JPPIPA 10(4) (2024)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Potential Impact of Anemia on BALB/c Mice Exposed to an Extremely Low Frequency 50 Hz Magnetic Field with an Intensity of 100 µT and 500 µT

Sudarti[1*], Trapsilo Prihandono[1], Revi Restanti[1]

[1]Pendidikan Fisika, Universitas Jember, Jember, Indonesia.

Received: December 11, 2023
Revised: March 18, 2024
Accepted: April 25, 2024
Published: April 30, 2024

Corresponding Author: Sudarti Sudarti
sudarti.fkip@unej.ac.id

DOI: 10.29303/jppipa.v10i4.6501

Abstract: Exposure threshold values (ELF MF) according to WHO, 100 µT for the public and 500 µT for workers, are still being debated. This study examines the potential impact of anemia in BULB/C mice exposed to ELF MF intensities of 100 µT and 500 µT. The research design used a completely randomized design with intensity and duration of exposure to ELF MF as factors. A sample of 60 male Bulb/C mice were divided into 6 groups, 2 groups exposed to ELF MF 100 µT, 2 groups exposed to ELF MF 500 µT, and 2 control groups. Indicators of anemia include the number of erythrocytes, hemoglobin levels and hematocrit using the complete blood count (CBC) method. Two Way Anova analysis ($\alpha = 5\%$), proved that the intensity factor had a significant effect ($p < 0.05$) on the number of erythrocytes, hemoglobin levels and hematocrit levels, while the length of exposure factor had no effect ($p > 0.05$). Conclusion: Exposure to ELF MF intensity of 100 µT for 30 days has the potential to cause anemia in BULB/c mice, but there appears to be an adaptive response due to exposure to ELF MF 500 µT.

Keywords: Anemia; ELF Magnetic Field; Erythrocytes; Hematocrit; Hemoglobin

Introduction

Regrettably, it is inevitable that we find ourselves immersed in a vast expanse of extremely low-frequency electromagnetic fields (ELF EMF) in actuality, with a frequency range of 0–300 Hz (Cios et al., 2021). The current WHO recommendation states that the acceptable levels of exposure to ELF electric and magnetic fields (at frequencies of 50 or 60 Hz) are 5 kV/m and 100 µT for the general population, and 10 kV/m and 500 µT for workers (WHO, 2007). However, this advice is still the subject of ongoing controversy (Qi et al., 2015). Epidemiological studies provide more evidence of a correlation between extremely low-frequency magnetic fields (ELF MF) and the occurrence of several cancers, including leukemia, brain cancer, and breast cancer (Malagoli et al., 2023). Researchers studied people who were exposed to electric fields at work (levels below 1µT and 1 V/m) and found that they had a statistically significant effect on the number, shape, and movement of sperm. The objective of this study is to investigate the potential effects of anemia in BALB/c mice when exposed to very low-frequency 50 Hz magnetic fields with intensities of 100 µT and 500 µT.

This work holds significant importance given the genuine presence of exposure to extremely low frequency magnetic fields (ELF MF) at levels of around 100 µT in the environment (Wang et al., 2021). Accumulating epidemiological evidence indicates a link between exposure to extremely low frequency electromagnetic fields (ELF-EMF) and the occurrence of childhood cancer, Alzheimer's disease (AD), and miscarriage (Karimi et al., 2020). Nevertheless, the fundamental process remains obscure, necessitating further investigation to elucidate it (Nezamtaheri et al., 2022). The ELF magnetic field, also known as the ELF EMF, exerts a greater influence on biological systems compared to the electric field component (Panagopoulos et al., 2021). The magnetic field has the ability to permeate biological substances, and its force interacts

How to Cite:
Sudarti, S., Bektiarso, S., & Restanti, R. (2024). Potential Impact of Anemia on BALB/c Mice Exposed to an Extremely Low Frequency 50 Hz Magnetic Field with an Intensity of 100 µT and 500 µT. *Jurnal Penelitian Pendidikan IPA*, *10*(4), 2050–2058. https://doi.org/10.29303/jppipa.v10i4.6501

with ions or charges, altering the potential of the cell membrane (Sudarti et al., 2018).

Studies increasingly show that exposure to extremely low frequency (ELF) magnetic fields might hinder the formation and multiplication of bacteria. Exposure to extremely low frequency magnetic fields (ELF MF) at an intensity of 500 µT successfully inhibited the proliferation of salmonella bacteria in Vanamae shrimp and cow's milk (Sudarti et al., 2022; Sudarti, Permatasari, Ratnasari, et al., 2022). The vitamin C content in red wine was effectively conserved by exposing it to a magnetic field strength of 900 µT, which inhibited the growth of dangerous bacteria (Sudarti et al., 2022). The study revealed that subjecting apple tomatoes to a magnetic field strength of 1000 µT successfully inhibited the proliferation of detrimental bacteria, so ensuring the preservation of their (Sudarti et al., 2022). However, research has revealed that an intensity of 200 µT can stimulate the growth of bacteria in the cocoa bean fermentation process (Sudarti et al., 2022), whilst an intensity of 300 µT has been found to increase the production of edamame fruit (Sudarti et al., 2023). According to another study, it was found that the optimal dose to suppress the growth of lactic acid-forming bacteria in green cayenne pepper was an exposure intensity of 500 µT for a duration of 120 minutes (Nuriyah & Sudarti, 2022). This indicates that exposure to extremely low frequency magnetic fields (ELF MF) can have both advantageous and harmful consequences, contingent upon variables such as the intensity and duration of the exposure, as well as the characteristics of the cells involved (Nezamtaheri et al., 2022).

