de leurs stations relais. *Pathologie et biologie*, 48(6), 525-528.
- Santini, R., Santini, P., Seigne, M., & Danze, J. M. (2001). LETTRES-Symptomes exprimes par des riverains de stations relais de telephonie mobile. *Presse Medicale*, 30(32), 1594-1594.
- Santini, R., Santini, P., Danze, J. M., Le Ruz, P., & Seigne, M. (2002). Enquête sur la santé de riverains de stations relais de téléphonie mobile: I/Incidences de la distance et du sexe. *Pathologie Biologie*, 50(6), 369-373.
- Santini, R., Santini, P., Le Ruz, P., Danze, J. M., & Seigne, M. (2003). Survey study of people living in the vicinity of cellular phone base stations. *Electromagnetic biology and Medicine*, 22(1), 41-49.
- Santini, R., Santini, P., Danze, J. M., Le Ruz, P., & Seigne, M. (2003). Symptoms experienced by people in vicinity of base stations: II/Incidences of age, duration of exposure, location of subjects in relation to the antennas and other electromagnetic factors. *Pathologie-biologie*, 51(7), 412-415.
- Satta, G., Mascia, N., Serra, T., Salis, A., Saba, L., Sanna, S., ... & Cocco, P. (2018). Estimates of environmental exposure to radiofrequency electromagnetic fields and risk of lymphoma subtypes. *Radiation research*, 189(5), 541-547.
- Schmiedel, S., Brüggemeyer, H., Philipp, J., Wendler, J., Merzenich, H., & Schüz, J. (2009). An evaluation of exposure metrics in an epidemiologic study on radio and television broadcast transmitters and the risk of childhood leukemia. *Bioelectromagnetics*, 30(2), 81-91.



- Shinjyo, T., & Shinjyo, A. (2014). Significant Decrease of Clinical Symptoms after Mobile Phone Base Station Removal—An Intervention Study. *Umwelt medizin gesellschaft (Environmental Medicine Company)*, 27, 294-301.
- Schoeni, A., Roser, K., Bürgi, A., & Rössli, M. (2016). Symptoms in Swiss adolescents in relation to exposure from fixed site transmitters: a prospective cohort study. *Environmental Health*, 15(1), 1-8.
- Seitz, H., Stinner, D., Eikmann, T., Herr, C., & Rössli, M. (2005). Electromagnetic hypersensitivity (EHS) and subjective health complaints associated with electromagnetic fields of mobile phone communication—a literature review published between 2000 and 2004. *Science of the total environment*, 349(1-3), 45-55.
- Singh, M. M., & Pati, A. K. (2016). Effects of radiation emanating from base transceiver station and mobile phone on sleep, circadian rhythm and cognition in humans—a review. *Biological Rhythm Research*, 47(3), 353-388.
- Singh, K., Nagaraj, A., Yousuf, A., Ganta, S., Pareek, S., & Vishnani, P. (2016). Effect of electromagnetic radiations from mobile phone base stations on general health and salivary function. *Journal of International Society of Preventive & Community Dentistry*, 6(1), 54.
- Smith-Roe, S. L., Wyde, M. E., Stout, M. D., Winters, J. W., Hobbs, C. A., Shepard, K. G., and Witt, K. L. (2020). Evaluation of the genotoxicity of cell phone radiofrequency radiation in male and female rats and mice following subchronic exposure. *Environmental and Molecular Mutagenesis*, 61(2), 276-290.
- Starkey, S. J. (2016). Inaccurate official assessment of radiofrequency safety by the Advisory Group on Non-ionising Radiation. *Reviews on environmental health*, 31(4), 493-503.
- Stewart, A., Rao, J. N., Middleton, J. D., Pearmain, P., & Evans, T. (2012). Mobile telecommunications and health: report of an investigation into an alleged cancer cluster in Sandwell, West Midlands. *Perspectives in public health*, 132(6), 299-304.
- Swanson, R. L., Hampton, S., Green-McKenzie, J., Diaz-Arrastia, R., Grady, M. S., Verma, R., ... & Smith, D. H. (2018). Neurological manifestations among US government personnel reporting directional audible and sensory phenomena in Havana, Cuba. *Jama*, 319(11), 1125-1133.
- Szmigielski, S., Sobiczewska, E., & Kubacki, R. (2001). Carcinogenic potency of microwave radiation: overview of the problem and results of epidemiological studies on Polish military personnel. *European Journal of Oncology*, 6, 193-200.
- Taheri, M., Roshanaei, G., Ghaffari, J., Rahimnejad, S., Khosroshahi, B. N., Aliabadi, M., & Eftekharian, M. M. (2017). The effect of Base Transceiver Station waves on some

