Advances in Life Science and Technology
ISSN 2224-7181 (Paper) ISSN 2225-062X (Online)
Vol.24, 2014

Effect of GSM Radiation on White Blood Cells.

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Abstract
The effect of continuous-wave radiation on peripheral blood in albino mice was investigated. A radiation frequency of 2450MHz was applied at an average power density of induced field 10mW/cm^2. Ten 13 week old albino mice with average body mass of 35.0g were divided into 3 groups, preliminary group, control group, C and the irradiated group, E. Two (2) mice were used for preliminary studies, four (4) were kept to serve as control batch, and four (4) were exposed to microwaves for 60 days, at 2 hours per day. Peripheral blood samples were taken immediately after irradiation on the 1st, 16th, 32nd and the 60th day of the experiment. The total white blood cells count of both control, C batch and exposed, E batch, as well as the differential white blood cells count were investigated. The morphology of cells was also observed, during each session of the investigation in comparison with control C batch. The results revealed a decrease in the total white cell count which consistently continued in irradiated E batch from the 1st day of irradiation in the sample of the irradiated E batch in comparison with the control C batch samples. Slight increase in relative proportion of the neutrophil was observed in E batch sample in comparison with the C batch samples. Our investigation confirms wave exposure affects the white blood cells parameters of exposed animals.

1.0 Introduction

It has been proven that radiation affect the health of animals, but are also useful for their development. Research has shown that ionizing radiations is or can be dangerous, non-ionizing radiation in the other hand, has also become a source of concern, since it is now certain that high and low dosages are harmful to the human system, causing cataracts, burns and temporary sterility. Electromagnetic radiation can be arranged in a spectrum that extends from waves of extremely high frequency with short wavelengths to extremely low frequency with long wavelengths in order of decreasing energy. The electromagnetic spectrum consists of gamma rays, x-rays, ultraviolet radiation, visible light, infrared radiation, microwaves and radio waves.

Non-ionizing radiation for many years has been studied, experimented and documented that high dosages are harmful. In recent years, however, with the proliferation of the "Global System for Mobile Communication" (GSM) phone, the possible effects of these devices which are known to emit low level non-ionizing radiation began to be a matter of scientific concern. GSM networks operate at various radio frequencies. Most operate at 900MHz or 1800MHz. The transmission power in the handset is limited to a maximum of 2 watt in GSM850/900 and 1 watt in GSM 1800/1900. Part of the wave emitted by a mobile handset is absorbed by the human head.

It has been proven that, the brain cells are most affected by the radiations. Lai and Singh (1996) found "double strand DNA breakage on somatic cells", having been exposed to radio waves similar to that of the GSM phone level. Magras and Xenos (1997) also reported an "irreversible sterility in mice" after 3 generations of exposure kept within a communication antenna area. This work investigated the effect radiation on blood (white blood cells) using mice. Low energy microwave was used having almost the same frequency and energy intensity similar to radiation emitted by the Global System for Mobile Communication (GSM) phones and network antennae. We limited the research to differential white blood count, total white blood count and morphological formations of white blood cells.

2.0 Literature Review

The rate at which radiation is absorbed by the human body is measured by the Specific Absorption Rate (SAR), and its maximum levels for modern handsets have been set by governmental regulating agencies in many countries. In the USA, FCC has set a SAR limit of 1.6 W/kg for most parts of the body. Results from a Swedish scientific team at the Karolinska Institute (Lönn et al, 2004) have suggested that continuous use of a mobile phone for a decade or longer can lead to a small increase in the probability of getting acoustic neuroma, a type of brain tumour. Another area of worry about effects on the population's health, have been the radiation emitted by base stations (the antennas on the surface which communicate with the phones), because, in contrast to mobile handsets, it is emitted continuously. Due to the attenuation of power with the square of distance, field intensities drop rapidly with distance away from the base of the antenna.

