Hormozgan Medical Journal

doi 10.34172/hmj.2022.06

Hormozgan Med J. 2022; 26(1):30-34

Research Article

Deleterious Effects of Exposure to 900 MHz Radiofrequency Waves on Brain Trace Elements Improved by Administration of Vitamins

Mansour Azimzadeh[1], **Gholamali Jelodar**[1*]

[1]Department of Basic Science, School of Veterinary Medicine, Shiraz University, Shiraz, Iran

***Correspondence to**
Gholamali Jelodar,
Email: jelodar@shirazu.ac.ir

Abstract

Background: There is an increasing public concern about the harmful effect of exposure to electromagnetic radiation emitted from base transceiver stations (BTS).

Objectives: This study was carried out to evaluate the impact of exposure to 900 MHz radiofrequency (RF) on the concentration of brain trace elements (TEs), including zinc (Zn), manganese (Mn), copper (Cu), and iron (Fe), as well as the protective effect of vitamins (C and E) supplementation.

Methods: In this study, 30 male rats were assigned into three non-exposed groups, including sham I, II, and III receiving saline, vitamin C, and vitamins C+E, respectively, and three exposed groups, including sham-exposed (saline), test I (vitamin C), and test II (vitamins C+E). The exposed groups were exposed to RF for one month (4 h/day) and the brain TE levels were measured using atomic absorption spectrophotometry.

Results: Compared with the non-exposed groups (I, II, and III), a remarkable elevation in the concentration of Mn, Fe, Cu, and Cu/Zn ratio accompanied by a significantly lower level of Zn was noticed in the rats' brain of the sham-exposed group ($P<0.05$). However, pretreatment with both vitamins C and C+E improved the evaluated TE imbalances caused by exposure to 900 MHz RF with no significant difference between the two test groups ($P>0.05$).

Conclusion: Disruption of brain TEs homeostasis caused by the exposure to 900 MHz RF improved and normalized by pretreatment with vitamins C and E+C.

Keywords: Electromagnetic wave, Copper, Iron, Manganese, Vitamins C and E, Zinc

Received December 16, 2020, **Accepted**: July 27, 2021, **Published Online**: March 29, 2022

Background

Mobile phones and the base transceiver stations (BTS) antennas are the most popular radiofrequency wave (RFW) user devices, and there is increasing public concern about their potential adverse health effects. Several studies have investigated and reported the detrimental effects of radiofrequency (RF) on various animal tissues (1, 2).

In fact, due to the position of mobile phones during a voice call, and relatively high RFW absorption in the brain tissue, clinical and experimental studies revealed the potentially deleterious effects of these waves on tiredness, anxiety, headache, stress (3), and impairment of learning processes (4, 5).

Trace elements (TEs) have a critical functional role in various physiological and biochemical actions in the biological systems in humans and animals (6). Zinc (Zn), iron (Fe), manganese (Mn), and copper (Cu) have a protective function against the generation of reactive oxygen species (ROS) in the brain and neurodegenerative diseases, and they regulate enzyme activation and gene expression (7). Fe has a main role in oxidative energy production and is involved in respiratory chain proteins and oxidative enzymes (8). Cu has a functional role in enzymatic activities linked to brain signal transduction and neurotransmitter function (9) and is presented in the enzymes and proteins, including Cu/Zn superoxide dismutase and cytochrome C oxidase (10). Furthermore, Fe and Cu are well-known redox-active metals with a functional role in the reactive radicals generation and cycling reactions, which can develop uncontrolled oxidative stress (11).

Alteration of the brain Zn homeostasis causes neurological and behavioral disorders such as Alzheimer's disease and impairment of cognitive and learning processes (12). Besides, both Cu and Zn have a critical duty in the free-radical generation chain and decreasing the peroxidation ratio (13). The Cu/Zn ratio is a well-known sensitive indicator of inflammation and oxidative stress (14).

Mn has a vital role in brain development and function, carbohydrate metabolic process, and maybe enzymatic antioxidant defenses (MnSOD, and catalase) (15). Mn has a well-known neurotoxic property and maybe the central mechanism through which oxidative stress develops degenerative brain disorders (16).