Erythrocytes, often known as human red blood cells, contain many types of ions that play a crucial role in preserving osmotic equilibrium and ensuring proper cell functionality. The presence of electric fields and extremely low-frequency (ELF) magnetic fields in the surroundings will exert a force on ions present in the bloodstream. The study findings indicated that being exposed to an extremely low-frequency (ELF) electric field with an intensity of 2.0 kV/m had an impact on the motion of red blood cells, also known as erythrocytes, in whole blood (Kanemaki et al., 2022). Prolonged exposure to ELF electromagnetic fields (EMF) significantly hinders the growth of cells, thereby potentially raising concerns about the development of anemia (Nezamtaheri et al., 2022).

Anemia is a medical disorder characterized by a lower-than-normal count of red blood cells in the body. Erythrocyte count, hemoglobin level, and hematocrit value are crucial parameters for diagnosing anemia. A diminished quantity of erythrocytes or reduced hemoglobin levels within erythrocytes might result in a decreased hematocrit, suggesting the presence of anemia (Nguyen & Pandey, 2019). The study's results are important because they help us understand what might happen to our bodies when we are exposed to 100 µT and 500 µT extremely low frequency (ELF) magnetic fields.

This study aims to examine "erythrocyte response and the potential impact of anemia on bulb/C mice exposed to ELF magnetic fields with intensities of 100 µT and 500 µT". Erythrocytes, or red blood cells, are the most abundant type of blood cell in the human body. Its function is to transport oxygen from the lungs to the tissues of the body and carry carbon dioxide from the tissues back to the lungs for removal. Human erythrocytes contain several types of ions that are important for maintaining osmotic balance and cell function. Exposure to ELF electric and magnetic fields in the environment will exert a force on the ions in the blood. A 2022 study reported that exposure to ELF electric fields at an intensity of 2.0 kV/m affects the movement of red blood cells or erythrocytes in whole blood (Kanemaki et al., 2022).

Anemia is a clinical condition that occurs when the number of red blood cells in the body is lower than usual. The number of erythrocytes, hemoglobin, and hematocrit are essential indicators for diagnosing anemia. A low number of erythrocyte or low hemoglobin level in erythrocytes can cause a low hematocrit, signaling the possibility of anemia (Nguyen & Pandey, 2019). The results of this study are as literacy in providing a more precise explanation of potential biological effects by exposure to ELF magnetic fields of 100 µT and 500 µT intensities.

Method

Sample Preparation of Bulb/C Mice

This study was an experimental laboratory study, with a sample of 60 male Bulb/C mice aged four weeks, with the criteria of looking healthy, without defects, active, and with a body weight of around 20-25 grams. Before being treated, the mice were acclimated to laboratory conditions for seven days. Cultivation was carried out by placing mice in cultivated cages with a capacity of 5 per cage in an air-conditioned laboratory room. Animal feed and drink were given by ad libitum.

Research Design

The treatment in this study was exposure to ELF magnetic fields with intensity of 100 μT and 500 μT intermittently 2 hours/day for 15 days and 30 days. The sample of 60 male Bulb/C mice aged four weeks was divided into six groups. The control group for 15 days (K1) and for 30 days (K2), the group exposed to a magnetic field intensity of 100 μT for 15 days (E1,1) and 30 days (E1,2), and the group exposed to a magnetic field intensity of 500 μT for 15 days (E2,1) and 30 days (E2,2).

The research design is presented as follows (see figure 1).

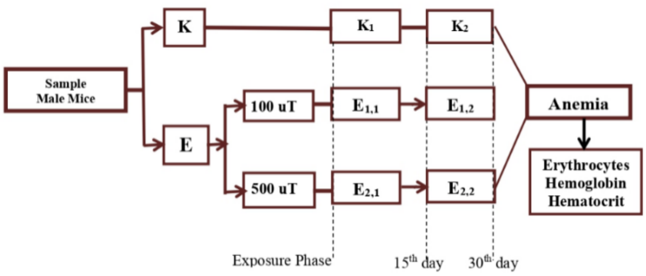

Figure 1. Research Design

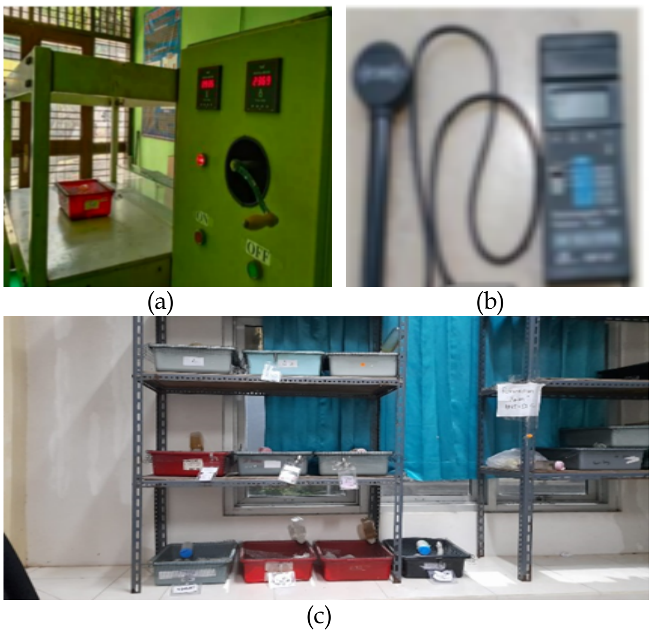

Figure 2. a) Generator ELF, b) EMF Tester-827, c) Laboratory Room for the cultivation of Bulb/C Mouse Bulb/C

ELF Magnetic Field Exposure Procedure

The source of exposure to the ELF magnetic field in this study used an ELF Generator, namely an ELF magnetic field generating machine, and a tool to measure ELF magnetic fields using EMF-Test 827 at the Advanced Physics Laboratory of the FKIP University of Jember (see Figure 2). Every day the samples were exposed to an ELF magnetic field for 2 hours, then placed in the experimental animal cultivation laboratory at the FKIP, University of Jember.

