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Effects of radiofrequency electromagnetic radiation with a focus on haematology parameters: a brief review and future research needs

N. Žura, I. Žura Žaja, P. Perić, K. Malarić, S. Milinković Tur, N. Poljičak Milas, V. Rimac, J. Pejaković Hlede, S. Kunštek, M. Pećin and M. Vilić*

Abstract

The use of radiofrequency electromagnetic radiation (RF-EMR) has steadily increased since the 1950s. RF-EMR is used in medicine, industry, household appliances, security and navigation, and especially in wireless telecommunications and animal husbandry. The widespread use of RF-EMR, especially with the introduction of 5G networks, raises concerns about potential adverse effects on human and animal health. The effects and mechanisms of RF-EMR impacts of 5G network frequencies on human and animal health are still unknown or poorly understood. Current research findings include the biological effects of RF-EMR on genotoxicity, cell proliferation, gene expression, cell signalling, cell membrane function, and the function of immune, hematopoietic, and reproductive systems. Exposure of humans and laboratory animals to RF-EMR emitted from cell phones and many other electronic devices of 4G and older technologies has been shown to have detrimental effects on blood cells and to cause changes in the complete blood count. This depends on the type of organisms exposed, sources, frequency, electric field level and duration of exposure. There is sparse data in the available literature on the effects of RF-EMR on haematology indicators and erythrocyte morphometry in domestic animals. Therefore, the aim of this scientific review is to highlight the effects of RF-EMR on haematology indicators, erythrocyte morphometry, and platelet activation in humans and animals, taking into account the findings on the effects of 5G electromagnetic radiation on these indicators. Considering the

Nikolino ŽURA, PT, PhD student, Clinical Hospital Center Zagreb, University of Applied Health Sciences Zagreb, Croatia; Ivona ŽURA ŽAJA*, (Corresponding author, e-mail: izzaja@vef.unizg.hr), DVM, PhD, Associate Professor, Suzana MILINKOVIĆ TUR, DVM, PhD, Full Professor, Nina POLJIČAK MILAS, DVM, PhD, Full Professor, Jadranka PEJAKOVIĆ HLEDE, DVM, PhD, Assistant Professor, Sandra KUNŠTEK, BSc, Expert Associate, Marko PEĆIN, DVM, PhD, Associate Professor, Marinko VILIĆ, DVM, PhD, Full Professor, Faculty of Veterinary Medicine, University of Zagreb, Croatia; Porin PERIĆ, MD, PhD, Associate Professor, Clinical Hospital Center Zagreb, Faculty of Medicine, University of Zagreb, Croatia; Krešimir MALARIĆ, PhD, Full Professor, Faculty of Electrical Engineering and Computing, University of Zagreb, Zagreb, Croatia; Vladimira RIMAC, PhD, Clinical Hospital Center Zagreb, Croatia

ubiquitous electromagnetic pollution, it is important to gain knowledge about the effects of RF-EMR on human and animal health. In addition, it is necessary to determine the effects following *in vitro* exposure of blood to RF-EMR, especially due to the storage and use of blood and blood products in transfusion medicine.

Key words: *radiofrequency electromagnetic radiation; biological effects; complete blood count; erythrocyte morphometry; platelet activation*

Introduction

The use of radiofrequency electromagnetic radiation (RF-EMR) has steadily increased since the 1950s. RF-EMR is used in medicine (magnetic resonance, radiofrequency ablation), industry (heating and welding), household appliances (baby monitors, wireless Wi-Fi routers, microwave ovens), security and navigation (radar), and above all in wireless telecommunications (radio and television, mobile telephony), and animal husbandry (wireless technology in animal husbandry and agriculture, wireless "fitness trackers", Wi-Fi farming) (Henschenmacher et al., 2022).