All the various types of blood cells are produced in the bone marrow daily. They all arise from the hematopoietic

stem cells. These stem cells are very rare (only 1 in 10,000 bone marrow cells), they are attached probably by adherence junctions to osteoblasts, living in the inner surface of the bone cavities. They reproduce by mitosis. The production of various cells are regulated or controlled by cytokines. Cytokines comprise of:- Interleukins: produces T and B lymphocyte,Erythropoietin: for red blood cells, Thrombopoietin: for platelets, Granulocytes: macrophage progenitor or factor, produces

(a) Neutrophils.
(b) Eosinophils
(c) Basophils.

Finally, some macrophage stimulating factor produces the monocytes.

2.1 Biological Effects Of Microwaves

The intensity (or power intensity) of microwave in the environment is measured in unit such as mW/cm^2 (milliwatts per square centimeter). However, the intensity provides little information on the biological consequence unless the amount of energy absorbed by the irradiated object is known. This is generally given as the Specific Absorption Rate (SAR), which is the rate of energy absorbed by a unit mass (e.g. one kg of tissue) of the object, and usually expressed as W/kg. The absorption rate and distribution of microwave energy in an organism depend on many factors. These include: dielectric composition (i.e. ability to conduct electricity) of the irradiated tissue, e.g. bones with a lower water content, absorb less of the energy than muscles; the size of the object relative to the wavelength of the microwave, shape, geometry, orientation of the object and configuration of the radiation, e.g., how close is the object from the microwaves source? These factors make distribution of energy absorbed in an irradiated organism extremely complex and non-uniform, and also lead to the formation of so called 'hot spot' of concentrated energy in the tissue. An experiment reported by Chou et al (1985) measuring local energy absorption rates (SAR) in different areas of the brain in a rat exposed to microwave, has shown that "two brain regions less than a millimeter apart can have more than a two-fold difference in SAR". Persson et al (2005) found a linear dose-response relationship for dark neurons at 50 days after exposure, with most prominent occurrence at SAR 200mW/kg.

However, the distribution of energy in the head of a user of mobile phone is more discrete because of the relatively stationary position of the phone. 'Hot spots' may form in certain areas of the head, As a reference, from theoretical calculations (e,g, Dimbylow and Mann 1994; Martens et al 1995), peak 'hot spots' SAR in the head tissue of a user of mobile phone can range from 2 to 8W/kg per watt output of the device, The peak energy output of mobile telephone can range from 0.6-1 watt, although the average output could be much smaller. Thus, in summary, the pattern of energy absorption inside and irradiated body is non-uniform, and biological responses are dependent on distribution of energy and the whole body part that is affected (Lai et al; 1984a, 1998). This further indicates that the pattern of energy absorption could be an important determining factor of the nature of the response of blood in the veins of a mouse which is in motion. There are also data showing different frequencies producing different effects, or an effect was observed at one frequency and not at another is sparse. An example is the study by Sanders et al, (1984) who observed that "microwave at frequencies of 200 and 591 MHz, but not at 2450MHz, produced effects on energy metabolism in neural tissue". For example changes in blood-brain barrier have been reported after exposure to microwave of 915MHz (Salford et al,1944); 1200MHz (Frey et al 1975), 450MHz (Sheppard et al, 1979) and 915MHz (Dutta et al,1984).

An important question regarding the biological effects of microwave system adapt to the perturbation and with continued exposure, when will homeostasis break down leading to irrepairable damage? The question of whether an effect will cumulate over time with repeated exposure is particularly important in considering the possible health effects of mobile phone usage, since it involves repeated exposure of short duration over a long period (years) of time.

Existing results indicate changes in the response characteristics of the nervous system with repeated exposure, suggesting that the effects are not 'forgotten" after each episode of exposure. Depending on the responses studied in the experiments, several outcomes have been reported.

1. An effect was observed only after prolonged (or repeated) exposure, but not after one period of exposure (e.g. Baranski 1972, Takashima et al 1979).
2. An effect disappeared after prolonged exposure suggesting habituation (e.g. Lai et al 1992).
3. Different effects were observed after different durations of exposure (e.g. Baranski, 1972; Serventie et al 1974; Snyder et al. 1971).

This conclusion is important since mobile phone radiation is modulated at low frequencies. This also raises the question of how much do low frequency electric and magnetic fields contribute to the biological.effects of mobile phones radiation?

