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Effect Exposure of Mobile Phone Radiation on Blood Parameters in Rats

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Abstract

The aim of the research was to assess effects of short and long-period exposure to radiation from mobile phone on blood indices in experimental rats. In this study forty mature female rats were used; the animals were divided into two experimental group, each group consists of twenty animals. Short-period group of rats were exposed to cell phone radiation for different duration 30 m, 60 m, and 90 m per day for six weeks. Long-period group of rats were exposed to radiation from mobile phone for different duration 2h, 4h, and 6h per day for three months. The study noticed that there was significant ($P \leq 0.05$) elevation in total white blood cells and the study demonstrated significant increment ($P \leq 0.05$) in percentage of lymphocytes (71.1%) of rats which exposed to radiation from mobile phone for short-period in (90 minutes) compared to the control group (42.64%). While, the study revealed that there was a significantly ($P \leq 0.05$) lower percentage of neutrophils (15.36%) in rats that were exposed to mobile phone radiation for long-period in (6 hours) compared with the control group (52.12%). The study recorded that there was a significant ($P \leq 0.05$) elevation in total red blood corpuscles and packed cell volume of rats exposed to radiation from mobile phone for short and long-period in different times compared with control. On the other hand, the research indicated that there was a significant ($p \leq 0.05$) decrement in mean corpuscles volume (MCV), mean corpuscle hemoglobin (MCH), mean corpuscle hemoglobin concentration and red blood cell distribution width standard deviation (RDW-SD) of rats to radiation from mobile phone for short and long-period in different times than control group.

Keywords: Environmental pollution, Mobile phone radiation, Blood parameters

تأثير التعرض لإشعاع الهاتف المحمول على معايير الدم في الجرذان

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الخلاصة

الهدف من البحث هو تقييم آثار التعرض القصير والطويل الامد الى الإشعاع من الهاتف المحمول على مؤشرات الدم في الجرذان المختبرية. في هذه الدراسة استعملت أربعين أنثى جرذ ناضجة وقسمت الحيوانات إلى تجربتين كل تجربة تتكون من عشرين حيواناً. تعرضت تجربة الجرذان قصيرة الامد لإشعاع الهاتف المحمول لفترات مختلفة 30 دقيقة و 60 دقيقة و 90 دقيقة يومياً لمدة ستة أسابيع، وتعرضت تجربة الجرذان طويلة الامد للإشعاع من الهاتف المحمول لفترات مختلفة 2 ساعة و 4 ساعات و 6 ساعات يومياً لمدة ثلاثة أشهر. لاحظت الدراسة وجود ارتفاع ملحوظ ($P \geq 0.05$) في العدد الكلي لخلايا الدم البيض. وأظهرت الدراسة زيادة ملحوظة ($P \geq 0.05$) في نسبة الخلايا الليمفاوية (71.1%) في الجرذان التي تعرضت للإشعاع

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من الهاتف المحمول لفترة قصيرة (90 دقيقة) مقارنة مع مجموعة السيطرة (42.64%). بينما أوضحت الدراسة أن هناك انخفاض ملحوظ ($P \geq 0.05$) في نسبة لايا الدم البيض المتعادلة (15.36%) في الجرذان التي تعرضت لإشعاع الهاتف المحمول لفترة طويلة (6 ساعات) مقارنة مع مجموعة السيطرة (52.12%). سجلت الدراسة وجود ارتفاع ملحوظ ($P \geq 0.05$) في العدد الكلي لكريات الدم الحمراء وحجم مكذاس الدم للجرذان المعرضة للإشعاع من الهاتف المحمول لفترات قصيرة وطويلة في أوقات مختلفة مقارنة مع السيطرة. من ناحية أخرى، أشار البحث إلى وجود انخفاض ملحوظ ($p \leq 0.05$) في متوسط حجم كرية الدم الحمراء (MCV)، ومتوسط هيموجلوبين كرية الدم الحمراء (MCH)، ومتوسط تركيز الهيموجلوبين في كرية الدم الحمراء، وتوزيع كريات الدم الحمراء (RDW-SD) في الفئران المعرضة للإشعاع من الهاتف المحمول لفترات قصيرة وطويلة في أوقات مختلفة مقارنة مع مجموعة السيطرة.