An endogenous redox agent, vitamin C, is arguably a potent water-soluble chain-breaking antioxidant, along with lipid-soluble vitamin E that limits the generation of ROS, especially in the brain, and protects membrane lipids and proteins from oxidative damage. Vitamin C is a cofactor for several enzymes and acts as an electron donor. The reduced activity of vitamin C play an important role in iron and folic acid metabolism, regenerating vitamin E, and scavenging ROS (17).

Both vitamins E & C have a neuroprotective function and are known as necessary molecules in neuronal survival and maintenance in the central nervous system (CNS), particularly against oxidative stress-linked diseases (18, 19). Moreover, the protective effects of vitamin C against RFW on learning and memory (4, 20) and oxidative index (21) have already been reported.

Objectives

In the experimental studies about the evaluation of electromagnetic side effects, several parameters, including specific absorption rate (SAR), duration of exposure, the frequency of waves, and distance from radiation source have been identified as the most important determining factors. The main differences between our experimental condition and others include the frequency wave (900 MHz), SAR (0.035 W/kg), and duration of exposure (4 weeks). Moreover, most of the studies used serum/plasma but we used brain tissues because the brain is the most sensitive organ for electromagnetic side effects due to the high content of lipid and the presence of the blood-brain barrier. In addition, we used the vitamin treatment (C and C+E) as an antioxidant and neuroprotective factor with considering the functional and vital role of these vitamins on the brain TEs homeostasis.

Materials and Methods

Animals

In this experiment, 30 colony-bred male rats (Sprague Dawley) weighing 190 ± 20 g in the Shiraz Animal House Center were included. Animals were kept at a constant temperature (20 ± 2˚C), 12-h light-dark cycle, and had free access to water and food. Exposure time was set and carried out between 9 am and 1 pm.

Experimental Protocol

We studied the effect of 900 MHz RF on the Cu, Fe, Mn, and Zn concentrations in the brain tissue and the protective role of pretreatment of vitamins (C or E+C) after 30 consecutive days of treatments. All rats were divided into six equal groups (n = 5) as the three non-exposed groups, including sham I (saline), sham II vitamin C (250 mg/kg), sham III vitamin C (200 mg/kg + E 100 mg/kg), and three exposed groups (exposed for 30 continuous days, 4 h/d), including sham-exposed (saline), test I (vitamin C 250 mg/kg) and test II (vitamin C 200 mg/kg + vitamin E 100 mg/kg). Vitamins and saline were administrated orally by gavage.

Radiofrequency Field Exposure Device

We used a simulator emitting a 900 MHz field through a vertical antenna (12 cm) which produces a power density of 0.6789 mW/cm^2 measured by a spectrum analyzer (Rohde and Schwarz, Germany). The signal generator was positioned at a 1-meter distance from the cages of exposed groups (groups 4-6) and the value of specific absorption rate (SAR) was detected by a field-probe device (300 kHz - 18 GHz, Wave Control, Spain) at 0.035 W/kg.

Sampling and Tissue Preparation

On the last day of the exposure period, the rats were anesthetized using a 2% diethyl ether-saturated cotton ball in a chamber for 3–5 minutes and euthanized by whole blood collection through the heart puncture. The brain tissue was instantly harvested and kept at -70 °C for evaluating TEs (Cu, Fe, Mn, and Zn) following washing with distilled water.

Evaluation of TEs

Atomic absorption spectrophotometry (Shimadzu AA-670, Kyoto, Japan) was used to detect the amount of Cu, Fe, Mn, and Zn. The UV-Visible detector was used for Cu: 324.8 nm, Fe: 248.3 nm, Mn: 279.6 nm, and Zn: 213.9 nm. To prepare brain tissues for evaluation of the TEs, they were dried at 60°C for 24 hours, dissolved in a blend of nitric acid and perchloric (7:3 ratios, respectively), then kept in a 55°C water bath to complete digestion and double distilled water was used to dilute the samples.