The widespread use of RF-EMR, especially with the introduction of the 5G network, raises public concerns about possible harmful effects on human and animal health (Saliev et al., 2019; Hardell and Carlberg, 2020; Karipidis et al., 2021; Žura et al., 2023a). Current research includes the biological effects of RF-EMR on genotoxicity, cell proliferation, gene expression, cell signalling and cell membrane function (Nguyen et al., 2017) as well as on the immune system, hematopoietic (Jbireal et al., 2018), and reproductive systems (Simkó and Mattsson, 2019; Butković et al., 2023; Žura Žaja et al., 2023a, 2024). However, there is still sparse information in the available literature on the effects of RF-EMR of the 5G network on cells, tissues, organs and organisms. On the one hand, it is a new generation of wireless technology that uses different frequencies than previous technologies. On the other hand, it is certainly too early to predict the real effects of exposure of humans and living beings to the electromagnetic fields of the 5G network, as it has recently been introduced with a tendency for expansion. In the absence of long-term studies on the effects of 5G technology on the health of humans and other living beings and based on the results of previous generations of wireless technologies and possible harmful effects, it is necessary to start researching the effects of 5G technology on different organ systems and under as many different circumstances as possible (Banik et al., 2003; Simkó and Mattsson, 2019; Hardell and Carlberg, 2020; Elzanaty et al., 2021; Karipidis et al., 2021).

Exposure of humans and laboratory animals to RF-EMR emitted from cell phones and other 4G and older technology electronic devices has been shown to have deleterious effects on blood cells and/or changes in complete blood counts (CBC). This depends on the organism exposed, sources of RF-EMR, frequency, electromagnetic field strengths and duration of exposure (Jbireal et al., 2018). However, to date, no studies have been performed to determine the effects of RF-EMR on haematology indicators of domestic animals, with the exception of one study conducted on *in vitro* exposed blood of sows in the 5G network (Žura et al., 2023b). Data on morphometric indicators of erythrocytes after exposure of humans and laboratory animals to RF-EMR are unknown, with the exception of studies on sow blood exposed *in vitro* to the 5G network (Žura et al., 2023c). Knowledge about the effect of RF-EMR on platelet activation after exposure to human and/or *in vitro* human blood is also limited. Gaining knowledge about the effect of RF-EMR after *in vitro* blood exposure is of particular importance due to the storage and use of blood and blood products in transfusion medicine (Stoll and Wolkers, 2011; Nguyen et al., 2017).

The aim of this scientific review is to demonstrate the effects of RF-EMR on selected haematology indicators in humans and animals.

Electromagnetic radiation

All living beings have been exposed to electromagnetic radiation since the formation of the earth. Radiation is the transmission of energy through particles or electromagnetic waves. When energy is transmitted via electromagnetic waves, this radiation is referred to as electromagnetic radiation (EMR). The spectrum of electromagnetic radiation is shown in Figure 1.

Electromagnetic radiation is divided into ionising and non-ionising radiation depending on its energy. Ionising radiation has enough energy to ionise atoms and molecules, *i.e.*, it has enough energy to eject electrons out of atoms (ionise atoms), which can damage biological molecules in living things. For example, when cells are exposed to ionising radiation, the deoxyribonucleic acid (DNA) molecule can be damaged, increasing the risk of developing genetic and malignant diseases. Sources of ionising radiation can be natural (cosmic, cosmogenic and terrestrial) or anthropogenic (man-made), such as devices used in medicine (X-ray and CT machines), industry (radi-

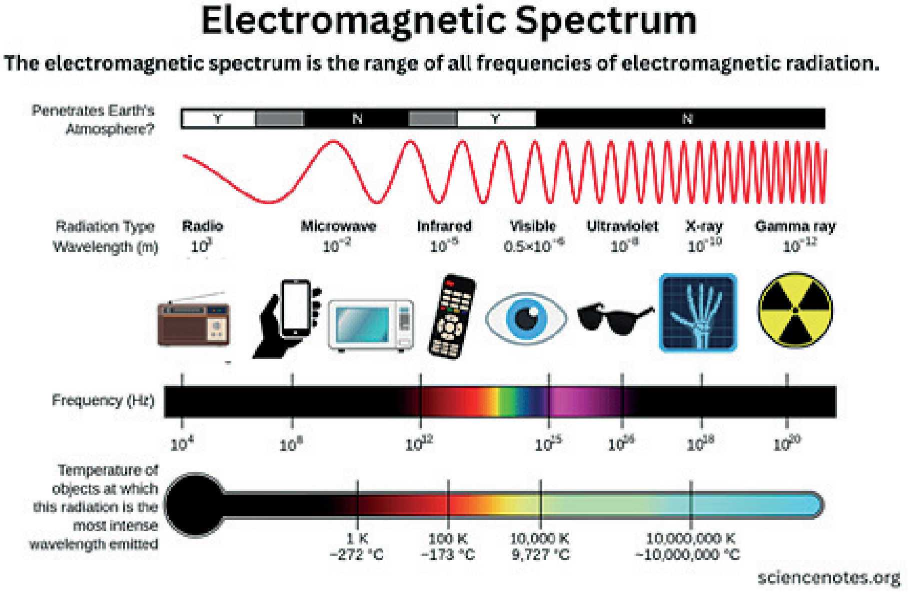

Figure 1. Spectrum of electromagnetic radiation (taken from https://sciencenotes.org/electromagnetic-spectrum-definition-and-explanation)

ography, food preservation) and nuclear explosions, and thus artificially generated radionuclides (Žura Žaja et al., 2021; PHO, 2023).