Ethical Requirements

This research was conducted with permission from the Health Research Ethics Commission No.1745/UN25.8/KEPK/DL/2022 dated 06 October 2022.

Anemia Checking

The assessment of anemia indications in this study through the complete blood count (CBC) method in the laboratory "New Prosenda" through the assessment of indicators of the number of red blood cells, hemoglobin levels, and hematocrit. Anemia assessment was carried out after the Bulb/C mice samples were exposed to ELF magnetic fields with the intensity of 100 μT and 500 μT intermittently 2 hours/day for 15 days and 30 days. Erythrocyte measurements were carried out by counting the number of red blood cells per microliter of blood (cells/µL). Hemoglobin is the iron-rich protein in red blood cells that carries oxygen to the body; a measurement of hemoglobin shows the hemoglobin level per deciliter (grams/dl). Hematocrit is a percentage of blood cells contained in the blood (%). The results of the normal distribution test showed that all groups of research data were not normally distributed, so Kruskal Wallis and Mann Whitney used a comparative analysis through the SPSS tool with α = 5%.

Research Stages

The stages of this research are presented in the Figure 3.

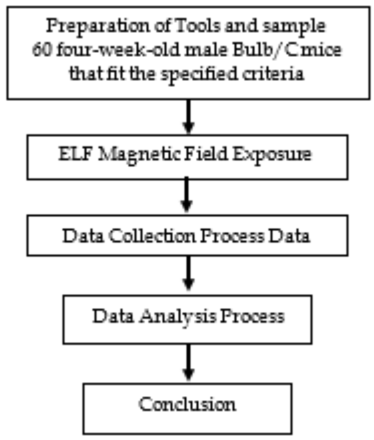

Figure 3. Research Stages

Result and Discussion

Variables investigated as impact by exposure to ELF magnetic fields on the Bulb/C mice is anemia with indicators of the number of erythrocytes, hemoglobin levels, and hematocrit levels and has been examined in the laboratory by the method of complete blood count (CBC) test.

Analysis Results

The research data analysis aimed to compare the effects of exposure to the ELF magnetic field on the response of erythrocytes and the potential for anemia. Based on the results of the Normal distribution test, it showed that all data groups were not normally distributed. Therefore, data analysis was carried out using Kruskal Wallis and Mann Whitney through the SPSS tool with α =5%. In the following, the results of data analysis are presented in tables and bar graphs for each indicator of anemia.

Number of Erythrocytes

Erythrocytes, also known as red blood cells, are one of the human body's most abundant types of blood cells. It is the main component of blood and functions in transporting oxygen from the lungs to other body tissues, as well as carrying carbon dioxide, which is produced as a by-product of metabolism back to the lungs to be excreted (Kuhn et al., 2017). Red blood cells are produced in the spinal cord through a process called erythropoiesis (Zhang et al., 2014). Erythrocytes has a life span of about 120 days in circulation before being destroyed and replaced by new erythrocytes (Thiagarajan et al., 2021). Data on the results of measurements of the number of erythrocytes of Bulb/C mice in the control group and the group exposed to ELF magnetic fields of the intensity of 100 μT and 500 μT intermittently 2 hours/day for 15 days and 30 days are presented in the following bar graph (see Figure 4).

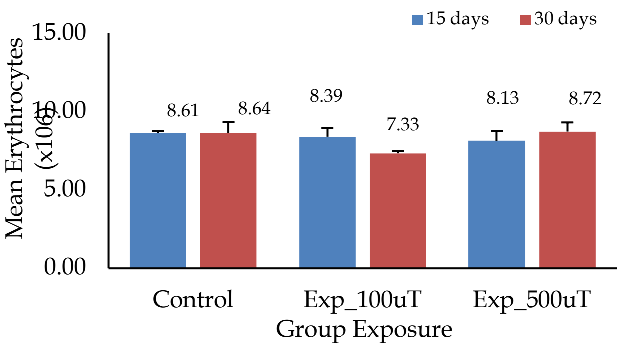

Figure 4. Average Number of Erythrocytes in Bulb/C Mice

Furthermore, to determine the impact of ELF magnetic field exposure on the number of erythrocytes in Bulb / C mice, the results of a comparative analysis of the number of erythrocytes with Kruskal Wallis and Mann Whitney were presented in the following table 1.

Table 1. Results of Comparative Analysis of the Mean Number of Erythrocytes

Anemia indicator	Exposure time	Blood examination results data		
		Control	Exposure to 100 µT	Exposure to 500 µT
Erythrocyte (x 106 cel/µL)	15 days	8.61 ± 0.147a	8.39 ± 0.548 b	8.13 ± 0.616 b

Note: Different superscripts show significant differences (P<0.05), and the same superscripts show no significant differences (P>0.05).

Based on the data presented in Graph 1 and the results of Kruskal Wallis statistical analysis and Mann Whitney in Table 1 showed that the average results of examining the number of erythrocytes in the control group on days 15 (K1) and 30 (K2) were not significantly different (p > 0.05). While the number of erythrocytes in the sample group of Bulb/C mice exposed to an ELF magnetic field intensity of 100 T intermittently 2 hours/day for 15 days (E1,1) and 30 days (E1,2), was significantly (p <0,05) was lower than the control. The number of erythrocytes in the sample group of Bulb/C mice exposed to an ELF magnetic field intensity of 500 T intermittently for 2 hours/day for 15 days (E2,1) was significantly (p <0.05) lower than the control (K1). There were an increase in the number of erythrocytes in the sample group of Bulb/C mice exposed to an ELF magnetic field of 500 T intensity intermittently for 2 hours/day for 30 days (E2,2), but not significant (p > 0.05) in control (K2) or compared (E2.1).