Therefore, frequency, intensity, exposure duration, and the number of exposure episodes can affect the response to microwave radiation and these factors can interact with others and produce different effects. In addition, in order to understand the biological consequences of microwave radiation exposure, one must know whether the effect is cumulative, whether compensatory responses result and when homeostasis will break down. Studies

have been conducted on the effects of microwaves radiation on blood and the immuno-competent system, but the results are frequently contradictory and the reasons for the discrepancies are not always easily identified. Based on available experimental data, it is believed that both beneficial and adverse health effects can be induced by microwave radiations, depending on conditions of exposure. Multiple sources of mobile communication microwave and others results in chronic exposure of significant part of the general public.

3.0 Materials And Method

The effect of continuous-wave microwave radiation on the blood of white mice (albino mice) was systematically experimented. Microwave frequency of 2450MHz was used with a power density of an induced field of 10mWlcm^2. Ten 13-week-old mice with an average body mass of 35g were divided into two (2) groups, control group, C and exposed group E. Each group had four (4) mice. Two mice, out of the ten were used in preliminary studies for proper understanding of parameters standard. The E batch (group) of mice were exposed to microwaves for sixty (60) days contained in a plexi cage. Exposure was limited to 2 hours per day, blood samples were taken on the 1st, 16th, 32nd and 60th day for the following examinations:

(i) Temperature
(ii) Total white blood count
(iii) Differential white blood count
(iv) Microscopic assessment of structural morphology of stained white blood cells.

Two kinds of specimen used in conducting this research were:

(i) Primary Specimen**:** These were blood samples of the C and E batches; four each.
(ii) Secondary Specimen**:** These were batches of E and C mice (alive) four per batch.

Each batch of specimen (secondary) was kept in a sterile well-ventilated plastic cage or also called plexi-cage. Various instruments and reagents were used in conducting the research. The microwave source used was a modified soft-touch micro-chef LG oven with continuous operation that produced 2450MHz, with an average power density of electromagnetic field of 10mW/cm^2. A rectal veterinary thermometer was used for the temperature measurement. The control C batch and expose E batch of mice were kept in two (2) separate plexi-plastic cages containing 4 mice in each cage. The E batch was then placed inside the moulinex microwave oven, regulation buttons were then set at a frequency of 2450MHz and power of 10mW/cm^2. Irradiation was allowed for 2 hours each day. This procedure continued for a span of 60 days. However, the C batch was kept separately from the E batch in a separate room.Temperature reading was done before and after exposure at each session by inserting an alcohol veterinary thermometer through the rectal opening of the mice.Using a 1 mm capillary needle, the venous blood was withdrawn from the vein and was done aseptically to avoid contamination.A visual microscopic count of the total white blood cells contained in a sample was done. That was achieved after the proper dilution technique and mounting for the counting using the manual longitudinal method of differential count.Morphology examination in terms of variation in size, shape and colours of stained cells were carried out.

4.0 Results And Analysis

The haematological parameters show some significant changes in the blood samples (specimen) of a 35.0g of average weight albino mice that was exposed to microwave radiations similar to that of the GSM phone with frequency 2450MHz at a power density of 10mW/cm^2 in four experiment sessions of the 1st, 16th, 32nd and 60th day of exposure. The total blood count, differential blood counts and temperature values have all been arranged in statistical table 1 and histograms 1-6 for easy comparison of the result of the exposed, E batch and the control, C batch of the mice, used for the research. Table 1 is the result of the preliminary experiment was done on the entire blood of the mice showing the following parametric values:

(i) White blood cells count (total)
(ii) Red blood cells count (total)
(iii) Haemoglotin value
(iv) Pack cells volume (PCV)
(v) Mean cells volume (MCV)
(vi) Mean cells haemoglobin (MCH)
(vii) Mean cells haemoglobin concentration ((MCHC)
(viii) Platelets count.

The following results have been presented using histograms. They include:

(a) White blood cells count vs sessions, figure 1
(b) Lymphocytes (number) vs sessions, figure 2
(c) Neutrophils (number) vs sessions, figure 3
(d) Eosinophils (number) vs sessions, figure 4
(e) Monocytes (number) vs sessions, figure 5
(f) Temperature readings of the four sessions, figure 6

However, the basophils showed no significant response since the probability of finding a single cell is 1/10 in sessions of experiment due to its very little amount in the entire blood, was left out and labelled as

"negligible".