Statistical Analysis

All collected data were expressed as mean ± SE. Statistical analysis was done by one-way analysis of variance (ANOVA) followed by Tukey's multiple comparisons test. *P* value was set at < .05.

Results

The concentrations of Cu, Fe, Mn, and Zn levels (mean ± SEM) and Cu/Zn in the brain tissue are presented in Figure 1.

In the sham-exposed group, the mean Zn level (12.29 ± 0.63) was significantly lower than other study groups, while a significant increase in the mean Cu (1.27 ± .16), Fe (29.48 ± 1.69), Mn (0.49 ± 0.01), and Cu/Zn ratio (0.26 ± 0.01) was noticed.

As depicted in Figure 1, vitamin supplementation (test groups I & II) significantly improved all TEs status in the brain tissue, but there was no significant difference between test I (vitamin C) and test II (combined C+E) groups.

A significant increase was noticed in the Fe level in the test II group compared to the sham III group ($P < 0.05$). The Zn level significantly decreased in the test I group compared to the sham I and II groups ($P < 0.05$). There

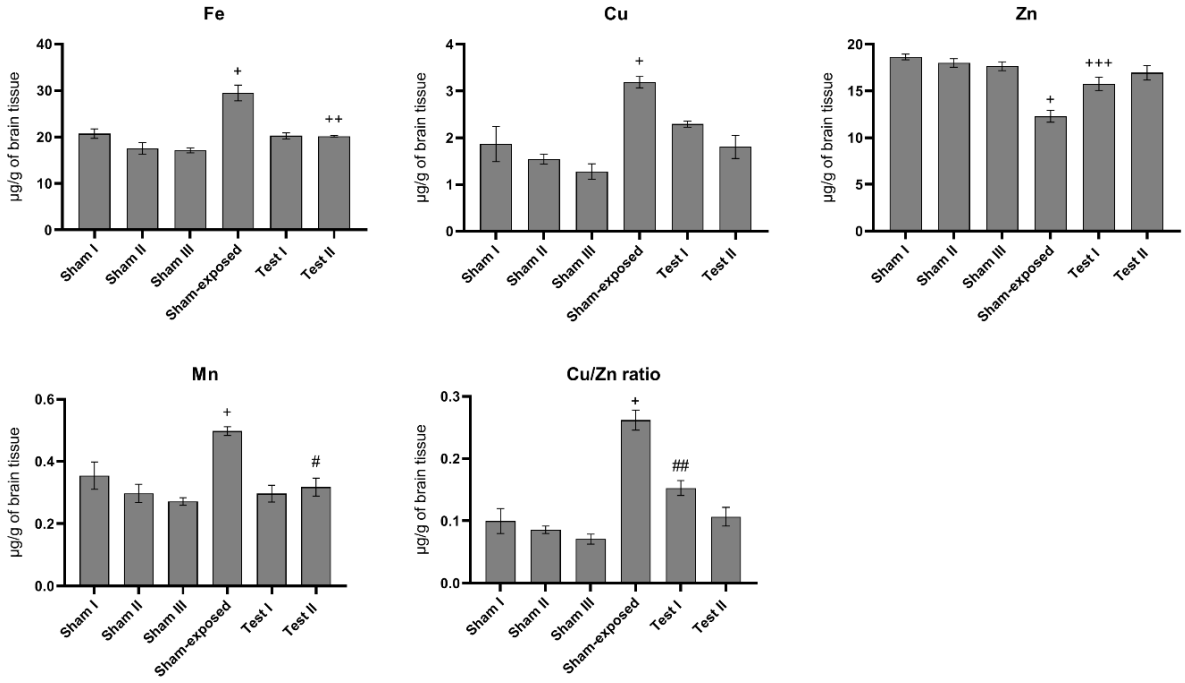

Figure 1. The concentration of all trace elements was measured by using atomic absorption spectrophotometry. Columns represent mean ± SEM. Sham groups (I, II & III) were not exposed to RFW and received distilled water, vitamin C 250 mg/kg, or a combination of vitamins E (100 mg/kg) and C (200 mg/kg), respectively. Sham-exposed, Test I, and II groups were exposed to 900 MHz RFW (4 h/day for 30 continuous days) and received distilled water, vitamin C (250 mg/kg), or vitamins E (100 mg/kg + C 200 mg/kg), respectively. (+) The significant difference with all groups. (++) The significant difference with sham III. (+++) The significant difference with sham I & II. (#) The significant difference with sham III. (##) The significant difference with test I ($P<0.05$). Abbreviations: Cu, copper; Fe, iron; Mn, manganese; Zn, zinc.

was a significant decrease in the Mn level in sham III group compared to the sham I group. Cu/Zn ratio in the test I group was significantly higher than sham II ($P<0.05$).