The normal number of erythrocytes in mice can vary depending on the race, age, and health condition of the individual. According to Benković et al (2012), the number of erythrocytes in normal mice is around 8.77 (x106). Sitasiwi & Isdadiyanto (2017) reported that the number of erythrocytes in the control group mice was around 8,168 – 9,492 (x106). The results of this study illustrated that exposure to ELF magnetic fields with intensities of 100 µT and 500 µT intermittently 2 hours / day for 15 days and 30 days affected the number of blood erythrocytes of Bulb / C mice samples, but still within the range of normal values. It appears that intermittent exposure to ELF magnetic field intensity of 100 µT 2 hours / day for 30 days significantly reduces the number of erythrocytes to below normal values of 7.33 ± 1.356 (x106).

Hemoglobin Levels

Hemoglobin is a protein found in erythrocytes and gives red color to red blood cells (Gell, 2018). One of its main functions is to bind oxygen and spread it throughout the body (Ahmed et al., 2020). Data on the measurement of hemoglobin levels of bulb/C mice in the control group and the group exposed to ELF magnetic fields of 100 µT and 500 µT intermittently 2 hours/day for 15 days and 30 days, are presented in the following bar graph (see Figure 5).

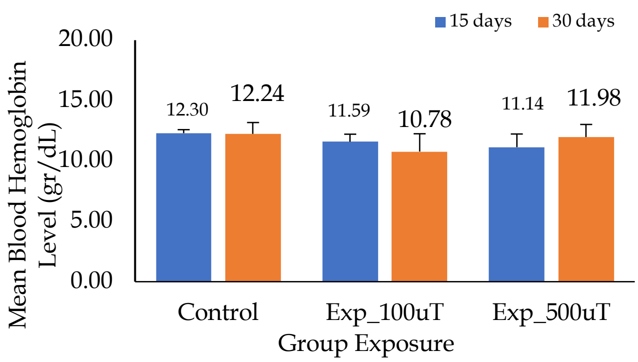

Figure 5. Average Hemoglobin Levels in Bulb/C Mice

Normal hemoglobin levels in mice can vary depending on race, age, and individual health conditions. In the same study, the hemoglobin level of the control group mice was 15.90 (g/dL) (Akin-Osanaiye et al., 2015). The study reported that the hemoglobin level of the control group mice was around 14.26 ± 0.671(g/dL) (Fotsing et al., 2021). The same also reported the normal value of rat Hb ranged from 11.6-16.1 g/dL (Douglas & Wardrop, 2010). In the following, the results of a comparative analysis with Kruskal Wallis and Mann Whitney are presented to explain the impact of ELF magnetic field exposure on hemoglobin levels in Bulb/C mice (see Table 2).

Table 2. Results of Comparative Analysis of Mean Hemoglobin Levels

Anemia indicator	Exposure time	Blood examination results data		
		Control	Exposure to 100 µT	Exposure to 500 µT
Hemo globin (g/dL)	15 days	12.30 ± 0.29 a	11.59 ± 0.62 a	11.14 ± 1.09 a
	30 days	12.24 ± 0.94 a	10.78 ± 1.47 b	11.98 ± 1.04 a

Note: Different superscripts show significant differences (P<0.05), and the same superscripts show no significant differences (P>0.05).

Based on the statistical analysis results of Kruskal Wallis and Mann Whitney in Table 2 and data presentation in Graph 2, illustrated that there was no significant difference (p > 0.05) in hemoglobin levels of Bulb/C mice between the 15-day control group (K1), the 30-day control group (K2), the group exposed to an intensity ELF magnetic field of 100 T for 15 days (E1-1), intensity of 500 T for 15 days (E2-1), intensity of 500 T for 30 days (E2-2), but all are still within the range of normal values. While the hemoglobin level in the Bulb/C mice exposed to the ELF magnetic field intensity of 100 T for 30 days (E1-2) significantly decreased (p <0.05) to below normal values (10.78 ± 1.47) g/dL.

Hematocrit Levels

Hematocrit measures the number of red blood cells in the blood and is commonly used to identify the presence of anemia and measure hemoglobin levels (Karakochuk et al., 2019). Data on the results of measuring the hematocrit levels of Bulb/C mice in the control group and the group exposed to ELF magnetic fields of intensity of 100 μT and 500 μT intermittently 2 hours/day for 15 days and 30 days are presented in the following bar graph (see Figure 6).

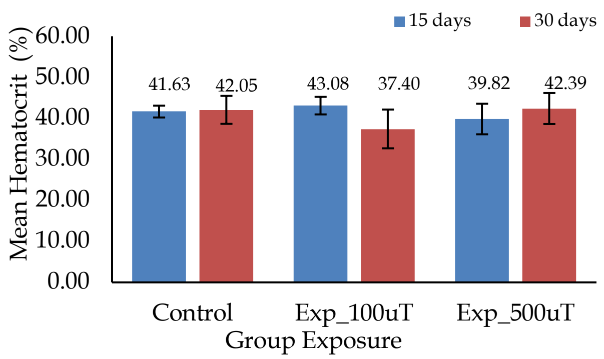

Figure 6. Average Hematocrit Levels in Bulb/C Mice

Given that hematocrit level data in all groups were not normally distributed, data analysis was carried out using Kruskal Wallis and Mann Whitney to explain the impact of ELF magnetic field exposure on hematocrit levels in bulb/C mice presented in the following table 3,

Table 3. Results of Comparative Analysis of Mean Hematocrit Levels

Anemia Indicator	Time Exposure	Blood Examination Results Data		
		Control	Exposure to 100 µT	Exposure to 500 µT
Hematocrit (%)	15 days	41.63 ± 1.44 a	43.08 ± 2.59 a	39.82 ± 3.72 a
	30 days	42.05 ± 3.41 a	37.40 ± 4.72 b	42.39 ± 3.78 a

Note: Different superscripts show significant differences (P<0.05), and the same superscripts show no significant differences (P>0.05).