Table 1: Complete Blood Count Of Albino-Mice.

SN	Parameters	Values/Units (mean)
1	Red blood cells (total count)	9.87 x 10^{9}lliter
2	White blood cells (total count)	4.9 x 10^{6}lliter
3	Haemoglobin value	17.1 gmldl
4	Pack cells volume, PCV	51.7%
5	Mean cells volume, MCV	5.23 x 10-^{9} Flliter
6	Mean cells haemoglobin, MCH	1.73 x 10-^{8} pglliter
7	Mean cells haemoglobin concentration, MCHC	3.30 x 10-^{1} glliter
8	Platelets count	886 x 10^{9}llitre

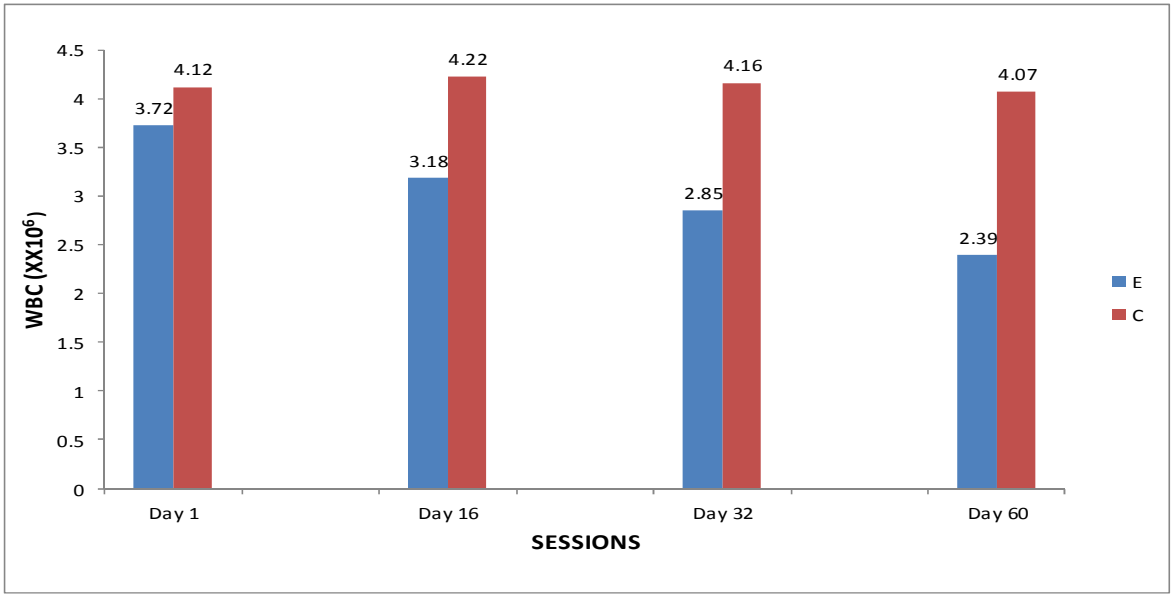

Figure 1: Total White Blood Cells Count Versus Session Of Irradiation

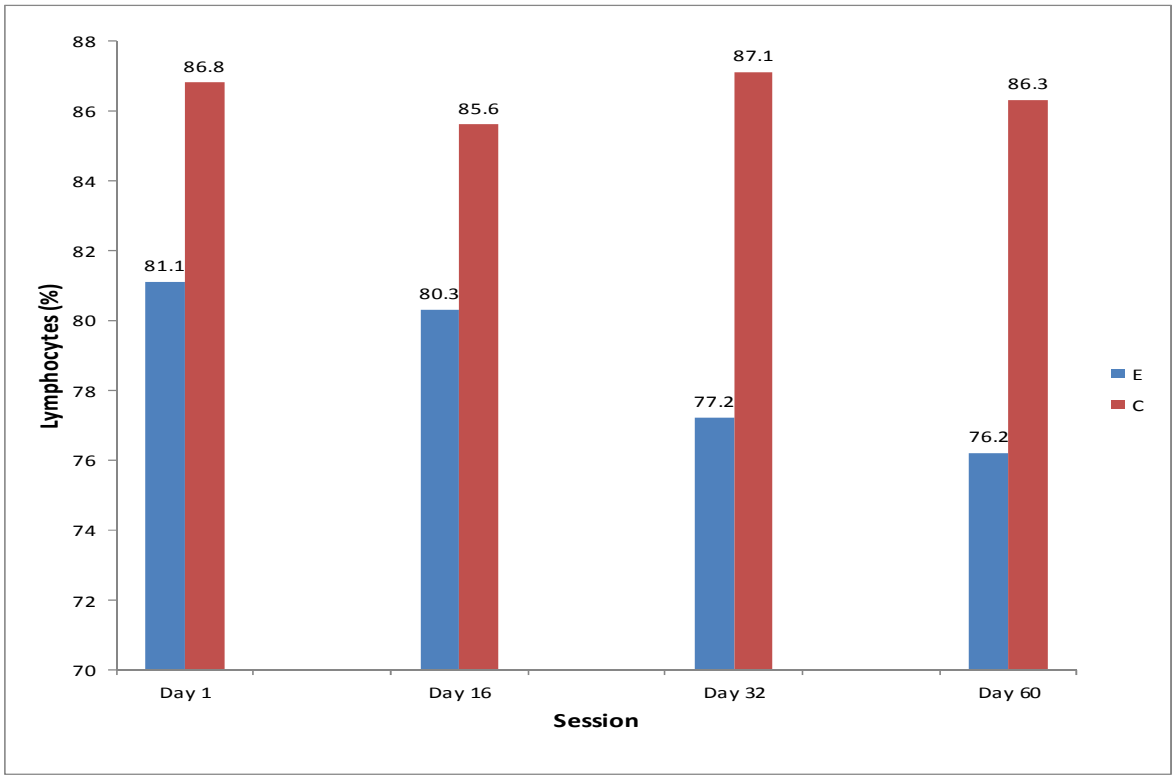

Figure 2: Percentage Of Lymphocytes Versus Session Of Irradiation.

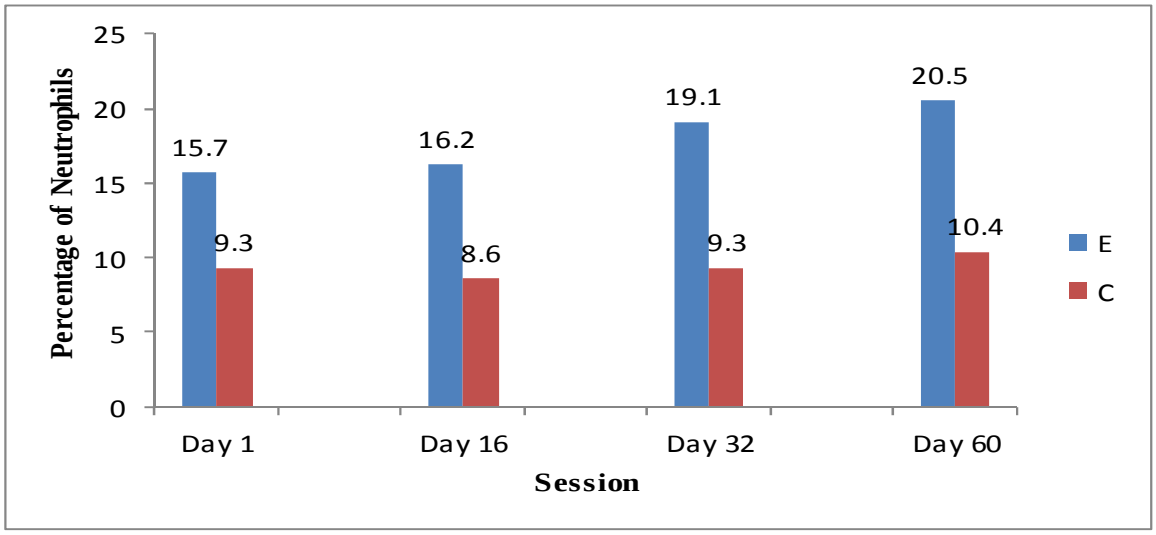

Figure 3: Percentage Of Neutrophils Versus Session Of Irradiation.