Non-ionising electromagnetic radiation, i.e., electromagnetic radiation with frequencies below 30 PHz, does not have sufficient energy to ionise atoms and molecules and is divided into the radio frequency (RF) and optical spectrum. The RF spectrum occupies the frequency range from 3 Hz to 300 GHz and, according to the International Telecommunication Union (ITU), is divided into ranges from very low frequency (VLF) to extremely high frequency (EHF), while the optical spectrum is divided into infrared, visible and ultraviolet radiation (Malarić et al., 2016). Sources of non-ionising electromagnetic radiation can also be natural or artificial. Natural sources of EMR include: the electromagnetic field of the earth, electrostatic field of the atmosphere, sunlight, thunder and lightning discharges. People are constantly exposed to natural electromagnetic waves to which the human body has become accustomed (Verma et al., 2023). However, a hundred years ago, humans created artificial sources of high-frequency electromagnetic radiation. Today, wireless communication technology is the largest and fastest growing source of RF-EMR of anthropogenic origin. Artificial (anthropogenic) sources of RF-EMR include satellite communications, radio communication systems, television and radio transmitters, mobile phones, cordless phones, microwave ovens and other sources from the field of wireless communication systems (WLAN - Wireless Local Area Network, Bluetooth, Wi-Fi devices) (Yousif and Alsahlany, 2022). It is also important to emphasise that every electrical device generates an electric and magnetic field. Therefore, high-voltage power lines, substations and various electrical devices, including modern electrically powered vehicles, are also among the artificial sources of EMR (Kivrak et al., 2017).

The accelerated development and widespread use of wireless technology based on RF-EMR has raised public concern about the possible consequences for the health of living beings exposed to this type of radiation.

Therefore, RF-EMR has been the subject of numerous studies both of people who use wireless devices directly and of people who are indirectly exposed due to the increasing number of sources in their environment, which is more pronounced in densely populated areas (Magiera and Solecka, 2020).

Over the last three decades, wireless communication, especially mobile telephony, has developed considerably. Different technologies have been used, characterised by the term generation (G), e.g., 1G, 2G, 3G, 4G and 5G. Nowadays, people live under the umbrella of RF-EMR. Everyone has a mobile phone, and every family has three to four mobile phones in the house (Verma et al., 2023). For example, the exposure levels to RF-EMR around frequency of 1 GHz band have increased 10^{18} times over natural levels (Bandara and Carpeter, 2018).

The widespread presence of artificial sources of EMR (including Wi-Fi devices) in the natural environment has led to the introduction of legislation worldwide to protect the environment. In the European Union, the basic legislation protecting the public from EMR is Council Recommendation (1999/519/EC) of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (Council Recommendation, 1999).

In 2020, the International Commission on Non-Ionizing Radiation Protection (ICNIRP, 2020) recommended guidelines for the protection of humans exposed to radiofrequency electromagnetic fields in the 100 kHz to 300 GHz range that provide a high level of protection for all people from the proven adverse health effects of short- and long-term, continuous and discontinuous radiofrequency electromagnetic fields. It is important to note that the ICNIRP uses only operational thresholds to set restrictions when these are lower (more conservative) than the adverse health effects demonstrated in the radiofrequency literature or when the radiofrequency literature does not provide sufficient evidence to derive a threshold for adverse health effects. To protect against exposure to non-ionising electromagnetic radiation, physical quantities and associated units of measurement are defined, which are referred to as "basic restrictions" and reference quantities.