1. Introduction

Cell phones have become essential part of daily life. It produces radiation fields around them when in use, thus electromagnetic pollution increased [1]. It is radio instruments that transmit and receive radiation of radiofrequency radiation at 900–2000 MHz [2]. Electromagnetic fields from mobile phones cause changes in immune activity in cultured Peripheral blood mononuclear cells [3]. In addition, some previous studies reported that exposure of radiation from cellular phone causes effects include headache, warmth on and behind the ear, fatigue, decreased concentration, dizziness, memory loss, tingling and numbness [4].

Moreover, WHO organization illustrated that radiations produced by the mobile phone were hard for health of human and some of them were not. It was scientifically demonstrated that the radiations from mobile phones could cause variant diseases; especially the brain of human being and it will give them hardships adjusting to their daily organized work path [5]. The potential health risks of a mobile phone can be divided into two parts: these are non-thermal effect and thermal effect; the major concern of non-ionizing radiation is the thermal effect [6]. Also, it has been shown that electromagnetic radiation (EMR) may cause fluctuations in heart rate (HR), oxidative stress, inflammation in the eyes and inner ear damage [7,8,9]. The purpose of this research is to assess the effects of short and long-period exposure to radiation produced by mobile phone on hematological indices in experimental rats.

2. Material and methods

Animals of experimental:

This study was performed on 40 female Wistar Albino rats (*Rattus norvegicus*). Their mean body weight was (150-200 gm.) and age (10-12) weeks. The laboratory rats were divided into two experimental groups, each group consists of 20 animals (short-period and long-period experiments). Short-period experiments: rats were exposed to the electromagnetic field (EMF) from mobile phone for different duration 30 min., 30 min., and 30 min. per day for six weeks. In addition, long-period experiments rats were exposed to the electromagnetic field (EMF) from mobile phone for different duration different duration 2hr, 4hr, and 6hr per day for three months. The animals were housed in the animal house of “Faculty of Science, University of Kufa”, under standard environment condition “temperature 25-28 C° and 12 h light-dark cycle and allowed access to a standard water and diet”. All animal experiments had been approved by central committee for bioethics in University of Kufa and were performed according to these guidelines. “All institutional and national guidelines for the care and use of laboratory animals were followed.”

Exposure of EMF from mobile phone:

Testing female Wistar albino rats were exposed to the electromagnetic field (EMF) from mobile phone “Samsung Galaxy S III with frequency 1.2 GHz” in different times, which according to the GSM, operates with microwave carrier frequencies in the range 850-2100

MHz. Animals were kept in individual cages made of plastic “designed cages 50 × 25 × 35 cm”. Mobile phone was placed on top of each cage during the hours of exposure. The telephones were positioned in close contact with the rats.

Collection of blood sample:

Following the end of exposure, each animal was slightly anaesthetized by combination of (0.5 ml ketamine & 0.1 ml xylazine) [10]. The rats were put after anesthesia on dissection bowl, the forward and behind limbs were fixed by fine pins. Heart puncture was done and blood was drawn very gently and slowly by “3 ml and 5 ml disposable syringe”. It was placed in an EDTA tube and mixed comprehensively, then used for the estimation of blood analysis by an automatically analyzer.

Hematological analysis:

The hematological indices were carried out on blood from EDTA tube using “Ruby Abbott., U.S.A”, Ruby is hematology analyzer to perform red blood corpuscles (RBC), white blood cell (WBCs), hemoglobin (HB), Erythrocyte sedimentation rate (ESR) and packed cell volume (PCV) on EDTA [11].

