

## THE EFFECT OF 5G WIRELESS COMMUNICATION STANDARD ON ADULTS AND CHILDREN

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Introduction of the fifth-generation wireless networks (5G) will increase the number of 5G base stations and 5G-enabled devices. This review sought to find the answer to the key question: can such devices be harmful? The review covers scientific data published from 2009 to 2022 and available at eLibrary, PubMed, Google Scholar, Cyberleninka. We investigated the problems of definition, regulation, accumulation of data on 5G networks, and summarized the papers reporting how electromagnetic fields in 5G frequency bands affect adults and children. Despite the large amount of contradictory data, the available studies do not provide adequate information that could enable a meaningful assessment of the safety of 5G networks.

**Keywords:** electromagnetic fields, 5G, children and adolescents, overview, environmental factors, electronic devices

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## ВЛИЯНИЕ ИСПОЛЬЗОВАНИЯ СРЕДСТВ БЕСПРОВОДНОЙ СВЯЗИ СТАНДАРТА 5G НА ВЗРОСЛЫХ И ДЕТЕЙ

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Внедрение беспроводных сетей пятого поколения (5G) увеличит количество базовых станций и других устройств, работающих с этим стандартом связи. Целью настоящего обзора было найти ответ на главный вопрос: могут ли такие устройства оказывать негативное воздействие на здоровье? Поиск информации за период с 2009 по 2022 г. осуществляли с использованием информационных порталов и платформ eLibrary, PubMed, Google Scholar, Cyberleninka. В обзоре рассмотрены проблемы, связанные с определением, нормированием и накоплением данных по сетям 5G. Приведены работы по оценке влияния используемых в сетях 5G электромагнитных полей радиочастотного диапазона на взрослых и детей. Несмотря на большое количество противоречивых данных, имеющиеся исследования не предоставляют адекватной информации, которой было бы достаточно для значимой оценки безопасности сетей 5G.

**Ключевые слова:** электромагнитные поля, 5G, дети и подростки, обзор, факторы среды обитания, электронные устройства

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In the last few decades, we have seen the development of technologies that enable wireless communications, Wi-Fi and cellular networks in particular. The first mobile phones and first-generation base stations were introduced in the 1970s; they were available to few, but as the number of users increased, new generations of wireless communication networks (2G, 3G, 4G) were deployed, each making data transmission faster and relying on new technology. Each subsequent generation uses higher frequency electromagnetic waves to transmit ever larger amounts of data at higher speeds to more places. Currently, the next generation of mobile communication networks is being actively introduced all over the world.

5G is the fifth-generation wireless communication technology. It is the next evolutionary development that replaces 3G and 4G networks and offers improved mobile data transmission capabilities. 5G relies on waves of much higher frequencies (from 3 to 300 GHz). Deployment of 5G networks expectedly entails development of self-driving vehicles, virtual reality and the Internet of Things technologies.

The high frequency waves carrying data within 5G networks commonly fail to penetrate walls of buildings, vegetation, and bounce off steel structures. Therefore, good 5G signal reception in buildings requires amplifiers, and the network antennas must be placed every 100-300 meters, which is much closer than for the previous generation networks. These many sources of electromagnetic radiation can endanger health of the population [3].

This is especially important for preserving health of the young people, since children are sensitive to environmental factors, including those of physical nature. In the second decade of the 21<sup>st</sup> century, both stationary and mobile electronic devices have become ubiquitous in the educational and leisure activities of children, adolescents and youth, which means they are already constantly exposed to electromagnetic radiation emitted by base stations, Wi-Fi spots, smartphones, electronic learning tools. Expanding this list with 5G antennas only translates into greater irradiation.

We have reviewed scientific papers dedicated to the influence of electromagnetic fields of 5G networks on human beings. The papers were searched for in the eLibrary, PubMed, Google Scholar, Cyberleninka databases.