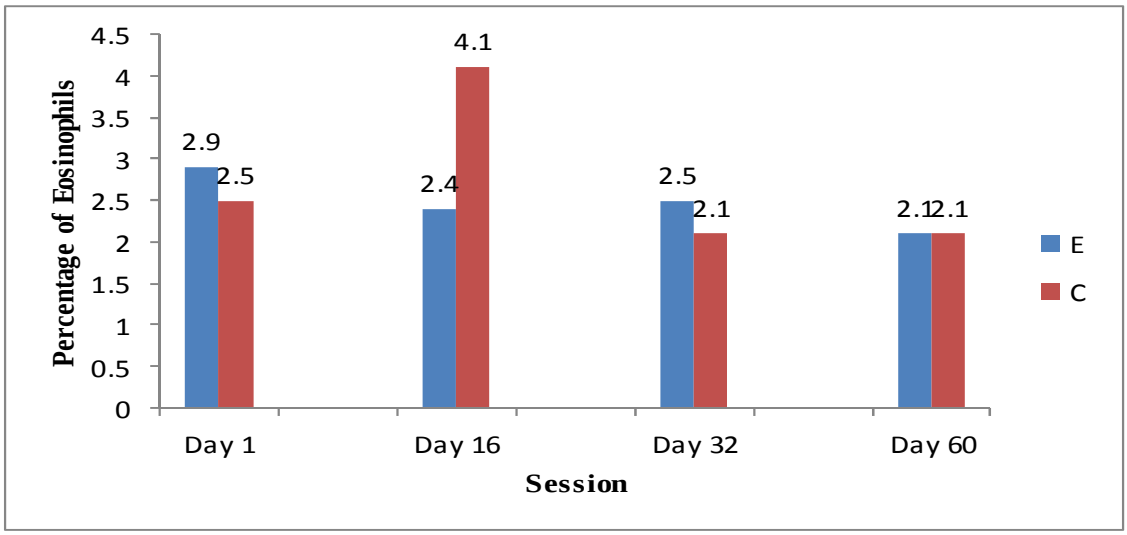

Figure 4: Percentage of Eosinophils versus session of Irradiation.

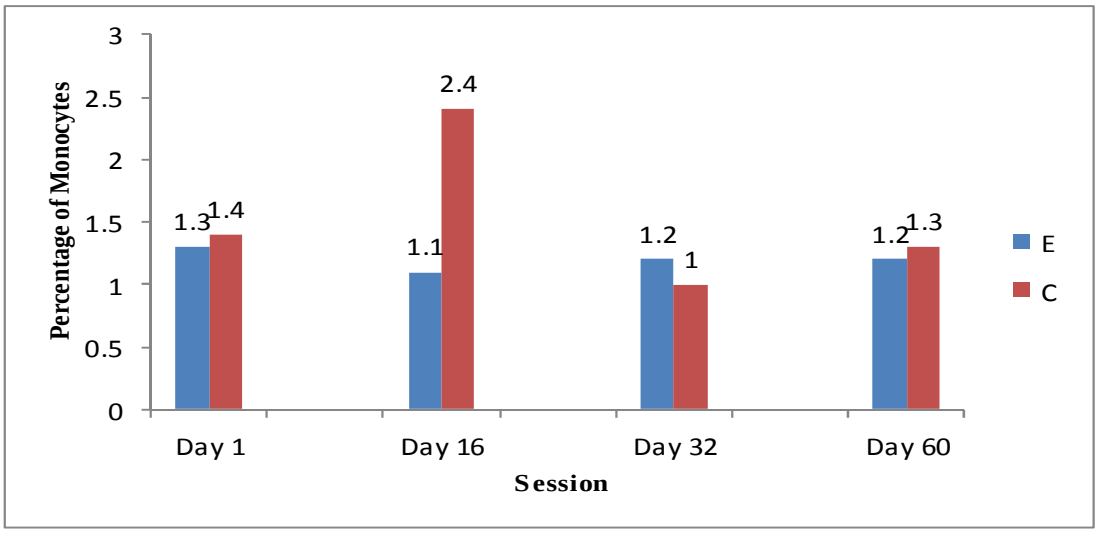

Figure 5: Percentage of Monocytes versus session of Irradiation.