3. Results

The study revealed that there was a significant ($P \leq 0.05$) elevation in total leukocytes count of rats which exposed to mobile phone radiation for short-period (60 and 90 minutes) compared with control group (Table 1).

The results recorded that there was a significantly ($P \leq 0.05$) higher percentage of lymphocytes of rats which exposed to radiation from mobile phone for short and long-period in different times compared with the control group (Table 1, 2).

Table 1-Impact of short-period exposure to radiation from mobile phone on total and differential counts of leukocytes in female rats

Parameters	Control	Time exposure (minutes)		
		30 minutes	60 minutes	90 minutes
Total leukocytes count ($\times 10^3$) (cell/mm ³)	6.6 \pm 0.73	6.81 \pm 0.78	7.76 \pm 0.11 ^{ab}	8.27 \pm 0.08 ^{abc}
Neutrophils (%)	52.12 \pm 2.6	21.6 \pm 1.14 ^a	23 \pm 0.7 ^{ab}	23.4 \pm 0.83 ^{ab}
Lymphocytes (%)	42.64 \pm 3.35	73.4 \pm 1.14 ^a	71.1 \pm 0.89 ^{ab}	71.1 \pm 0.83 ^{ab}
Monocytes (%)	3.6 \pm 0.35	3.64 \pm 0.15	4.6 \pm 0.44 ^a	4.38 \pm 0.53 ^a
Eosinophils (%)	1.24 \pm 0.87	1.26 \pm 0.15	0.8 \pm 0.54	0.62 \pm 0.53
Basophils (%)	0.4 \pm 0.18	0.1 \pm 0.01 ^a	0.5 \pm 0.01	0.5 \pm 0.01

Notes: SD = Standard deviation. (a) = indicates to significant difference ($p \leq 0.05$) than control. (b) = indicates to significant difference than with (30 minutes) at ($p \leq 0.05$). (c) = indicates to significant difference than with (60 minutes) at ($p \leq 0.05$).

Table 2-Impact of long-period exposure to radiation from mobile phone on total and differential counts of leukocytes in female rats

Parameters	Control	Time exposure (hours)		
		2 hours	4 hours	6 hours
Total leukocytes count ($\times 10^3$) (cell/mm ³)	6.45 \pm 0.43	6.65 \pm 0.44	8.58 \pm 0.083 ^{ab}	9.5 \pm 0.76 ^{ab}
Neutrophils (%)	52.12 \pm 2.61	21.82 \pm 0.58 ^a	24.5 \pm 0.89 ^{ab}	15.36 \pm 1.25 ^{abc}
Lymphocytes (%)	42.6 \pm 3.35	71.84 \pm 1.34 ^a	71.5 \pm 0.7 ^a	79.6 \pm 2.01 ^{abc}
Monocytes (%)	3.6 \pm 0.35	4.92 \pm 0.29 ^a	3.06 \pm 0.05 ^a	3.58 \pm 0.62
Eosinophils (%)	1.24 \pm 0.87	0.88 \pm 0.26	0.46 \pm 0.49 ^b	1.16 \pm 0.13 ^c

Basophils (%)	0.4±0.18	0.26±0.134	0.2±0.00	0.3±0.1
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Notes: SD = Standard deviation. (a) = indicates to significant difference ($p \leq 0.05$) than control. (b) = indicates to significant difference than with (2 hours) at ($p \leq 0.05$). (c) = indicates to significant difference than with (4 hours) at ($p \leq 0.05$).

Results of short-period experiment are showed in (Table 3). This study found that there was a significant ($P \leq 0.05$) increment in packed cell volume (PCV) of rats exposed to radiation from mobile phone for time exposure of 60 minutes than control.

This study also revealed that there was a significant ($P \leq 0.05$) elevation in total red blood corpuscles of rats which exposed to mobile phone radiation for long-period in different times than control (Table 4).