The commonization of electronic devices used for work, training, and leisure directly increases the intensity and time of exposure of people to electromagnetic fields (EMFs). Used in educational settings, electronic devices have a number of unique advantages: they expand capabilities and ensure equal access to education, enable learning personalization, instant feedback and evaluation of the results thereof, make the learning process independent of time and place, raise the effectiveness of classroom time, foster formation of new student communities, drive development of continued education, support self-training, facilitate assistance to students with disabilities. However, uncontrolled use of electronic devices increases the time of exposure to the radio frequency electromagnetic fields (RF EMFs) [4, 5].

The influence of this factor has already been shown both at the molecular and body level, as reflected in the fundamental works by the leading Russian scientists. The currently used wireless communication technology standards are 3G, 4G and 5G, and their combination translates into a complex effect of EMFs of various frequencies [6, 7].

To date, there have been published thousands of articles describing the biological effects of exposure to EMFs. There are strict restrictions on exposure to higher-level EMFs that can harm health of a human being; these restrictions are formulated in national and international rulebooks. However, researchers have not yet come to a consensus regarding the effects of low-level fields and their ability to trigger biological reactions in the body and affect how people feel [8].

At the same time, scientific community is growing increasingly concerned about the potential adverse biological consequences of practical application of RF EMFs and their impact on health. Most of the reports experts have written about the effects of exposure to EMFs do not contain information about potential harm to human beings [9–13].

At the same time, there have been published works in which scientists expressed their concern about the lightning-fast introduction of the modern data transmission systems, 5G networks in particular. Compared to the like systems common just a few decades ago, the respective new developments have unprecedented potential to create more intense levels of RF EMFs (e.g., with greater energy flux densities) a human being may be exposed to. At the same time, the currently available accumulated data on the safety of 5G networks are insufficient. The number of much longer term studies that suggest harmfulness of RF EMFs is growing [14–19].

In his work [20], J.W. Frank identifies four main problems associated with the use of 5G networks. The first is the lack of a clear understanding of what 5G is, because there is still no approved definition therefore, the meaning of this concept differs country to country.

The second problem is the rapidly growing number of laboratory studies demonstrating the destructive effects of high-frequency EMFs *in vitro* and *in vivo* [21]. The third problem is the insufficient quantity of high-quality epidemiological studies dedicated to the adverse effects exposure to 5G EMFs has on human health, but this one is offset by the emerging epidemiological data on the harmful impact of high-frequency EMFs emitted in the networks of the previous generations. In particular, we refer to the study [22] that presents convincing evidence of cancer affecting the brain, auditory nerve and the breast, the genesis of which is associated with exposure to strong RF EMFs peculiar to the networks of the previous generation.

And the last problem is the conflict of interests accompanying the work of many researchers that study EMFs. For example, a report [23] shows that studies funded by private organizations interested in the investigated sources of the EMFs, as a rule, find no connections, and studies funded by the state or independent organizations present quite the opposite conclusions.

However, not everyone agrees with such statements. An article [24] by the team of researchers compared the concern about the development of 5G networks with the panic around the spread of electricity in the early 20th century; to support such a comparison, they tried to investigate the problem from an engineering standpoint and formulated several questions: is there really evidence of a link between carcinogenesis and exposure to 5G network EMFs?; will the spread of 5G lead to an uncontrolled growth of the number of base stations and the level of EMFs?; are there no experimental studies covering radiation emitted by the 5G base stations? The team failed to

find irrefutable scientific evidence that would allow answering these questions in the affirmative. However, they recognize the need to assess any potential health effects of low-level RF EMFs generated by all devices, including those in close proximity to users (5G smartphones, tablets, laptops, etc.).