- immunological and hematological factors in exposed persons. *Human antibodies*, 25(1-2), 31-37.
- Urbiniello, D., Joseph, W., Huss, A., Verloock, L., Beekhuizen, J., Vermeulen, R., ... & Rösli, M. (2014). Radio-frequency electromagnetic field (RF-EMF) exposure levels in different European outdoor urban environments in comparison with regulatory limits. *Environment international*, 68, 49-54.
- Viel, J. F., Clerc, S., Barrera, C., Rymzhanova, R., Moissonnier, M., Hours, M., & Cardis, E. (2009). Residential exposure to radiofrequency fields from mobile phone base stations, and broadcast transmitters: a population-based survey with personal meter. *Occupational and environmental medicine*, 66(8), 550-556.
- Vijay, S., & Choudhary, M. P. (2017). Study on health effects of mobile tower radiation on human beings. *Int. Res. J. Eng. Technol*, 4(11), 1548-1552.
- Waldmann-Selsam, C., Balmori-de la Puente, A., Breunig, H., and Balmori, A. (2016). Radiofrequency radiation injures trees around mobile phone base stations. *Science of the Total Environment*, 572, 554-569.
- Wang, J., Su, H., Xie, W., & Yu, S. (2017). Mobile phone use and the risk of headache: a systematic review and meta-analysis of cross-sectional studies. *Scientific reports*, 7(1), 1-7.
- Wallace, D., Eltiti, S., Ridgewell, A., Garner, K., Russo, R., Sepulveda, F., ... & Fox, E. (2010). Do TETRA (Airwave) base station signals have a short-term impact on health and well-being? A randomized double-blind provocation study. *Environmental health perspectives*, 118(6), 735-741.
- World Health Organization (WHO) (2015). International EMF Project – Progress Report. [https://cdn.who.int/media/docs/default-source/radiation-international-emf-project-reports/emf-iac-2016-progress-report.pdf?sfvrsn=7b2836c0\\_2](https://cdn.who.int/media/docs/default-source/radiation-international-emf-project-reports/emf-iac-2016-progress-report.pdf?sfvrsn=7b2836c0_2)
- Wiedemann, P. M., Thalmann, A. T., Grutsch, M. A., & Schütz, H. (2006). The impacts of precautionary measures and the disclosure of scientific uncertainty on EMF risk perception and trust. *Journal of risk research*, 9(4), 361-372.
- Wolf, R., & Wolf, D. (2004). Increased incidence of cancer near a cell-phone transmitter station. *International Journal of Cancer Prevention*, 1(2), 123-128.
- 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.
- Yetiş, C., & Kayili, M. T. (2021). Determination of EMF Pollution in the Context of Urban Health: The Case of Safranbolu. *Computational Research Progress in Applied Science &*

Engineering (CRPASE): Transactions of Civil and Environmental Engineering 7 (2021) 1–10. Article ID: 2418.

Yildirim, M. S., Yildirim, A., Zamani, A. G., & Okudan, N. (2010). Effect of mobile phone station on micronucleus frequency and chromosomal aberrations in human blood cells. *Genetic counseling*, 21(2), 243.

Zinelis, S. A. (2010). The precautionary principle: Radiofrequency exposures from mobile telephones and base stations. *Environmental health perspectives*, 118(1), A16-A16.

Zosangzuali, M., Lalremruati, M., Lalmuansangi, C., Nghakliana, F., Pachuau, L., Bandara, P., & Siama, Z. (2021). Effects of radiofrequency electromagnetic radiation emitted from a mobile phone base station on the redox homeostasis in different organs of Swiss albino mice. *Electromagnetic Biology and Medicine*, 1-15.

Zothansياما, Zosangzuali, M., Lalramdinpuii, M., & Jagetia, G. C. (2017). Impact of radiofrequency radiation on DNA damage and antioxidants in peripheral blood lymphocytes of humans residing in the vicinity of mobile phone base stations. *Electromagnetic biology and medicine*, 36(3), 295-305.

Zwamborn APM, Vossen SHJA, van Leersum BJAM, Ouwens MA, Mäkel WN. 2003. Effects of global communication system radio-frequency fields on well being and cognitive functions of human subjects with and without subjective complaints.

Highlights

- This study updates the knowledge on the effects of base station antennas on humans
- Studies performed with mobile phone base stations close to apartments were selected
- Considering all the studies reviewed globally (n=38), 73.6% (28/38) showed effects
- The effects are radiofrequency sickness, cancer and changes in biochemical parameters
- Similar effects from RF by different sources reinforce the conclusions of this review

Journal Pre-proof

**Declaration of interests**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Journal Pre-proof