However, the result also showed that there was a significant ($p \leq 0.05$) decrease in mean corpuscles volume (MCV), mean corpuscle hemoglobin (MCH) and mean corpuscle hemoglobin concentration of rats exposed to mobile phone radiation for long-period in three times than control group (Table 3,4).

Also, it can be clearly seen that a significant ($P \leq 0.05$) decrement red blood cell distribution width standard deviation (RDW-SD) of rats exposed to mobile phone radiation for 90 minutes compared with control group (Table 3).

Table 3-Impact of short-period exposure to radiation from mobile phone on total red blood corpuscles and red blood cell absolute values in female rats

Parameters	Control	Time exposure (minutes)		
		30 minutes	60 minutes	90 minutes
Total RBCs ($\times 10^6$) (corpuscle/ mm^3)	6.08±0.41	6.68±0.11 ^a	7.1±0.02 ^a	7.3±0.15 ^a
Hb (g/dl)	12.56±0.62	13.44±0.49	14.28±0.13 ^a	14.2±0.22 ^a
PCV (%)	38.42±1.5	38.42±1.1	40.46±0.58 ^{ab}	40.28±0.77 ^b
MCV (fL)	86.2±5.1	56.44±1.04 ^a	55.4±0.54 ^a	54.38±0.08 ^{ab}
MCH (pg)	30.1±0.02	19.9±0.27 ^a	20.8±0.54 ^a	19.1±0.16 ^a
MCHC (g/dl)	32.28±0.14	35.28±0.1 ^a	34.6±0.54 ^a	35.04±0.05 ^a
RDW-SD (fL)	41.44±4.05	31.06±0.55 ^a	30.06±0.054 ^a	30.8±1.08 ^a
RDW-CV (%)	14.34±0.32	14.06±0.05	14.16±0.05	14±0.57 ^a

Notes: SD = Standard deviation. (a) = indicates significant difference ($p \leq 0.05$) than control. (b) = indicates significant difference than with (30 minutes) at ($p \leq 0.05$). (c) = indicates significant difference than with (60 minutes) at ($p \leq 0.05$).

Table 4-Impact of long-period exposure to radiation from mobile phone on total red blood corpuscles and red blood cell absolute values in female rats

Parameters	Control	Time exposure (hours)		
		2 hours	4 hours	6 hours
Total RBCs ($\times 10^6$) (corpuscle/ mm^3)	6.08±0.41	6.7±0.04 ^a	6.83±0.054 ^a	7.1±0.054 ^a
Hb (g/dl)	12.56±0.62	13.14±0.05	13.14±0.054	13.5±0.054 ^a
PCV (%)	38.82±2.07	36.72±0.43	36.6±0.054	37.36±0.054
MCV (fL)	86.2±5.17	54.4±1.09 ^a	54.06±0.054 ^a	52.24±0.054 ^{abc}
MCH (pg)	30.13±0.02	19.5±0.27 ^a	19.34±0.054 ^a	18.84±0.054 ^a
MCHC (g/dl)	32.28±0.14	35±0.00 ^a	35.04±0.054 ^a	35.04±0.054 ^a
RDW-SD (fL)	41.44±4.05	28.62±0.65 ^a	30.32±0.08 ^{ab}	32.26±1.61 ^{abc}
RDW-CV (%)	14.34±0.32	13.92±0.1	14.4±0.07	14.98±0.58

Notes: SD = Standard deviation. (a) = indicates significant difference ($p \leq 0.05$) than control. (b) = indicates significant difference than with (2 hours) at ($p \leq 0.05$). (c) = indicates significant difference than with (4 hours) at ($p \leq 0.05$).

4. Discussion

This study found that there was a significant ($P \leq 0.05$) elevation in total leukocytes count of rats which exposed to radiation from mobile phone for short and long-period in 60 minutes and 90 minutes compared with control group (Table 1). This result agreed with [12] who found that total leukocytes count was significantly increased in mice exposed to mobile phone electromagnetic waves (EMW) compared with control group. The results from this study indicates that significant increase in total WBCs due to the negative action of exposure to electromagnetic waves (EMW) that induced the haemopoietic system to produce more lymphocytes causing high number in the blood stream. In addition, [13] elucidated significant increase in the white blood cells as well as the percentage of lymphocytes. This may arise under the effect of radiation exposure, increased body resistance and temperature.