Hematocrit levels in normal rats are around 37.6% - 51% (Douglas & Wardrop, 2010). A low hematocrit can indicate anemia, a condition in which the body has few red blood cells (Domenica Cappellini & Motta, 2015). Based on the statistical analysis results of Kruskal Wallis and Mann Whitney in Table 3 and data presentation in Graph 3, illustrated that there was no significant difference (p > 0.05) in the hematocrit levels of Buib/C mice between the 15-day control group (K1), the 30-day control group (K2), the group exposed to an intensity ELF magnetic field of 100 μT for 15 days (E1-1), intensity of 500 μT for 15 days (E2-1), intensity of 500 μT for 30 days (E2-2). However, all are still within the range of normal values. Meanwhile, the hematocrit level in Bulb/C mice exposed to the ELF magnetic field intensity of 100 μT for 30 days (E1-2) significantly decreased (p <0.05) to below normal values (37.40 ± 4.72) %

Discussion

Cells can be viewed as individuals at the cellular level who constantly respond to environmental stimuli or stressors through cellular responses and attempt to defend themselves. The mechanism for responding to sustained stressors is referred to as General Adaptation Syndrome (GAS). If the stressor is too severe, it will result in deviation from homeostasis. Under certain conditions, the cell can respond to the stressor and minimize the impact of the stressor until homeostasis can be restored. According to Selye's theory, GAS takes place in three sequential phases: 1) the alarm phase is also known as the "fight or flight" response, 2) the resistance or adaptation phase, 3) and finally, fatigue if stress is not resolved and homeostasis is not restored (Meduri & Chrousos, 2020). This discussion will examine the response of blood cells, especially erythrocytes, to the stressor of ELF magnetic field exposure based on Selye's theory. Changes in anemia indicators including the number of erythrocyte, hemoglobin levels, and hematocrit levels are a form of cell response to the stressor.

The results of this study illustrated that changes in the number of erythrocytes, hemoglobin levels, and hematocrit levels in Bulb/C mice exposed to an ELF magnetic field intermittently for 2 hours/day for 15 days and 30 days at intensities of 100 μT and 500 μT had the same pattern. The pattern of changes in the number of erythrocytes, hemoglobin levels, and hematocrit levels in Bulb/C mice exposed to an ELF magnetic field with an intensity of 100 μT intermittently for 2 hours/day decreased on the 15th day. It decreased on the 30th day until it reached a value below normal. While the pattern of changes in the number of erythrocytes, hemoglobin levels, and hematocrit levels in bulb / C mice exposed to ELF magnetic fields with an intensity of 500 µT intermittently 2 hours/day decreased on the 15th day and increased again on the 30th day to the original condition (not significantly different ($p > 0.05$) compared to controls).

This pattern reflects the existence of the General Adaptation Syndrome (GAS) mechanism. The possible mechanism underlying the erythrocyte cell responds that the magnetic field force of the ELF is able to interact directly with the cell membrane and has an impact on increasing intracellular calcium (Wu et al., 2018). This condition can stimulate or inhibit cell proliferation, depending on the intensity and duration of exposure. Exposure to a very high-intensity ELF magnetic field of 100 mT intermittently for 2 hours every day for a period of 28 days is effective in suppressing tumor growth (Barati et al., 2021).

Cell response to exposure to the ELF magnetic field intensity of 100 μT, reflects the alarm phase, namely the initial response to a stressor on day 15. There was a decrease in the number of erythrocytes, hemoglobin levels, and hematocrit levels not significant ($p > 0.05$), and it continued to decrease on the 30th day significantly ($p < 0.05$) until it reached a value below normal. The possible underlying mechanism is that exposure to the ELF magnetic field with an intensity of 100 μT can inhibit cell proliferation by disrupting cell cycle development, thereby weakening cell function (Masoudi-Khoram & Abdolmaleki, 2022).

The report of impact research results by exposure to ELF magnetic field intensity 100 µT proved that exposure to ELF magnetic field (50 Hz, 100 µT) for 20 hours in white male rats aged eight weeks did not show a significant impact (Zhou et al., 2016). Further reports that intermittent exposure to ELF magnetic fields (50 Hz, 100 µT) for 1 hour was shown to cause less DNA distress than controls (Wang et al., 2019). Researchers previously reported that exposure to EMF intensity of 2-10 µT in cell culture for 1 hour per day can inhibit the growth of malignant cells and does not affect the growth of non-malignant cells (Buckner et al., 2015). While other studies also reported, that exposure to ELF magnetic fields (60 Hz, 120 µT) was able to stimulate the proliferation of human umbilical vein endothelial cells (Juutilainen et al., 2018). Based on the results of this study and the support of other previous studies, it can be said that exposure to ELF magnetic fields with an intensity of 100 µT for 30 days had the potential to cause anemia. But it still needs to be re- proved, because it is possible that if the exposure is continued for a longer time, it will go to the adaptation phase and back to normal conditions.