The basic restrictions are closely related to radiofrequency induced adverse health effects. Some of these are physical quantities inside an exposed body that are difficult to measure. These quantities include the induced electric field (E_{ind}, measured in volt per meter; V/m), specific energy absorption (SA, measured in joule per kilogram; J/kg), absorbed energy density (U_{ab}, measured in joule per square meter; J/m^2), absorbed power density (S_{ab}, measured in watt per square meter; W/m^2), and specific absorption rate (SAR, measured in watt per kilogram; W/kg). The main component of the radiofrequency electromagnetic field acting on the body is the electric field. Electric fields inside the body are called induced electric fields ($E_{\mathbf{ind}}$) and can affect the body in various ways that are potentially relevant to health. On the other hand, from a health risk perspective, the quantity of EMF energy absorbed by biological tissue is of greatest interest, as this is largely responsible for the heating effects that depend on frequency. Below about 6 GHz, for example, the absorbed energy is described by SAR, while above 6 GHz it is useful to describe exposure in terms of $S_{\mathbf{ab}}$. According to ICNIRP (2020), the basic exposure limit to electromagnetic fields is expressed by the SAR value, which is most commonly used in practise and is actually a measure of the rate of energy absorption per unit mass of biological tissue.

Reference quantities are measurable, *i.e.*, easier to evaluate, and their monitoring indirectly ensures compliance with the basic restrictions. The reference quantities relevant for the ICNRP guidelines are incident electric field strength (E_{inc}, measured in volt per meter; V/m), incident magnetic field strength (H_{inc}, measured in ampere per meter; A/m), incident power density (S_{inc}, measured in watt per square meter; W/m^2), plane-wave equivalent incident power density (S_{eq}, measured in watt per square meter; W/m^2), incident energy density (U_{inc}, measured in joule per square meter; J/m^2) and plane-wave equivalent incident energy density (U_{eq}, measured in joule per square meter; J/m^2) — all measured outside the body — and electric current (I, measured in ampere; A) measured inside the body.

Biological effects of radiofrequency electromagnetic radiation

More than 3 billion people worldwide are exposed to EMR every day (Fragopoulou et al., 2010). The exposure of living organisms to EMR has been the subject of numerous scientific studies, as the results of previous studies have confirmed that this radiation causes changes and harmful effects in biological systems (Lai, 2021; Pophof, 2023; Verma et al., 2023). The biological effects of EMR are divided into thermal and non-thermal.

The thermal effect is related to the heating of cells/tissues when exposed to EMR, especially at high power densities of 100 mW/cm² (1000 W/m²) and above. The thermal effect is due to the rotation and vibration of water molecules caused by the absorption of RF-EMR energy from mobile phones and Wi-Fi devices in human tissue (Manna and Ghosh, 2016). It is possible that any interaction between the radiofrequency field and the tissues of living beings causes a transfer of energy that leads to an increase in temperature. The RF-EMR emitted by mobile phones is usually absorbed by the skin and other surface tissues and causes a negligible increase in the temperature of the brain or other organs in the body (Megha et al., 2012).

Non-thermal effects are those that are not directly related to temperature change, but to other changes in tissue that are related to the amount of energy absorbed (Leszczynski et al., 2002; Challis, 2005). Previous studies have found a number of cellular responses to RF-EMR, including gene expression (Piacentini et al., 2008; Goodman et al., 2009), cell differentiation and proliferation (Schwartz et al., 2008; Foletti et al, 2009), apoptosis, changes in ion homeostasis (Iorio et al., 2011), modulation of membrane receptors (De-Mattei et al., 2009) and an increased concentration of free radicals (Simk, 2007; Di-Loreto et al., 2009).