Regarding differential leukocytes count, the results recorded that there was significantly ($P \leq 0.05$) higher percentage of lymphocytes of rats which exposed to radiation from mobile phone for short and long-period in different times compared with the control group (Table 1,2). Similarly [14] reported increase in total WBC, with percentage of lymphocytes and neutrophils, monocytes as well as a significant increase in PCV, RBCs, Hb and platelet count in mice (Swiss albino) exposed to 4 hours per day) for 30 days to EMFs (50 Hz, 2 MT) 6-week. Moreover, [15] showed that the increase in the proportion of lymphocytes linked with inflammation of lymphatic the lymph gland, which appear as a result of continuous exposure to electromagnetic waves, especially the children. Environmental factors including magnetic fields are more sensitive to actively lymphocytic proliferation [16]. Furthermore, long-period exposure to EMR was associated a raise in WBCs manifested by increase proportion of lymphocytes; MCHC and platelet count in rats [17].

This study found that there was a significant ($P \leq 0.05$) elevation in total red blood corpuscles of rats exposed to radiation from mobile phone for long-period of different times than control (Table 4). This finding agreed with the results obtained by [18] which found total red blood corpuscles were significantly higher in rats exposed to microwave radiation ($P < 0.01$) than control group. They concluded that increment of total red blood corpuscles may respond to indicative of the hypoxia. This result perhaps due to high exposure of electromagnetic radiation caused hypoxia. Hypoxia increased renal erythropoietin secretion which in turn, stimulates red bone marrow production of a greater number of RBC and Hb in the circulating blood. The increase in total red blood corpuscles with short and long-period exposure to electromagnetic radiation from cellular phone probably respond to hypoxia-like status.

The results of the short-period experiment are shown in (Table 3). This study found that there was a significant ($P \leq 0.05$) elevation in packed cell volume (PCV) of rats exposed to mobile phone radiation for time exposure 60 minutes comparison with control group. Similar findings were recorded [4] and found prolonged or continued exposure of low and high electromagnetic radiation of mobile phones was associated with increased hemoglobin total red and blood corpuscles in experimental rats. The researchers explained these results that long-time exposure of electromagnetic radiation of mobile phones might expose to detrimental impacts to blood components and functions of liver.

This study revealed that there was a significant ($p \leq 0.05$) decrement in mean corpuscles volume (MCV), mean corpuscle hemoglobin (MCH) and mean corpuscle hemoglobin concentration of rats exposed to short and long-period mobile phone radiation for three times than control group (Table 3,4). Similar findings were recorded by [19] who noted a decrement of MCV and MCH in albino rats when exposed high levels of electromagnetic field. Furthermore [20] observed sub-acute exposure to magnetic field on female rats increased in Hb and Ht levels because of hypoxia-like status induced by the static MF resulting probably

from the oxygen-binding impairment of Hb. In addition, [21] stated that French population living near riverside high-voltage transmission lines suffered from decrease in plasma iron.

The results also illustrated that that a significant ($P \leq 0.05$) decrement red blood cell distribution width standard deviation (RDW-SD) of rats exposed to radiation from mobile phone for 90 minutes comparison with control group (Table 3). Several studies reported that exposure to electromagnetic field caused a decrease iron in blood [22,23] Moreover, [24] demonstrated that the hypothesis of an action of static magnetic field "SMF" on hemoglobin was confirmed by the fact that SMF stimulated a prominent effect on structure of hemoglobin. Moreover, recent studies by [25] noted that animals exposed to moderate and strong static magnetic fields stimulated change in the absorption spectra and conductivity measurements of hemoglobin molecules.