Discussion

The findings of this study indicated that exposure to 900 MHz RF can cause imbalances in the brain TEs homeostasis. In agreement with our results, it has been reported that exposure to 950 MHz (1 h/d, 8 weeks) disrupted brain TEs homeostasis (22). Another study reported a decrease in Zn level following exposure to RFW emitted from the mobile phone (1800 MHz) (23). Moreover, some previous reports indicated that mobile phones and Wi-Fi irradiation induces oxidative damage in the kidney and testis by decreasing glutathione, Cu, and total antioxidants, while augmenting the rate of lipid-induced peroxidation and the Fe level (24).

However, there is controversy in the reported results following exposure to different electromagnetic fields (EMF). There was no alteration in the plasma content of Cu, Fe, Zn, and Mn in dairy cows exposed to 60 Hz extremely low-frequency (ELF) EMFs (25). Exposure to ELF-EMF (50 Hz) did not alter the serum concentration of Cu, Zn, and Fe in rats (26). Different methodologies, including the duration of exposure, the frequency used, distance, and intensity can be the reasons for discrepancies in different experiments.

A growing body of data has a consensus on oxidative stress as the important mediator of exposure to the radiation of mobile phones (27, 28). On the other hand, some important properties in the brain tissue such as fairly weak enzymatic defense, higher lipid density, Fe, and high aerobic metabolism are prone to lipid-induced peroxidation and finally oxidative stress (29).

A high level of Mn in the brain tissue can be neurotoxic, while a low level is required for proper and normal functioning (30). In our study, the Mn level in brain increased following exposure to 900 MHz RF, which is in consonance with other reports (31). Moreover, the accumulation of Mn in the liver, kidney, and brain following exposure to the EMF has already been reported (32). Mn uptakes into the brain either via the blood-brain barrier (BBB) or cerebrospinal fluid (33) and slow turnover of Mn in the brain (32) have been proposed for possible mechanisms.

In this study, pretreatment with both vitamins (C & C+ E) significantly improved the levels of all the evaluated brain TEs (Cu, Fe, Mn, Zn, and Cu/Zn ratio) following exposure to RF. As mentioned, oxidative stress is the primary cause of the deleterious effects of RFWs. Moreover, vitamins C and E have vital and interesting properties such as long-lasting defense against Fe-induced oxidative stress and Mn-induced hydroperoxides and neurotoxicity (34, 35), as well as neuroprotective property against neurodegenerative diseases (36). Besides, the beneficial effects of both vitamins against RF side effects on different body organs including the brain have been reported (4, 21). Moreover, combined treatment of vitamins C and E improves learning and memory and cognitive function (4,

37) in scopolamine-induced dementia (38).

The BBB is one of the regulators of the TEs balance in the brain (39), and some previous studies have suggested an increase in permeability of the BBB following exposure to mobile phone radiation (40, 41).

Accordingly, two main possible pathways, including oxidative stress and increased BBB permeability, can be responsible for the disturbed homeostasis of TEs in the brain following exposure to 900 MHz RF.

Conclusion

Disturbed brain TEs (Cu, Fe, Mn, and Zn) were the outcome of exposure to 900 MHz RF. Pretreatment with both vitamins (C & E+C), possibly due to their antioxidant and neuroprotective properties, ameliorated and normalized the negative and disruptive effects of exposure to RFW. There was no significant difference between the pretreatment with vitamin C alone or in combination with vitamin E. The finding of this study provided evidence about the beneficial effects of vitamin C and vitamin E+C against the deleterious effects of exposure to RFW in an experimental condition which may be applicable in humans. However, further studies are needed to confirm the findings of this study.