Another study [25] also reports that adoption of the 5G communication standard will not translate into more intense effect of EMFs on human beings. The researchers described measuring radio frequencies in a 5G network relying on low-power base stations mounted so people could be in their immediate vicinity. The measurements were taken near two NR base stations. One of them had an advanced antenna system capable of forming a beam, and the other a traditional microcell. The sites where the EMF's level was measured were located 0.5 to 100 m away from the stations; the researchers registered both the strongest and the time-averaged field levels at the maximum downstream traffic load. In addition, based on these measurements, they assessed the impact typical for various cases. A comparison with the maximum permissible exposure limits established by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) yielded the maximum exposure coefficients of 0.15 (professional case, at the distance of 0.5 m) and 0.68 (general public case, at the distance of 1.3 m). The effect on non-users was potentially much lower, depending on the activity of other users served by the base station and its beam-forming capabilities: 5 to 30 times lower for a base station with an improved antenna and almost 30 times lower for a traditional antenna base station.

Another study [26] reported similar results. In the worst-case scenario, the specific power was 62% of the maximum permissible level approved by the ICNIRP. However, the authors note that the radiation level increases significantly as the density of users grows and, consequently, there appear more emitting user devices. The level of exposure may increase even more in an environment with a large number of users.

Researchers from Madrid have demonstrated the adverse effects of 5G wireless communication networks [27]. They measured RF EMFs in real time on the street and inside houses, and surveyed residents; the latter revealed signs of unwellness (dizziness, headaches, sleep disorders, etc.).

The effect EMFs from 5G stations have on children and adolescents is a particularly interesting subject, since throughout their lives they are exposed to EMFs generated by stationary or mobile electronic devices [28]. For children, foreign scientists have proposed a comprehensive approach that allows factoring in the influence of all sources of EMFs on the body. For the purpose, they used spot and personal (portable) exposure meters that registered RF EMFs affecting children at school, at home, on playgrounds [29].

In a study conducted in Sweden [30], the effect of artificial EMFs on adolescents was assessed with the help of ExpoM-RF dosimeters. The researchers found that at school, smartphones generated much (67.2%) of the electromagnetic fields the students were exposed to, and the contribution of cellular base stations was only 19.8%. According to the dose calculations, exposure to the environmental sources (cellular network base stations, wireless phone base stations, LAN access points and mobile phones in the vicinity) averaged 6.0% of the brain irradiation dose and 9.0% of the whole body irradiation dose. Thus, the authors came to the conclusion that RF EMFs affecting the adolescents were mainly generated by their own mobile phones. The sources in the environment, like such cellular base stations, play a secondary role.

Another study revealed the relationship between the occurrence of psychomotor and cognitive function disorders in children and the intensity of their exposure to radiation from

base stations. Intense RF EMFs were associated with the arrested development of fine and gross motor skills, spatial working memory and attention in adolescent schoolchildren compared to their peers who were not exposed to such EMFs [31, 32].

At the same time, researchers have shown [33] that the somatic complaints from children cannot always be associated with exposure to base stations. Many authors second this position. In scientific papers, it is often stated that the intensity of EMF in classrooms and at home does not exceed the standards established in various countries, and therefore does not have a significant impact on health [34–37].