The pattern of cell response to exposure to the ELF magnetic field intensity of 500 μT intermittently for 2 hours/day showed an alarm stage response on the 15th day, namely, the number of erythrocytes, hemoglobin levels, and hematocrit levels decreased. However, on the 30th day, they will experience an adaptation phase, namely the number of erythrocytes, hemoglobin levels, and hematocrit levels will increase until they return to their original condition or experience reversibility. The decrease and increase in the number of erythrocytes, hemoglobin levels, and hematocrit levels were still within the normal range. The results of this study were relevant to the results of Song's research in 2018, which showed that single or repeated exposure to the ELF magnetic field (60 Hz, 6000 µT) can continuously encourage cell proliferation, but when without the ELF magnetic field the cells will return to normal (Song et al., 2018). Mechanism of the reversible response of erythrocytes to exposure to an intense ELF magnetic field500 T in this study because the exposure treatment was only given 2 hours/day, meaning that the condition was free of exposure for 22 hours, and this was sufficient for self-recovery.

Some research results on the impact of exposure to the intensity of ELF magnetic field 500 µT has been reported and is still contradictory. Exposure to magnetic fields of 500 and 1000µT may increase the proliferation rate of adipose-derived hMSCs according to the duration of exposure. Exposure to 50 Hz ELF magnetic field intensity of 500 µT intermittently 20 and 40 minutes/day for seven days was able to increase cell proliferation significantly (P <0.05) compared to control (Shahbazi-Gahrouei et al., 2017). However, exposure to the ELF magnetic field with intensities of 500 and 1000 µT in vivo can optimally encourage the entry of Ca2+ and cause apoptosis, thereby inhibiting the growth of cancer cells (Nezamtaheri et al., 2022). It is this difference in research results that must be verified through repeated research. The main thing that causes differences in research results is the Extremely Low Frequency (ELF) electromagnetic field generator used by each researcher is very different. The quality of exposure to the electric field and magnetic field produced by the ELF is also various, and the impact will also be different. Generators that use bare coils will produce larger heat waves, so that a huge magnetic field will be generated, but not the ELF magnetic field.

Conclusion

Exposure to ELF MF intensity of 100 µT for 30 days has the potential to cause anemia in BULB/c mice, but there appears to be an adaptive response due to exposure to ELF MF 500 µT.

Acknowledgments
The authors would like to thank the University of Jember for the Reworking Grant funding that has been provided through the decree of the Rector of the University of Jember Number: 7575/UN25/KP/2023 dated March 30, 2023

Author Contributions
Conceptualization, S, & PE; methodology, S.; validation, S, HD & AT.; formal analysis, S & HD; investigation, RR & PE; resources, S and PE; data curation, HD & AT.: writing—original drafting, S and HD; writing—review and editing, PE & AT: visualizations, E.P & AT. All authors have read and agree to the published version of the manuscript.

Funding
This research was funded by the University of Jember through the 2023 Reworking Grant.

Conflicts of Interest
All authors declare that they have no competing interests.

References

Ahmed, M. H., Ghatge, M. S., & Safo, M. K. (2020). Hemoglobin: Structure, Function and Allostery. *Subcell Biochem*, *94*, 123–163. https://doi.org/10.1007/978-3-030-41769-7

Akin-Osanaiye, B. C., Nok, A. J., Amlabu, E., & Haruna, E. (2015). Assessment of Changed in Serum Haematological Parameters in the Plasmodium berghei Infected Albino Mice Treated with Neem (Azadirachta indica) Extracts. *International Journal of Chemical and Biomolecular Science*, *1*(3), 148–152. Retrieved from http://www.aiscience.org/journal/ijcbshttp://creativecommons.org/licenses/by-nc/4.0/

Barati, M., Darvishi, B., Javidi, M. A., Mohammadian, A., Shariatpanahi, S. P., Eisavand, M. R., & Madjid Ansari, A. (2021). Cellular stress response to extremely low-frequency electromagnetic fields (ELF-EMF): An explanation for controversial effects of ELF-EMF on apoptosis. *Cell Proliferation*, *54*(12), 1–19. https://doi.org/10.1111/cpr.13154

Benković, V., Dikić, D., Grgorinić, T., Mladinić, M., & Željezi, D. (2012). Haematology and blood chemistry changes in mice treated with terbuthylazine and its formulation radazin TZ-50. *Bulletin of Environmental Contamination and Toxicology*, *89*(5), 955–959. https://doi.org/10.1007/s00128-012-0813-6

Buckner, C. A., Buckner, A. L., Koren, S. A., Persinger, M. A., & Lafrenie, R. M. (2015). Inhibition of cancer cell growth by exposure to a specific time-Varying electromagnetic field involves T-Type calcium channels. *PLoS ONE*, *10*(4), 1–16. https://doi.org/10.1371/journal.pone.0124136

Cios, A., Ciepielak, M., Stankiewicz, W., & Szymański, Ł. (2021). The influence of the extremely low frequency electromagnetic field on clear cell renal carcinoma. *International Journal of Molecular Sciences*, *22*(3), 1–12. https://doi.org/10.3390/ijms22031342

Domenica Cappellini, M., & Motta, I. (2015). Anemia in Clinical Practice-Definition and Classification: Does Hemoglobin Change With Aging? *Seminars in Hematology*, *52*(4), 261–269. https://doi.org/10.1053/j.seminhematol.2015.07.006

Douglas, J. W., & Wardrop, K. J. (2010). *Schalm's Veterinary Hematology* (6th ed). Wiley-Blackwell.