It has been observed that exposure to EMR causes an increased production of free radicals in the cellular environment, which can damage all biological molecules (proteins, lipids, DNA, etc.). In addition, the non-thermal effect is also mediated by the formation of reactive oxygen species (ROS) (Tkalec et al., 2007), which are involved in various physiological cell functions, though in excessive amounts they can be extremely harmful to cellular homeostasis (Cui et al., 2004). Their cytotoxic effect is manifested in the peroxidation of membrane phospholipids, leading to a change in membrane conductivity and a loss of membrane integrity (Halliwell, 2001). Living organisms have antioxidant mechanisms such as glutathione, glutathione peroxidase, catalase and superoxide dismutase to mitigate the harmful effects of ROS and the products generated by their deleterious effects on biological molecules (Calcabrini et al., 2017). Antioxidant mechanisms serve to prevent the formation of ROS or to stop the chain reaction triggered by ROS. Antioxidant defence mechanisms are weakened when the organism is exposed to EMR, which leads to the formation of an excessive amount of ROS, which in turn causes oxidative stress (Venugopal et al., 2002; Halliwell, 2007). Many studies have shown that EMR can trigger the formation of ROS in exposed cells *in vitro* (Zmyslony et al., 2004; Wu et al., 2008; Yao et al., 2008) and *in vivo* (Lai and Singh, 2004; Oktem et al., 2005; Tkalec et al., 2007). Kazemi et al. (2015) investigated the effect of 900 MHz RF-EMR exposure on the generation of oxidative stress and intracellular ROS levels in human mononuclear cells. Excessive production of ROS is one of the main causes of oxidative damage to lipids, proteins and nucleic acids. Therefore, it causes changes in enzyme activity and gene expression that eventually lead to various diseases, including sleep disorders, arthrosclerosis, loss of appetite, diabetes, vertigo, rheumatoid arthritis, cardiovascular diseases, nausea and stroke (Fridovich, 1999; Fang et al., 2002; Mattson, 2004). In addition, a disturbed balance between prooxidants and antioxidants can also cause lipid peroxidation due to excessive ROS formation. Lipid peroxidation is a process in which cell membranes are rapidly destroyed by the oxidation of phospholipid components containing unsaturated fatty acids. As this self-reinforcing chain reaction continues, lipid peroxides accumulate in the membrane and convert polyunsaturated fatty acids into biologically active substances (Halliwell, 1994).

Consequently, lipid peroxidation leads to significant damage in the cells, such as disruption of membrane transport, structural changes, cell membrane fluidity, damage to protein receptors in the cell membranes, and changes in the activity of cell membrane enzymes (Zmyslony and Jajte, 1998). Previous research has shown that free radicals play an important role in the development of many diseases such as diabetes and cancer (Basaga, 1990; Stadtman and Oliver, 1991; Ames et al., 1993; Kivrak et al., 2017).

The influence of electromagnetic radiofrequency radiation on haematology indicators

Excessive exposure of humans and animals to RF-EMR generated by mobile phones causes changes in the central nervous, cardiovascular and hematopoietic systems (Azab and Ebrahim, 2017; Jbireal et al., 2018).

The basic haematology laboratory analysis for assessing general health status, monitoring disease progression and detecting various disorders is the CBC (Alghamdi and El-Ghazaly, 2012). This analysis includes the determination of the number of erythrocytes, leukocytes and platelets per litre of blood and some of their morphological characteristics (Abdolmalek et al., 2012). The evaluation of CBC is the most important indicator for assessing the health status of humans and animals. The results of previous studies are controversial regarding the effects of RF-EMR on the levels of haematological and biochemical indicators in the blood of humans and animals (Kismali et al., 2012; Adebayo et al., 2019; Christopher et al., 2020; Hasan and Islam, 2020). Exposure of humans and experimental animals to RF-EMR emitted from cell phones and many other 4G and older technology electronic devices has been shown to have deleterious effects on blood cells (Jbireal et al., 2018). In addition, a disturbance of the values haematology indicators (number of erythrocytes, leukocytes and thrombocytes, values of haemoglobin and haematocrit and erythrocyte constants; mean cell volume (MCV), mean cell haemoglobin (MCH), mean cell haemoglobin concentration (MCHC), which depends on the type of exposed organisms, sources of RF-EMR, frequency of exposure, intensity and duration of exposure (Jbireal et al., 2018). RF-EMR from cell phones has also been shown to have deleterious effects on human blood cells, with an increase in the number of erythrocytes and a decrease in the number of leukocytes, lymphocytes and platelets after prolonged exposure (1 h) to RF-EMR *in vitro* (Kumari et al., 2016; Jbireal et al., 2018; Christopher et al., 2020). Exposure of sow blood to the 5G network for 2 h at a frequency of 700 MHz and 3500 MHz did not cause a change in the CBC value (Žura et al., 2023b).