5. Conclusions

It can be concluded that hematological parameters of rats were significantly affected after short and long-period exposure to radiation from mobile phone. The hematological analysis showed a significant elevation in values of white blood cells, lymphocytes, total red blood corpuscles and packed cell volume of rats after exposure to short and long-period to electromagnetic radiation from mobile phone. However, the study confirms that values of mean corpuscles volume and mean corpuscle hemoglobin concentration and red blood cell distribution width standard deviation were significantly decreased in rats after exposure to mobile phone electromagnetic radiation.

References

- [1] B. Dewulf, T. Neutens, W. Lefebvre, G. Seynaeve, C. Vanpoucke, C. Beckx and N. Van de Weghe, "Dynamic Assessment of Exposure to Air Pollution Using Mobile Phone Data," *International Journal of Health Geographics*, vol.15, no. 1, pp.1-14, 2016.
- [2] A.H. Frey, "Headaches from Cellular Telephones: Are They Real and What Are the Implications?," *Environmental Health Perspectives*, vol. 106, no. 3, pp. 101-103, 1998.
- [3] M.P. Dabrowski, W. Stankiewicz, R. Kubacki, E. Sobiczewska, and S. Szmigielski, "Immunotropic Effects in Cultured Human Blood Mononuclear Cells Pre-Exposed to Low-Level 1300 Mhz Pulse-Modulated Microwave Field", *Electromagnetic Biology and Medicine*, vol. 22, no. 1, 1-13, 2003.
- [4] A. Sani, M.M. Labaran, and B. Dayyabu, "Effects of Electromagnetic Radiation of Mobile Phones on Hematological and Biochemical Parameters in Male Albino Rats", *Eur Exp Biol*, vol. 8, no. 2, pp.11, 2018.
- [5] N. Maregu, "Long Period Exposure of Mobile Phone Radiation and Human", *Journal of Information Engineering and Applications*, vol. 6, 2016.
- [6] S. K. Myung, W. Ju, D.D. McDonnell, Y.J. Lee, G. Kazinets, C.T. Cheng, and J.M Moskowicz, "Mobile Phone Use and Risk of Tumors: a Meta-Analysis", *Journal of Clinical Oncology*, vol. 27, no.33, pp.5565, 2009.
- [7] B. Oral, M. Guney, F. Ozguner, N. Karahan, T. Mungan, S. Comlekci, and G. Cesur, "Endometrial Apoptosis Induced by A 900-Mhz Mobile Phone: Preventive Effects of Vitamins E And C", *Advances in Therapy*, vol. 23, no. 6, pp. 957-973, 2006.
- [8] N.K. Panda, R. Jain, J. Bakshi, and S. Munjal, "Audiologic Disturbances in Long-Period Mobile Phone Users", *Journal of Otolaryngology--Head & Neck Surgery*, vol. 39, no. 1, 2010.
- [9] L.S. Al-Jameel, R.S. Ahmed, and H.A. Shamran, H. A. "Ionizing Radiation Effect and DNA Damage in the Workers of Al-Tuwaitha Nuclear Site", *Iraqi Journal of Science*, 2636-2641, 2019.
- [10] S. Kavak, I. Meral, N. Pirinçci, M. Güneş, H. Demir, and K. Ceylan, K, "Effects of Shock Waves on Oxidative Stress, Antioxidant Enzyme and Element Levels in Kidney of Rats", *Biological Trace Element Research*, vol. 144, no. 1-3, pp. 1069-1076, 2011.
- [11] I. Mathieleers, G. Lsabel, S. Fadila, and G. Rick, "Abbott a Promise for Life", Com, Case book, 1-91, 2012.