Fotsing, C. B. K., Pieme, C. A., Nya, P. C. B., Chedjou, J. P., Ashusong, S., Njindam, G., Gatsing, D., Nengom, J. T., Teto, G., Nguemen, C., & Mbacham, W. F. (2021). Haptoglobin Gene Polymorphism among Sickle Cell Patients in West Cameroon: Hematological and Clinical Implications. *Advances in Hematology*, *2021*, 1–8. https://doi.org/10.1155/2021/6939413

Gell, D. A. (2018). Structure and function of haemoglobins. *Blood Cells, Molecules, and Diseases*, *70*, 13–42. https://doi.org/10.1016/j.bcmd.2017.10.006

Juutilainen, J., Herrala, M., Luukkonen, J., Naarala, J., & Hore, P. J. (2018). Magnetocarcinogenesis: Is there a mechanism for carcinogenic effects of weak magnetic fields? *Proceedings of the Royal Society B: Biological Sciences*, *285*(1879). https://doi.org/10.1098/rspb.2018.0590

Kanemaki, M., Shimizu, H. O., Inujima, H., Miyake, T., & Shimizu, K. (2022). Analysis of Red Blood Cell Movement in Whole Blood Exposed to DC and ELF Electric Fields. *Bioelectromagnetics*, *43*(3), 149–159. https://doi.org/10.1002/bem.22395

Karakochuk, C. D., Hess, S. Y., Moorthy, D., Namaste, S., Parker, M. E., Rappaport, A. I., Wegmüller, R., & Dary, O. (2019). Measurement and interpretation of hemoglobin concentration in clinical and field settings: a narrative review. *Annals of the New York Academy of Sciences*, *1450*(1), 126–146. https://doi.org/10.1111/nyas.14003

Karimi, A., Ghadiri Moghaddam, F., & Valipour, M. (2020). Insights in the biology of extremely low-frequency magnetic fields exposure on human health. *Molecular Biology Reports*, *47*(7), 5621–5633. https://doi.org/10.1007/s11033-020-05563-8

Kuhn, V., Diederich, L., Keller, T. C. S., Kramer, C. M., Lückstädt, W., Panknin, C., Suvorava, T., Isakson, B. E., Kelm, M., & Cortese-Krott, M. M. (2017). Red Blood Cell Function and Dysfunction: Redox Regulation, Nitric Oxide Metabolism, Anemia. *Antioxidants and Redox Signaling*, *26*(13), 718–742. https://doi.org/10.1089/ars.2016.6954

Malagoli, C., Malavolti, M., Wise, L. A., Balboni, E., Fabbi, S., Teggi, S., Palazzi, G., Cellini, M., Poli, M., Zanichelli, P., Notari, B., Cherubini, A., Vinceti, M., & Filippini, T. (2023). Residential exposure to magnetic fields from high-voltage power lines and risk of childhood leukemia. *Environmental Research*, *232*, 1–6. https://doi.org/10.1016/j.envres.2023.116320

Masoudi-Khoram, N., & Abdolmaleki, P. (2022). Effects of repeated exposure to 50 Hz electromagnetic field on breast cancer cells. *Electromagnetic Biology and Medicine*, *41*(1), 44–51. https://doi.org/10.1080/15368378.2021.1995872

Meduri, G. U., & Chrousos, G. P. (2020). General Adaptation in Critical Illness: Glucocorticoid Receptor-alpha Master Regulator of Homeostatic Corrections. *Frontiers in Endocrinology*, *11*(April), 1–28. https://doi.org/10.3389/fendo.2020.00161

Nezamtaheri, M. S., Goliaei, B., Shariatpanahi, S. P., & Ansari, A. M. (2022). Differential biological responses of adherent and non-adherent (cancer and non-cancerous) cells to variable extremely low frequency magnetic fields. *Scientific Reports*, *12*(1), 1–19. https://doi.org/10.1038/s41598-022-18210-y

Nguyen, N., & Pandey, M. (2019). Loxoscelism: Cutaneous and Hematologic Manifestations. *Advances in Hematology*, *2019*, 1–6. https://doi.org/10.1155/2019/4091278

Nuriyah, S., & Sudarti. (2022). Effect of Exposure to Magnetic Field ELF (Extremely Low Frequency) 500μT on pH and Physical Quality of Green Cayenne Pepper. *Jurnal Penelitian Fisika Dan Terapannya (Jupiter)*, *3*(3), 48–52. https://doi.org/10.31851/jupiter.v3i2.7224

Panagopoulos, D. J., Karabarbounis, A., Yakymenko, I., & Chrousos, G. P. (2021). Human-made electromagnetic fields: Ion forced-oscillation and voltage-gated ion channel dysfunction, oxidative stress and DNA damage (Review). *International Journal of Oncology*, *59*(5), 1–16. https://doi.org/10.3892/ijo.2021.5272

Qi, G., Zuo, X., Zhou, L., Aoki, E., Okamula, A., Watanebe, M., Wang, H., Wu, Q., Lu, H., Tuncel, H., Watanabe, H., Zeng, S., & Shimamoto, F. (2015). Effects of extremely low-frequency electromagnetic fields (ELF-EMF) exposure on B6C3F1 mice. *Environmental Health and Preventive Medicine*, *20*(4), 287–293. https://doi.org/10.1007/s12199-015-0463-5

Shahbazi-Gahrouei, D., Razavi, S., Koosha, F., & Salimi, M. (2017). Exposure of Extremely-Low Frequency (ELF) magnetic field may cause human cancer. *Acta Medica International*, *4*(1), 32. https://doi.org/10.5530/ami.2017.4.7