Acknowledgments

The authors thank Mr. Shamsaei for his technical assistance.

Conflict of interest

The authors announce to have no conflicts of interest.

Ethical Approval

The Institutional Research Ethics Committee of the School of Veterinary Medicine of Shiraz University approved all of the investigations involving animal use and care.

Funding/Support

The authors received no financial support for the research, authorship, and/or publication of this article.

References

1. Azimzadeh M, Jelodar G. Alteration of testicular regulatory and functional molecules following long-time exposure to 900 MHz RFW emitted from BTS. Andrologia. 2019;51(9):e13372. doi: 10.1111/and.13372.
2. de Gannes FP, Masuda H, Billaudel B, Poque-Haro E, Hurtier A, Lévêque P, et al. Effects of GSM and UMTS mobile telephony signals on neuron degeneration and blood-brain barrier permeation in the rat brain. Sci Rep. 2017;7(1):15496. doi: 10.1038/s41598-017-15690-1.
3. Colak C, Parlakpinar H, Ermis N, Tagluk ME, Colak C, Sarihan E, et al. Effects of electromagnetic radiation from 3G mobile phone on heart rate, blood pressure and ECG parameters in rats. Toxicol Ind Health. 2012;28(7):629-38. doi: 10.1177/0748233711420468.
4. Azimzadeh M, Jelodar G. The protective effect of vitamin supplementation (E and E + C) on passive avoidance learning and memory during exposure to 900 MHz RFW emitted from BTS. Toxicol Ind Health. 2020;36(2):93-8. doi: 10.1177/0748233720912058.
5. Azimzadeh M, Jelodar G, Namazi F, Soleimani F. Exposure to radiofrequency wave (RFW) generated by a base transceiver stations (BTS) antenna model affects learning and memory in female more than male rats. Int J Radiat Res. 2018;16(4):487-91.
6. Grochowski C, Blicharska E, Krukow P, Jonak K, Maciejewski M, Szczepanek D, et al. Analysis of trace elements in human brain: its aim, methods, and concentration levels. Front Chem. 2019;7:115. doi: 10.3389/fchem.2019.00115.
7. Lee TG, Park J-W, Shon HK, Moon DW, Choi WW, Li K, et al. Biochemical imaging of tissues by SIMS for biomedical applications. Appl Surf Sci. 2008;255(4):1241-8. doi: 10.1016/j.apsusc.2008.05.156.
8. Etebary S, Nikseresht S, Sadeghipour HR, Zarrindast MR. Postpartum depression and role of serum trace elements. Iran J Psychiatry. 2010;5(2):40-6.
9. Crayton JW, Walsh WJ. Elevated serum copper levels in women with a history of post-partum depression. J Trace Elem Med Biol. 2007;21(1):17-21. doi: 10.1016/j.jtemb.2006.10.001.
10. Horn D, Barrientos A. Mitochondrial copper metabolism and delivery to cytochrome c oxidase. IUBMB Life. 2008;60(7):421-9. doi: 10.1002/iub.50.