## References

- Di Ciaula A. Towards 5G communication systems: are there health implications. *International Journal of Hygiene and Environmental Health*. 2018; 221 (3): 367–75. DOI: 10.1016/j.ijheh.2018.01.011.
- Zmyślony M, Bieńkowski P, Bortkiewicz A, et al. Protection of the population health from electromagnetic hazards — challenges resulting from the implementation of the 5G network planned in Poland. *Medycyna Pracy*. 2019; 71 (1): 105–13.
- Grigorev JuG. Mobil'naja svjaz' i jelektromagnitnaja opasnost' dlja zdorov'ja naselenija. *Sovremennaja ocenka riska — ot jelektromagnitnogo smoga do jelektromagnitnogo haosa (obzor literaturny)*. *Vestnik novyh medicinskih tehnologij*. 2019; 26 (2): 88–95 (in Rus.).
- Anikina EI. Perspektivy primeneniya mobil'nyh ustrojstv dlja realizacii tehnologij jelektronnoho obuchenija v vysshem obrazovanii. *Innovacii v obrazovanii*. 2019; (6): 83–91 (in Rus.).
- Ushakov IB, Popov VI, Skoblina NA, Markelova SV. Dlitel'nost' ispol'zovanija mobil'nyh jelektronnyh ustrojstv kak sovremennyy faktor riska zdorov'ju detej, podrostkov i molodezhi. *Jekologija cheloveka*. 2021; (7): 43–50. DOI 10.33396/1728-0869-2021-7-43-50.
- Grigorev JuG. Standart 5G — tehnologicheskij skachok vpered v sotovoj svjazi: budet li problema so zdorov'em u naselenija? (pogruzenie v problemu). *Radiacionnaja biologija. Radiojekologija*. 2020; 60 (6): 627–34 (in Rus.).
- Grigorev JuG, Samojlov AS. 5G-standart sotovoj svjazi. *Summarnaja radiobiologicheskaja ocenka opasnosti planetarnogo jelektromagnitnogo obluchenija naselenija*. M.: FGBU GNC FMBC im. A.I. Burnazjana FMBA Rossii, 2021; 220 p.
- Chto takoe jelektromagnitnye polja? [Internet]. *World Health Organization*; 2016 [cited 2023 June 8]. Available from: <https://www.who.int/ru/news-room/questions-and-answers/item/electromagnetic-fields>.
- Karaboyscheva M. Effects of 5G wireless communication on human health. *European Parliament Research Service (EPRS): Brussels, European Parliament*. PE 646.172; 2020. URL: [https://www.europarl.europa.eu/RegData/etudes/BRIE/2020/646172/EPRS\\_BRI\(2020\)646172\\_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/BRIE/2020/646172/EPRS_BRI(2020)646172_EN.pdf).
- Swerdlow AJ. Health effects from radiofrequency electromagnetic fields. Report from the Independent Advisory Group on Non-ionising Radiation. In: *Documents of the 11 Health Protection Agency R, Chemical and Environmental Hazards*. RCE 20. UK; 2012. URL: [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/333080/RCE-20\\_Health\\_Effects\\_RF\\_Electromagnetic\\_fields.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/333080/RCE-20_Health_Effects_RF_Electromagnetic_fields.pdf).
- IARC. Non-ionizing Radiation, Part 2: Radiofrequency Electromagnetic Fields. *IARC Monographs on the evaluation of carcinogenic risks to humans*, Volume 102, France; 2013. URL: [https://www.ncbi.nlm.nih.gov/books/NBK304630/pdf/Bookshelf\\_NBK304630.pdf](https://www.ncbi.nlm.nih.gov/books/NBK304630/pdf/Bookshelf_NBK304630.pdf).
- SCENIHR. Potential Health Risks of Exposure to Electromagnetic Fields [EMF]. *European Commission*; 2015. URL: [https://ec.europa.eu/health/sites/health/files/scientific\\_committees/emerging/docs/scenihr\\_o\\_041.pdf](https://ec.europa.eu/health/sites/health/files/scientific_committees/emerging/docs/scenihr_o_041.pdf).
- ICNIRP. Guidelines for limiting exposure to electromagnetic fields (100 kHz to 300 GHz). *Health Phys*. 2020; 118 (5): 483–524. DOI:10.1097/HP.0000000000001210.

## Conclusion

The analysis of the scientific literature showed that, despite numerous studies and reviews dedicated to the influence of RF EMFs created by sources peculiar to the 5G standard networks, there is still no consensus in the scientific community about the possible negative impact associated therewith. There is no doubt that new technologies entail convenience for users and economic benefits. However, given the uncertainty, the task of assessing the potential risk to health of children and adults created by RF EMFs remains an urgent one.