Sitasiwi, A. J., & Isdadiyanto, S. (2017). Kadar Hemoglobin Dan Jumlah Eritrosit Mencit (Mus musculus) Jantan setelah Perlakuan dengan. *Buletin Anatomi Dan Fisiologi*, *2*(2013), 161–167. https://doi.org/10.14710/baf.2.2.2017.161-167

Song, K., Im, S. H., Yoon, Y. J., Kim, H. M., Lee, H. J., & Park, G. S. (2018). A 60 Hz uniform electromagnetic field promotes human cell proliferation by decreasing intracellular reactive oxygen species levels. *PLOS ONE*, *13*(7), 1–18. https://doi.org/10.1371/journal.pone.0199753

Sudarti, Permatasari, E., Ratnasari, I., & Laili, S. N. (2022). Physical Quality of Cow's Milk by Exposure to Magnetic Fields Extremely Low Frequency (ELF) 300 μT and 500 μT by inhibiting Salmonella and Escherichia Coli Growth. *Indonesian Review of Physics*, *5*(2), 73–79. https://doi.org/10.12928/irip.v5i2.5064

Sudarti, Qumairoh, U., & Prihandono, T. (2022). The effectiveness of exposure to magnetic fields of extremely low frequency 300T and 500T in inhibiting the proliferation of pathogenic bacteria to increase physical resistance of vannamei shrimp. *The 1st International Conference Science Physics and Education 2021 (ICSPE 2021)*, *2165*(2022), 1–12. https://doi.org/10.1088/1742-6596/2165/1/012038

Sudarti, S., Hariyati, Y., Sari, A. B. T., Sumardi, S., & Muldayani, W. (2022). Fermentation Process of Dry Cocoa Beans through Extremely Low Frequency (ELF) Magnetic Field Exposure. *Jurnal Penelitian Pendidikan IPA*, *8*(2), 584–591. https://doi.org/10.29303/jppipa.v8i2.1356

Sudarti, S., Nur, S. U. K., Permatasari, E., Dewi, N. M., &

Laili, S. N. (2022). Analysis of Physical Resistance of Apple Tomatoes After Exposed to A Magnetic Field Extremely Low Frequency (ELF) Intensity 600 μT and 1000 μT. *Jurnal Penelitian Pendidikan IPA*, *8*(6), 2872–2878. https://doi.org/10.29303/jppipa.v8i6.2306

Sudarti, S., Nuraini, L., Saleh, T. A., & Prihandono, T. (2018). The Analysis of Extremely Low Frequency (ELF) Electric and Magnetic Field Exposure Biological Effects around Medical Equipments. *International Journal of Advanced Engineering Research and Science*, *5*(7), 289–296. https://doi.org/10.22161/ijaers.5.7.37

Sudarti, S., Permatasari, E., Ningtyias, F. W., Mina, N. M., & Laksmiari, K. (2022). Analysis of Vitamin C Resistance in Red Grapes (Vitis vinifera) After Exposure to Extremely Low Frequency (ELF) Magnetic Fields Intensity 700 uT and 900 uT. *Jurnal Penelitian Pendidikan IPA*, *8*(2), 620–626. https://doi.org/10.29303/jppipa.v8i2.1386

Sudarti, S., Permatasari, E., Sumardi, S., Muldayani, W., Utoyo, E. B., & Prihatin, W. N. (2023). Extremely Low Frequency Electromagnetic Field Radiation (50 Hz, 200 μT & 300 μT) to Increase Edamame Productivity and Safety Risks to Health. *Jurnal Penelitian Pendidikan IPA*, *9*(8), 5979–5986. https://doi.org/10.29303/jppipa.v9i8.2494

Thiagarajan, P., Parker, C. J., & Prchal, J. T. (2021). How Do Red Blood Cells Die? *Frontiers in Physiology*, *12*, 8–10. https://doi.org/10.3389/fphys.2021.655393

Wang, M. H., Chen, K. W., Ni, D. X., Fang, H. J., Jang, L. S., & Chen, C. H. (2021). Effect of extremely low frequency electromagnetic field parameters on the proliferation of human breast cancer. *Electromagnetic Biology and Medicine*, *40*(3), 384–392. https://doi.org/10.1080/15368378.2021.1891093

Wang, Y., Liu, X., Zhang, Y., Wan, B., Zhang, J., He, W., Hu, D., Yang, Y., Lai, J., He, M., & Chen, C. (2019). Exposure to a 50 Hz magnetic field at 100 μT exerts no DNA damage in cardiomyocytes. *Biology Open*, *8*(8), 1–10. https://doi.org/10.1242/bio.041293

WHO. (2007). *Environmental Health Criteria 238:Extremely Low Frequency Fields*. WHO Press.

Wu, X., Du, J., Song, W., Cao, M., Chen, S., & Xia, R. (2018). Weak power frequency magnetic fields induce microtubule cytoskeleton reorganization depending on the epidermal growth factor receptor and the calcium related signaling. *PLOS ONE*, *13*(10), 1–27. https://doi.org/10.1371/journal.pone.0205569

Zhang, Y., Wang, L., Dey, S., Alnaeeli, M., Suresh, S., Rogers, H., Teng, R., & Noguchi, C. T. (2014). Erythropoietin action in stress response, tissue maintenance and metabolism. *International Journal of Molecular Sciences*, *15*(6), 1–10. https://doi.org/10.3390/ijms150610296

Zhou, L., Wan, B., Liu, X., Zhang, Y., Lai, J., Ruan, G., He, M., Chen, C., & Wang, D. W. (2016). The effects of a 50-Hz magnetic field on the cardiovascular system in rats. *Journal of Radiation Research*, *57*(6), 627–636. https://doi.org/10.1093/jrr/rrw090