11. Flora SJ. Structural, chemical and biological aspects of antioxidants for strategies against metal and metalloid exposure. Oxid Med Cell Longev. 2009;2(4):191-206. doi: 10.4161/oxim.2.4.9112.
12. Cunha MP, Machado DG, Bettio LE, Capra JC, Rodrigues AL. Interaction of zinc with antidepressants in the tail suspension test. Prog Neuropsychopharmacol Biol Psychiatry. 2008;32(8):1913-20. doi: 10.1016/j.pnpbp.2008.09.006.
13. Costanzo LL, De Guidi G, Giuffrida S, Sortino S, Condorelli G. Antioxidant effect of inorganic ions on UVC and UVB induced lipid peroxidation. J Inorg Biochem. 1995;59(1):1-13. doi: 10.1016/0162-0134(94)00048-f.
14. Malavolta M, Piacenza F, Basso A, Giacconi R, Costarelli L, Mocchegiani E. Serum copper to zinc ratio: relationship with aging and health status. Mech Ageing Dev. 2015;151:93-100. doi: 10.1016/j.mad.2015.01.004.
15. Perera NCN, Godahewa GI, Lee S, Kim MJ, Hwang JY, Kwon MG, et al. Manganese-superoxide dismutase (MnSOD), a role player in seahorse (*Hippocampus abdominalis*) antioxidant defense system and adaptive immune system. Fish Shellfish Immunol. 2017;68:435-42. doi: 10.1016/j.fsi.2017.07.049.
16. Harischandra DS, Ghaisas S, Zenitsky G, Jin H, Kanthasamy A, Anantharam V, et al. Manganese-induced neurotoxicity: new insights into the triad of protein misfolding, mitochondrial impairment, and neuroinflammation. Front Neurosci. 2019;13:654. doi: 10.3389/fnins.2019.00654.
17. Niki E. Interaction of ascorbate and alpha-tocopherol. Ann N Y Acad Sci. 1987;498:186-99. doi: 10.1111/j.1749-6632.1987.tb23761.x.
18. Rice ME. Ascorbate regulation and its neuroprotective role in the brain. Trends Neurosci. 2000;23(5):209-16. doi: 10.1016/s0166-2236(99)01543-x.
19. Lloret A, Esteve D, Monllor P, Cervera-Ferri A, Lloret A. The effectiveness of vitamin E treatment in Alzheimer's disease. Int J Mol Sci. 2019;20(4):879. doi: 10.3390/ijms20040879.
20. Jelodar G, Soleimani F, Azimzadeh M. Vitamin C improves passive avoidance learning and memory in rats exposed to radiofrequency waves generated by a base transceiver station (BTS) antenna model. Zahedan J Res Med Sci. 2018;20(11):e80229. doi: 10.5812/zjrms.80229.
21. Alzoubi KH, Khabour OF, Rashid BA, Damaj IM, Salah HA. The neuroprotective effect of vitamin E on chronic sleep deprivation-induced memory impairment: the role of oxidative stress. Behav Brain Res. 2012;226(1):205-10. doi: 10.1016/j.bbr.2011.09.017.
22. Gharib OA. Effect of kombucha on some trace element levels in different organs of electromagnetic field exposed