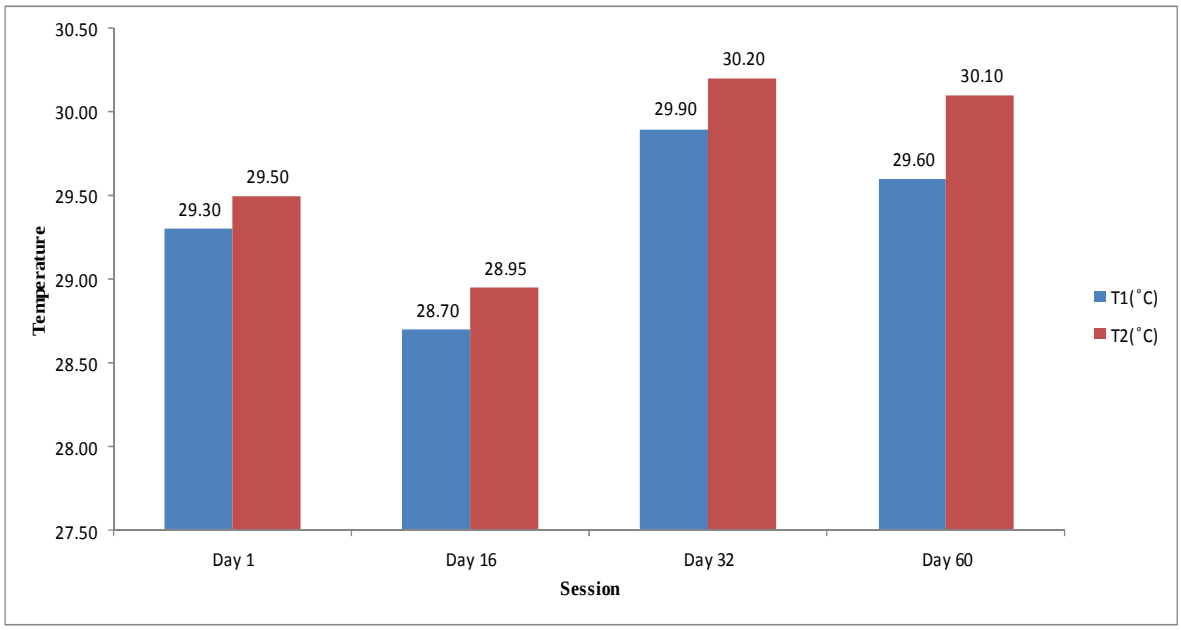

Figure 6: Temperature before T_1(°C)and after T_2(°C) Irradiation.

4.1 Morphology Results

The whole white cells cytoplasm were not deformed but there were few changes in the stained colour of lymphocyte nucleus which instead of staining deep-purple, as seen in the 1st session, it became paler successively in which, at the last session (both day) it was very pale as seen in irradiated E batch. The granules of neutrophils which showed pinkish in normal or control batch, were seen to degenerate in the cytoplasm of exposed, E batch, which at 60th day, the cytoplasm was almost clear with just a few dust-like granules. However, the sizes of all cells were not affected, they were well formed, and with intact nucleus, except for the pale purple appearance of the nucleus of lymphocyte and disappearance of granules in neutrophils which are significant changes between the 1st session and the 4th session progressively.

5.0 Discussions And Implication Of Results

When electromagnetic radiation passes from one medium to another, it can be reflected, refracted, transmitted, or absorbed, depending on the biological system and frequency of the radiation. Absorbed microwave energies can be converted to other forms of energy to cause interference with the functioning of the Biological System. This research has demonstrated experimentally that other types of energy conversion are possible. Interactions at the microscopic level leading to perturbations in complex macromolecular biological systems of cell membranes and subcellular structures have been observed.