However, in rats exposed to RF-EMR at a frequency of ≈1800 MHz for 5 weeks, there was a significant increase in the leukocyte count (Adebayo et al., 2019). Other studies have shown that exposure of experimental animals to RF-EMR increased the platelet count (Abdolmaleki et al., 2012; Alghamdi and El-Ghazaly, 2012; Al-Uboody, 2015; Jbireal et al., 2018). Exposure of mice to RF-EMR from a mobile phone for different durations of 0.5 h, 1 h, 2 h and 4 h per day for three weeks led to a significant decrease in haemoglobin (Hgb), haematocrit (HTC), MCV and MCHC, leukocyte count, platelet count and ionised calcium (Awwad et al., 2017). However, long-term exposure of male dogs to mobile phones (1962–1966 MHz, specific absorption rate 0.96 W/kg) for 2 h/day, 5 days/week over 10 weeks had no effect on haematology parameters. The Hgb and HTC concentration and counts of erythrocytes, thrombocytes, lymphocytes and monocytes did not change, while MCHC concentration and the counts of leukocytes, neutrophils, eosinophils and basophils was significantly lower. However, the decreased values haematology indicators were still within the reference range for dogs, *i.e.*, no negative effect of mobile phone exposure haematology indicators was found in healthy dogs when exposed to RF-EMR for 10 weeks (Dong et al., 2022). Exposure of humans and rats to EMR from mobile phones and base stations damages erythrocyte cell membranes and causes the formation of a significantly higher concentration of nitric oxide and peroxynitrite free radicals in human erythrocytes (Alghamdi, 2012; Hasan et al., 2014; Hasan and Islam, 2020).

In addition, it has been shown that RF-EMR from cell phones at a frequency of 900–1800 MHz has harmful effects on erythrocytes in blood smears of mice after short and long-term exposure. Namely, the effect is reflected in a colour change of the central part of the erythrocytes (hypochromic erythrocytes), and the shape (rouleaux formation) and appearance of pathological forms of erythrocytes (echinocytes, anisocytosis, poikilocytosis, teardrop shape), with a higher extent of damage with a longer exposure (Alghamdi and El-Ghazaly, 2012).

The influence of electromagnetic radiofrequency radiation on erythrocyte morphometry

Morphometry is the simplest form of imaging cytometry and refers to the assessment of cells or tissues by measuring various cellular features in two-dimensional view (Poljičak-Milas et al., 2009). More recent research uses sophisticated and advanced measurements of erythrocytes using computer programs (Adili et al., 2017; Žura Žaja et al., 2019, 2023b; Ahmed et al., 2021). Using computer analysis of morphometric images of erythrocytes and multivariate statistical methods, including principal component analysis and cluster analysis, it is possible to determine the presence of subpopulations of sheep erythrocytes based on their morphometric indicators (Žura Žaja et al., 2019). Data on morphometric indicators of erythrocyte size and shape after exposure of humans and laboratory animals and/or *in vitro* blood to RF-EMR obtained by computerised image analysis have not been investigated. The first results on changes in morphometric indicators of erythrocytes after a 2-hour exposure of sow blood to a 5G network *in vitro* at a frequency of 3500 MHz were obtained by Žura et al. (2023c). The authors found a decrease in the values for erythrocyte outline, minimum radius and contour index, as well as significantly higher values for erythrocyte solidity, elongation and form factor in the exposed samples.

The influence of electromagnetic radiofrequency radiation on platelet activation

Flow cytometry has been significantly improved in recent years and was previously used to measure platelet activation for clinical and research purposes (Ramström et al., 2016; Alzua et al., 2020). Knowledge about the effect of RF-EMR after exposure to human and/or *in vitro* human blood on platelet activation is scarce. Khamidova (2014) found that individuals working under direct and continuous exposure to RF-EMR (frequencies in the range of 650 to 800 MHz) showed different changes in platelet activation, most frequently hyperaggregation, *i.e.*, increased platelet activation, which was dependent on the duration of work under the exposure conditions. The only study on the effect of RF-EMR on human platelets *in vitro* was conducted by Lippi et al. (2017). The authors indeed showed a significant reduction in platelet aggregation/adhesion and an increase in their size after 30-minute *in vitro* exposure of human blood to RF-EMR from a mobile phone operating in the 900 MHz frequency band.

Concluding considerations

RF-EMR of various frequencies of anthropogenic origin are present throughout the human and animal environment, posing a potential health threat. Although several studies have been conducted on the effects of radiofrequency radiation on CBC, there is a lack of research on other important haematology indicators such as platelet activation and erythrocyte morphometry. Based on the above, it is important to determine if and how exposure to RF-EMR affects blood samples analysed in healthcare facilities with blood analyzers equipment. This is important to make a valid diagnosis and/or to monitor the effect of therapy and prognosis of the disease. Therefore, the aim of this article was to highlight the lack of much needed research, especially as blood and its components are increasingly exposed both *in vitro* and *in vivo*. In addition, it is important to determine how exposure to RF-EMR affects blood products such as erythrocytes and platelets intended for transfusion, *i.e.,* whether these cells have a shorter lifespan or are less functional due to exposure to RF-EMR.