rats. J Radiat Res Appl Sci. 2014;7(1):18-22. doi: 10.1016/j.jrras.2013.11.002.
23. Erken G, Küçükatay MB, Turgut S, Erken HA, Cömlekçi S, Divrikli U, et al. The effects of electromagnetic fields generated from 1800 MHz cell phones on erythrocyte rheological parameters and zinc level in rats. Balkan Med J. 2012;29(2):139-43. doi: 10.5152/balkanmedj.2011.021.
24. Özorak A, Nazıroğlu M, Çelik Ö, Yüksel M, Özçelik D, Özkaya MO, et al. Wi-Fi (2.45 GHz)- and mobile phone (900 and 1800 MHz)-induced risks on oxidative stress and elements in kidney and testis of rats during pregnancy and the development of offspring. Biol Trace Elem Res. 2013;156(1-3):221-9. doi: 10.1007/s12011-013-9836-z.
25. Burchard JF, Nguyen DH, Block E. Macro- and trace element concentrations in blood plasma and cerebrospinal fluid of dairy cows exposed to electric and magnetic fields. Bioelectromagnetics. 1999;20(6):358-64.
26. Li K, Ma S, Ren D, Li Y, Ding G, Liu J, et al. Effects of electromagnetic pulse on serum element levels in rat. Biol Trace Elem Res. 2014;158(1):81-6. doi: 10.1007/s12011-014-9903-0.
27. Alkis ME, Bilgin HM, Akpolat V, Dasdag S, Yegin K, Yavas MC, et al. Effect of 900-, 1800-, and 2100-MHz radiofrequency radiation on DNA and oxidative stress in brain. Electromagn Biol Med. 2019;38(1):32-47. doi: 10.1080/15368378.2019.1567526.
28. Jelodar G, Nazifi S, Akbari A. The prophylactic effect of vitamin C on induced oxidative stress in rat testis following exposure to 900 MHz radio frequency wave generated by a BTS antenna model. Electromagn Biol Med. 2013;32(3):409-16. doi: 10.3109/15368378.2012.735208.
29. Fang KM, Cheng FC, Huang YL, Chung SY, Jian ZY, Lin MC. Trace element, antioxidant activity, and lipid peroxidation levels in brain cortex of gerbils after cerebral ischemic injury. Biol Trace Elem Res. 2013;152(1):66-74. doi: 10.1007/s12011-012-9596-1.
30. Quintanar L. Manganese neurotoxicity: a bioinorganic chemist's perspective. Inorganica Chim Acta. 2008;361(4):875-84. doi: 10.1016/j.ica.2007.09.008.
31. Stam R. Electromagnetic fields and the blood-brain barrier. Brain Res Rev. 2010;65(1):80-97. doi: 10.1016/j.brainresrev.2010.06.001.
32. Çelik MS, Güven K, Akpolat V, Akdağ MZ, Nazıroğlu M, Gül-Güven R, et al. Extremely low-frequency magnetic field induces manganese accumulation in brain, kidney and liver of rats. Toxicol Ind Health. 2015;31(6):576-80. doi: 10.1177/0748233713480204.
33. Schmitt C, Strazielle N, Richaud P, Bouron A, Ghersi-Egea JF. Active transport at the blood-CSF barrier contributes to manganese influx into the brain. J Neurochem. 2011;117(4):747-56. doi: 10.1111/j.1471-4159.2011.07246.x.
34. Peres TV, Schettinger MR, Chen P, Carvalho F, Avila DS, Bowman AB, et al. "Manganese-induced neurotoxicity: a review of its behavioral consequences and neuroprotective strategies". BMC Pharmacol Toxicol. 2016;17(1):57. doi: 10.1186/s40360-016-0099-0.
35. Cordova FM, Aguiar AS Jr, Peres TV, Lopes MW, Gonçalves FM, Pedro DZ, et al. Manganese-exposed developing rats display motor deficits and striatal oxidative stress that are reversed by Trolox. Arch Toxicol. 2013;87(7):1231-44. doi: 10.1007/s00204-013-1017-5.
36. Crouzin N, Ferreira MC, Cohen-Solal C, Barbanel G, Guiramand J, Vignes M. Neuroprotection induced by vitamin E against oxidative stress in hippocampal neurons: involvement of TRPV1 channels. Mol Nutr Food Res. 2010;54(4):496-505. doi: 10.1002/mnfr.200900188.
37. Hasanein P, Shahidi S. Effects of combined treatment with vitamins C and E on passive avoidance learning and memory in diabetic rats. Neurobiol Learn Mem. 2010;93(4):472-8. doi: 10.1016/j.nlm.2010.01.004.
38. Lee L, Kang SA, Lee HO, Lee BH, Jung IK, Lee JE, et al. Effect of supplementation of vitamin E and vitamin C on brain acetylcholinesterase activity and neurotransmitter levels in rats treated with scopolamine, an inducer of dementia. J Nutr Sci Vitaminol (Tokyo). 2001;47(5):323-8. doi: 10.3177/jnsv.47.323.
39. Strazielle N, Ghersi-Egea JF. Physiology of blood-brain interfaces in relation to brain disposition of small compounds and macromolecules. Mol Pharm. 2013;10(5):1473-91. doi: 10.1021/mp300518e.
40. Tang J, Zhang Y, Yang L, Chen Q, Tan L, Zuo S, et al. Exposure to 900 MHz electromagnetic fields activates the mkp-1/ERK pathway and causes blood-brain barrier damage and cognitive impairment in rats. Brain Res. 2015;1601:92-101. doi: 10.1016/j.brainres.2015.01.019.
41. Sırav B, Seyhan N. Effects of GSM modulated radio-frequency electromagnetic radiation on permeability of blood-brain barrier in male & female rats. J Chem Neuroanat. 2016;75(Pt B):123-7. doi: 10.1016/j.jchemneu.2015.12.010.