- [12] W.S.H. Al-Uboody, “ Effect of Mobile Phone Electromagnetic Waves on the Hematological and Biochemical Parameters in Laboratory Mice (Mus Musculus)”, *Bas. J. Vet. Res*, vol. 14, no. 2, pp. 250-264, 2015.
- [13] S. A. Mariam and A.E.G. Nawal, “ Effects of Exposure to Electromagnetic Field on Of Some Hematological Parameters in Mice”, *Open Journal of Medicinal Chemistry*, 2012.
- [14] M.A. Hashem, and N.L. El-Sharkawy, “Haemato-Biochemical and Immunotoxicology Effects of Low Electromagnetic Field and Its Interaction With Lead Acetate in Mice”, *Iraqi Journal of Veterinary Sciences*, vol. 23, no. 3, 2009.
- [15] H.A. Zelly, “ Do Not Harm from Them If We Avoided Risks: Equipment Hair Potential Health Problems”, *Welcome to the magazine*, San Francisco,2007.
- [16] D. Mohammadnejad, J.S. Rad, A. Azami, B. Khojasteh, F. Rajaei, H.T. N. Abadei, and A. Lotfi, “Protective Effect of Vitamin E Supplement in Electromagnetic Field Induced Damages in Spleen: An Ultrastructural and Light Microscopic Studies “, *Global Veterinaria*, vol. 4, no. 4, pp. 416-421, 2010.
- [17] A. Gul, H. Çelebi, and S. Uğraş, “The Effects of Microwave Emitted by Cellular Phones on Ovarian Follicles in Rats”, *Archives of Gynecology and Obstetrics*, vol. 280, no. 5, pp. 729-733, 2009.
- [18] M.S. Esfahani, B. Radmehr, and A. Kohbodi, “Detection of Probable Effects of Microwave Exposure of Blood Parameters Of RBC, PCV And Hb in Rat“, *Pakistan Journal of Biological Sciences: PJBS*, vol. 10, no. 24, pp. 4567-4569, 2007.
- [19] G. Purushothaman, G. Gajalakshmi, S. Qairunnisa, B.A. Madhuri, and M. Chandrasekhar, M., “Evaluation of Hematological and Biochemical Parameters of Magnetic Field Exposed Albino Rats”, *Current Trends in Biotechnology and Pharmacy*, vol. 7, no. 3, pp. 804-807, 2013.
- [20] C. Sihem, A. Hafedh, S. Mohsen, P.J. Marc, and B.R. Khmais, “Effects of Sub-Acute Exposure to Magnetic Field on Blood Hematological and Biochemical Parameters in Female Rats”, *Turk J Hematol*, vol. 23, pp. 182-187, 2006.
- [21] E. Hachulla, M.T. Caulier-Leleu, O. Fontaine, L. Mehianoui, and P. Pelerin, “Pseudo-Iron Deficiency in A French Population Living Near High-Voltage Transmission Lines: A Dilemma for Clinicians”, *European Journal of Internal Medicine*, vol. 11, no. 6, pp. 351-352, 2000.
- [22] A.M. Stashkov, and I.E. Gorokhov, “Hypoxic and Antioxidant Biological Effect of Multi-Day Application of A Weak Variable Super-Low Frequency Magnetic Field”, *Biofizika*, vol. 43, no. 5, pp. 807-810, 1998.
- [23] I. Nourmohammadi, H. Ahmadvand, and M. Taghikhani, “Evaluation of Levels of Macro-and Micro-Nutrients in Workers Exposed to Electromagnetic Fields and Comparison with Levels of Patients with Leukemia”, *Iranian Biomedical Journal*, pp. 79-85, 2001.
- [24] S. Amara, H. Abdelmelek, M.S. Salem, R. Abidi, and M. Sakly, “Effects of Static Magnetic Field Exposure on Hematological and Biochemical Parameters in Rats”, *Brazilian Archives of Biology and Technology*, vol. 49, no. 6, pp. 889-895, 2006.
- [25] N.S. Hassan, and S.A. Abdelkawi, “Changes in Molecular Structure of Hemoglobin in Exposure To 50 Hz Magnetic Fields”, *Nature and Science*, vol. 8, no. 8, pp. 236-43, 2010.