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Učinci radiofrekventnog elektromagnetskog zračenja s osvrtom na neke hematološke pokazatelje: kratki pregled i potrebe budućih istraživanja

Nikolino ŽURA, mag. physioth., doktorand, Klinički bolnički centar Zagreb, Zdravstveno veleučilište Zagreb, Hrvatska: dr. sc. Ivona ŽURA ŽAJA, dr. med. vet., izvanredna profesorica, dr. sc. Suzana MILINKOVIĆ TUR, dr. med. vet., redovita profesorica, dr. sc. Nina POLJIČAK MILAS, dr. med. vet., redovita profesorica, dr. sc. Jadranka PEJAKOVIĆ HLEDE, dr. med. vet., docentica, Sandra KUNŠTEK, mag. ing. biochem., dr. sc. Marko PEĆIN, dr. med. vet., izvanredni professor, dr. sc. Marinko VILIĆ, dr. med. vet., redoviti profesor, Veterinarski fakultet Sveučilišta u Zagrebu, Hrvatska, dr. sc. Porin PERIĆ, dr. med., izvanredni profesor, Klinički bolnički centar Zagreb, Medicinski fakultet Sveučilišta u Zagrebu, Hrvatska; dr. sc. Krešimir MALARIĆ, dipl. ing., redoviti profesor, Fakultet elektrotehnike i računarstva Sveučilišta u Zagrebu, Hrvatska; dr. sc. Vladimira RIMAC, mag. med. biochem., Klinički bolnički centar Zagreb, Hrvatska

Od 1950-ih godina primjena radiofrekvencijskog elektromagnetskog zračenja (RF-EMZ) u stalnom je porastu. RF-EMZ se koristi u: medicini, industriji, kućanskim uređajima, sigurnosti i navigaciji, a posebno u bežičnoj telekomunikaciji, stočarstvu. Raširena uporaba RF-EMZ-a, posebice uvođenjem 5G mreže, prouzroči zabrinutost javnosti o mogućim štetnim učincima na ljudsko i životinjsko zdravlje. Učinci i mehanizmi djelovanja RF-EMZ na ljudsko i životinjsko zdravlje frekvencijskog pojasa iz 5G mreže do sada su gotovo nepoznati ili ako jesu vrlo oskudno istraženi. Dosadašnja istraživanja uključuju: biološki učinak RF-EMZ-a na genotoksičnost, staničnu proliferaciju, ekspresiju gena, staničnu signalizaciju, funkciju staničnih membrana te na funkciju imunosnog, hematopoetskog i reproduktivnog sustava. Dokazano je da izloženost ljudi i pokusnih životinja RF-EMZ-a koje su emitirali mobilni telefoni i drugi elektronički uređaji 4G i starije tehnologije uzrokuju štetne učinke na krvne stanice i promjenu kompletne krvne slike. Navedeno ovisi o vrsti izloženih živih bića, izvorima RF-EMZ-a, frekvenciji, učestalosti i trajanju izloženosti. U dostupnoj su literaturi podatci o učinku RF-EMZ-a na hematološke pokazatelje i morfometriju eritrocita domaćih životinja vrlo su oskudni. Stoga je cilj ovog preglednog znanstvenog rada prikazati učinak RF-EMZ na hematološke pokazatelje, morfometriju eritrocita i aktivaciju trombocita u ljudi i životinja s osvrtom na saznanja o učincima 5G elektromagnetskog zračenja na prethodno navedene pokazatelje. S obzirom na sveprisutno elektromagnetsko onečišćenje važno je steći saznanja o učinku RF-EMZ-a na zdravlje ljudi i životinja. Osim toga, potrebno je utvrditi i učinke nakon *in vitro* izlaganja krvi RF-EMZ-u zbog pohrane te primjene krvi i krvnih pripravaka u transfuzijskoj medicini.

Ključne riječi: *radiofrekventno elektromagnetsko zračenje, biološki učinci, kompletna krvna slika, morfometrija eritrocita, aktivacija trombocita*