- Carlberg M, Hardell L. Evaluation of mobile phone and cordless phone use and glioma risk using the Bradford Hill viewpoints from 1965 on association or causation. *Biomed Research International*. 2017. DOI: 10.1155/2017/9218486. URL: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5376454/pdf/BMRI2017-9218486.pdf>.
- Myung SK, Ju W, McDonnell DD, Lee YJ, Kazinets G, Cheng CT, et al. Mobile phone use and risk of tumors: a meta-analysis. *Journal of Clinical Oncology*. 2009; 27 (33): 5565–72.
- Bandara P, Carpenter DO. Planetary electromagnetic pollution: it is time to assess its impact. *Lancet*. 2018; (2): 512–4.
- Pall ML. Wi-Fi is an important threat to human health. *Environmental Research*. 2018; (164): 405–16.
- Deruelle F. The different sources of electromagnetic fields: dangers are not limited to physical health. *Electromagnetic Biology and Medicine*. 2020; 39 (2): 166–75. DOI: 10.1080/15368378.2020.1737811.
- Reem HMA, Fakhoury M, Lawand N. Electromagnetic field in Alzheimer's disease: a literature review of recent preclinical and clinical studies. *Current Alzheimer Research*. 2020; 17 (11): 1001–12.
- Frank JW. Electromagnetic fields, 5G and health: what about the precautionary principle? *Journal of Epidemiology & Community Health*. 2021; 75 (6): 562–6.
- Russell CL. 5G wireless telecommunications expansion: public health and environmental implications. *Environmental Research*. 2018; (165): 484–95. DOI: 10.1016/j.envres.2018.01.016.
- Miller AB, Sears ME, Morgan LL, Davis DL, Hardell L, Oremus M, et al. Risks to health and well-being from radio-frequency radiation emitted by cell phones and other wireless devices. *Front Public Health*. 2019; 7 (223): 1–10. DOI: 10.3389/fpubh.2019.00223.
- Carpenter DO. Extremely low frequency electromagnetic fields and cancer: how source of funding affects results. *Environmental Health*. 2019; (178): 1–7.
- Chiaraviglio L, Fiore M, Rossi E. 5G technology: which risks from the health perspective? In: *Marco MA, Melazzi NB, Buzzi S, Palazzo S, editors. The 5G Italy Book 2019: a Multiperspective View of 5G*. 2019; p. 39–59.
- Aerts S, Deprez K, Verloock L, Olsen RG, Martens L, Tran P, et al. RF-EMF exposure near 5G NR small cells. *Sensors (Basel)*. 2023; 23 (6): 3145. DOI: 10.3390/s23063145.
- Salem MA, Lim HS, Chua MY, Chien SF, Zarakovitis CC, Ng CY, et al. Investigation of EMF exposure level for uplink and downlink of 5G network using ray tracing approach. *International Journal of Technology*. 2022; 13 (6): 1298–307.
- López I, Félix N, Rivera M, Alonso A, et al. What is the radiation before 5G? A correlation study between measurements in situ and in real time and epidemiological indicators in Vallecas, Madrid. *Environmental Research*. 2021; (194): 110734. DOI: 10.1016/j.envres.2021.110734.
- Lukjanec GN, Makarova LV, Paranchev TM, et al. Vlijanie gadzhetov na razvitiye detej. *Novye issledovanija*. 2019; 1 (57): 25–35.
- Gallastegi M, Huss A, Santa-Marina L, Aurrekoetxea JJ, et al. Children's exposure assessment of radiofrequency fields: Comparison between spot and personal measurements. *Environment International*. 2018; (118): 60–9. DOI:10.1016/j.envint.2018.05.028.

30. Roser K, Schoeni A, Struchen B, Zahner M, et al. Personal radiofrequency electromagnetic field exposure measurements in Swiss adolescents. *Environment International*. 2017; (99): 303–14. DOI:10.1016/j.envint.2016.12.008.
31. Meo SA, Almahmoud M, Alsultan Q, Alotaibi N, et al. Mobile phone base station tower settings adjacent to school buildings: impact on students' cognitive health. *American Journal of Men's Health*. 2019; 13 (1): 1557988318816914. DOI: 10.1177/1557988318816914.
32. Guxens M, Vermeulen R, Eijdsen M, Beekhuizen J, et al. Outdoor and indoor sources of residential radiofrequency electromagnetic fields, personal cell phone and cordless phone use, and cognitive function in 5–6 years old children. *Environmental Research*. 2016; (150): 364–74. DOI: 10.1016/j.envres.2016.06.021.
33. Schoeni A, Roser K, Bürgi A, Rösli M. Symptoms in Swiss adolescents in relation to exposure from fixed site transmitters: a prospective cohort study. *Environmental Health*. 2016; 15 (1): 77. DOI: 10.1186/s12940-016-0158-4.
34. Simkó M, Mattsson Mats-Olof. 5G wireless communication and health effects—a pragmatic review based on available studies regarding 6 to 100 GHz. *International Journal of Environmental Research and Public Health*. 2019; 16 (18): 3406. DOI: 10.3390/ijerph16183406.
35. Magiera A, Solecka J. Radiofrequency electromagnetic radiation from Wi-Fi and its effects on human health, in particular children and adolescents. *Review Annals of the National Institute of Hygiene*. 2020; 71 (3): 251–9. DOI: 10.32394/rpzh.2020.0125.
36. Bhatt CR, Redmayne M, Billah B, Abramson MJ, et al. Radiofrequency-electromagnetic field exposures in kindergarten children. *Journal of Exposure Science & Environmental Epidemiology*. 2017; 27 (5): 497–504. DOI: 10.1038/jes.2016.55.
37. Karipidis K, Henderson S, Wijayasinghe D, Tjong L, et al. Exposure to radiofrequency electromagnetic fields from Wi-Fi in Australian schools. *Radiation Protection and Dosimetry*. 2017; 175 (4): 432–9. DOI: 10.1093/rpd/ncw370.

## Литература

1. Di Ciaula A. Towards 5G communication systems: are there health implications. *International Journal of Hygiene and Environmental Health*. 2018; 221 (3): 367–75. DOI: 10.1016/j.ijheh.2018.01.011.
2. Zmyślony M, Bieńkowski P, Bortkiewicz A, et al. Protection of the population health from electromagnetic hazards — challenges resulting from the implementation of the 5G network planned in Poland. *Medycyna Pracy*. 2019; 71 (1): 105–13.
3. Григорьев Ю. Г. Мобильная связь и электромагнитная опасность для здоровья населения. Современная оценка риска — от электромагнитного смога до электромагнитного хаоса (обзор литературы). *Вестник новых медицинских технологий*. 2019; 26 (2): 88–95.
4. Аникина Е. И. Перспективы применения мобильных устройств для реализации технологий электронного обучения в высшем образовании. *Инновации в образовании*. 2019; (6): 83–91.
5. Ушаков И. Б., Попов В. И., Скоблина Н. А., Маркелова С. В. Длительность использования мобильных электронных устройств как современный фактор риска здоровью детей, подростков и молодежи. *Экология человека*. 2021; (7): 43–50. DOI 10.33396/1728-0869-2021-7-43-50.
6. Григорьев Ю. Г. Стандарт 5G — технологический скачок вперед в сотовой связи: будет ли проблема со здоровьем у населения? (погружение в проблему). *Радиационная биология*. *Радиоэкология*. 2020; 60 (6): 627–34.
7. Григорьев Ю. Г., Самойлов А. С. 5G-стандарт сотовой связи. Суммарная радиобиологическая оценка опасности планетарного электромагнитного облучения населения. М.: ФГБУ ГНЦ ФМБЦ им. А.И. Бурназяна ФМБА России, 2021; 220 с.
8. Что такое электромагнитные поля? [Интернет]. Всемирная организация здравоохранения; 2016 [дата обращения 18.06.2023]. URL: <https://www.who.int/ru/news-room/questions-and-answers/item/electromagnetic-fields>.
9. Karaboytscheva M. Effects of 5G wireless communication on human health. *European Parliament Research Service (EPRS): Brussels, European Parliament*. PE 646.172; 2020. URL: [https://www.europarl.europa.eu/RegData/etudes/BRIE/2020/646172/EPRS\\_BRI\(2020\)646172\\_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/BRIE/2020/646172/EPRS_BRI(2020)646172_EN.pdf).
10. Swerdlow AJ. Health effects from radiofrequency electromagnetic fields. Report from the Independent Advisory Group on Non-ionising Radiation. In: Documents of the 11 Health Protection Agency R, Chemical and Environmental Hazards. RCE 20. UK; 2012. URL: [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/333080/RCE-20\\_Health\\_Effects\\_RF\\_Electromagnetic\\_fields.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/333080/RCE-20_Health_Effects_RF_Electromagnetic_fields.pdf).
11. IARC. Non-ionizing Radiation, Part 2: Radiofrequency Electromagnetic Fields. IARC Monographs on the evaluation of carcinogenic risks to humans, Volume 102, France; 2013. URL: [https://www.ncbi.nlm.nih.gov/books/NBK304630/pdf/Bookshelf\\_NBK304630.pdf](https://www.ncbi.nlm.nih.gov/books/NBK304630/pdf/Bookshelf_NBK304630.pdf).
12. SCENIHR. Potential Health Risks of Exposure to Electromagnetic Fields [EMF]. *European Commission*; 2015. URL: [https://ec.europa.eu/health/sites/health/files/scientific\\_committees/emerging/docs/scenihr\\_o\\_041.pdf](https://ec.europa.eu/health/sites/health/files/scientific_committees/emerging/docs/scenihr_o_041.pdf).
13. ICNIRP. Guidelines for limiting exposure to electromagnetic fields (100 kHz to 300 GHz). *Health Phys*. 2020; 118 (5): 483–524. DOI:10.1097/HP.0000000000001210.
14. Carlberg M, Hardell L. Evaluation of mobile phone and cordless phone use and glioma risk using the Bradford Hill viewpoints from 1965 on association or causation. *Biomed Research International*. 2017. DOI: 10.1155/2017/9218486. URL: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5376454/pdf/BMRI2017-9218486.pdf>.
15. Myung SK, Ju W, McDonnell DD, Lee YJ, Kazinets G, Cheng CT, et al. Mobile phone use and risk of tumors: a meta-analysis. *Journal of Clinical Oncology*. 2009; 27 (33): 5565–72.
16. Bandara P, Carpenter DO. Planetary electromagnetic pollution: it is time to assess its impact. *Lancet*. 2018; (2): 512–4.
17. Pall ML. Wi-Fi is an important threat to human health. *Environmental Research*. 2018; (164): 405–16.
18. Deruelle F. The different sources of electromagnetic fields: dangers are not limited to physical health. *Electromagnetic Biology and Medicine*. 2020; 39 (2): 166–75. DOI: 10.1080/15368378.2020.1737811.
19. Reem HMA, Fakhoury M, Lawand N. Electromagnetic field in Alzheimer's disease: a literature review of recent preclinical and clinical studies. *Current Alzheimer Research*. 2020; 17 (11): 1001–12.
20. Frank JW. Electromagnetic fields, 5G and health: what about the precautionary principle? *Journal of Epidemiology & Community Health*. 2021; 75 (6): 562–6.
21. Russell CL. 5G wireless telecommunications expansion: public health and environmental implications. *Environmental Research*. 2018; (165): 484–95. DOI: 10.1016/j.envres.2018.01.016.
22. Miller AB, Sears ME, Morgan LL, Davis DL, Hardell L, Oremus M, et al. Risks to health and well-being from radio-frequency radiation emitted by cell phones and other wireless devices. *Front Public Health*. 2019; 7 (223): 1–10. DOI: 10.3389/fpubh.2019.00223.
23. Carpenter DO. Extremely low frequency electromagnetic fields and cancer: how source of funding affects results. *Environmental Health*. 2019; (178): 1–7.
24. Chiaraviglio L, Fiore M, Rossi E. 5G technology: which risks from the health perspective? In: Marco MA, Melazzi NB, Buzzi S, Palazzo S, editors. *The 5G Italy Book 2019: a Multiperspective View of 5G*. 2019; p. 39–59.
25. Aerts S, Deprez K, Verloock L, Olsen RG, Martens L, Tran P, et al. RF-EMF exposure near 5G NR small cells. *Sensors (Basel)*. 2023; 23 (6): 3145. DOI: 10.3390/s23063145.
26. Salem MA, Lim HS, Chua MY, Chien SF, Zarakovitis CC, Ng CY, et al. Investigation of EMF exposure level for uplink and downlink of 5G network using ray tracing approach. *International Journal of Technology*. 2022; 13 (6): 1298–307.
27. López I, Félix N, Rivera M, Alonso A, et al. What is the radiation before 5G? A correlation study between measurements in situ and in real time and epidemiological indicators in Vallecas, Madrid.

- Environmental Research. 2021; (194): 110734. DOI: 10.1016/j.envres.2021.110734.
28. Лукьянец Г. Н., Макарова Л. В., Параничев Т. М. и др. Влияние гаджетов на развитие детей. Новые исследования. 2019; 1 (57): 25–35.
  29. Gallastegi M, Huss A, Santa-Marina L, Aurrekoetxea JJ, et al. Children's exposure assessment of radiofrequency fields: Comparison between spot and personal measurements. *Environment International*. 2018; (118): 60–9. DOI:10.1016/j.envint.2018.05.028.
  30. Roser K, Schoeni A, Struchen B, Zahner M, et al. Personal radiofrequency electromagnetic field exposure measurements in Swiss adolescents. *Environment International*. 2017; (99): 303–14. DOI:10.1016/j.envint.2016.12.008.
  31. Meo SA, Almahmoud M, Alsultan Q, Alotaibi N, et al. Mobile phone base station tower settings adjacent to school buildings: impact on students' cognitive health. *American Journal of Men's Health*. 2019; 13 (1): 1557988318816914. DOI: 10.1177/1557988318816914.
  32. Guxens M, Vermeulen R, Eijsden M, Beekhuizen J, et al. Outdoor and indoor sources of residential radiofrequency electromagnetic fields, personal cell phone and cordless phone use, and cognitive function in 5–6 years old children. *Environmental Research*. 2016; (150): 364–74. DOI: 10.1016/j.envres.2016.06.021.
  33. Schoeni A, Roser K, Bürgi A, Röösl M. Symptoms in Swiss adolescents in relation to exposure from fixed site transmitters: a prospective cohort study. *Environmental Health*. 2016; 15 (1): 77. DOI: 10.1186/s12940-016-0158-4.
  34. Simkó M, Mattsson Mats-Olof. 5G wireless communication and health effects—a pragmatic review based on available studies regarding 6 to 100 GHz. *International Journal of Environmental Research and Public Health*. 2019; 16 (18): 3406. DOI: 10.3390/ijerph16183406.
  35. Magiera A, Solecka J. Radiofrequency electromagnetic radiation from Wi-Fi and its effects on human health, in particular children and adolescents. *Review Annals of the National Institute of Hygiene*. 2020; 71 (3): 251–9. DOI: 10.32394/rpzh.2020.0125.
  36. Bhatt CR, Redmayne M, Billah B, Abramson MJ, et al. Radiofrequency-electromagnetic field exposures in kindergarten children. *Journal of Exposure Science & Environmental Epidemiology*. 2017; 27 (5): 497–504. DOI: 10.1038/jes.2016.55.
  37. Karipidis K, Henderson S, Wijayasinghe D, Tjong L, et al. Exposure to radiofrequency electromagnetic fields from Wi-Fi in Australian schools. *Radiation Protection and Dosimetry*. 2017; 175 (4): 432–9. DOI: 10.1093/rpd/ncw370.