The rapid proliferation of mobile communication systems have cause the general population exposure to microwave radiation, and the substantial increase in radiation levels is likely to be moving towards producing electromagnetic pollution. The problem of this extraneous radiation or pollution from mobile communication systems networks propagating over both short and long distances is that it may, in years to come, cover the whole globe. Experiments have shown that exposure to power densities of a few tens of mW/cm^2 to several hundred of mW/cm^2 depending on the size of the absorber can be dangerous or worst, terminal. Microwave at low level, long term exposure can induce effects in the nervous haematopoietic and immuno competent cell systems of animals. As the whole body is irradiated peripheral blood in veins, arteries and capillaries are affected by these radiations. Experiments carried out. in this research proved that the white blood cells are affected thereby placing the body immune system at danger, since the blood is constantly in motion.

5.1 Implication Of Results

The results of the research having exposed albino mice to a frequency of 2450MHz at a power density of $10mW/cm^2$ in four sessions of experiment at the 1st, 16th, 32nd and 60th day of exposure have shown a significant response of the white blood cells to microwave radiation at low intensities.

Due to the general principle of interaction between the microwave radiation and dielectric (water) molecules, it is expected that the temperature should increased. This was observed after every irradiation session during the research. The temperature increased between ranges of 0.2-0.5^oC which can cause micro thermal effect in cellular and subcellular levels. Lai et al (1984), explain that animals exposed to low intensities microwave, absorbed energies can cause changes in the thermoregulatory activities of its system. Seaman and Wachtel (1987) suggest that "biological systems alter their functions as a result of change in temperature of 0.5^oC. Therefore, the change in temperature of the irradiated E batch mice must have caused some genetic aberrations or disrupt the covalent bonds of DNA, causing it to misread the RNA (Ribonucleic Acid) of haemopoietic stem.

The decrease in lymphocytes in the white cells (blood) of the irradiated mice, implies the mice are vulnerable to lymphopenia, a condition of low or decrease count of lymphocytes. Lymphocytes play an important role in the immunological systems of all animals. It plays an important role in acquired immunity, protecting the body from "foreign substances, such as viruses and bacteria, they secrete specific antibodies which attach themselves to offending antigen, thereby making it open for immune destruction.

The exponential increased in the number of neutrophils in irradiated mice can lead to neutrophilia, this condition, can also be noticed in acute bacterial infections.

5.2 Implication of Morphology Discrepancies

The digressions in the morphology of stained white blood cells with Giemsa stain was observed in lymphocytes and neutrophils. The nucleus of Iymphocytes in all romanowsky stains appears deep-purple but as irradiation days increased, the deep-purple colour started decreasing to a pale-purple colour. This shows that, some vital components of the nucleus acid fast receptors, have been disrupted by the microwave. It was evident that the purple colour would likely disappear if exposure was not discontinued. By implication, this can lead to functionless cells; this is likely the bases of chromatin conformation in lymphocytes.

The gradual disappearance of granules in the cytoplasm of neutrophils can be said to have also been caused by some genetic aberration in the haemapoietic stem cells. The granules of neutrophils are the immunity weapon use in fighting antigens, when granules are reduced, it will have little or no effects on the attacking antigen. In the study of the so called "mobile communication - like" signals, the effects on blood of albino mice irradiated or expose at frequency of 2450MHz at power intensity of $10mW/cm^2$ show that, radiation of microwave is capable of disrupting biological activities in biological system.

The white blood cells mostly affected were the lymphocytes and neutrophils from the experiments, these effects

will increase as irradiation continues, which will likely cause further and intense damage to the white blood cells. The results obtained are in line with the hypothesis that GSM radiations may affect the parameters of white blood cells and their morphological formations, though experimented with continuous wave and the GSM is pulse wave but experiments have shown pulse microwave is much more destructive to biological tissues than continuous microwave. If the decrease in lymphocytes, increase in neutrophils and morphological digression can occur with continuous microwave, one would say that the effect would be more with pulse microwave.

6.0 Conclusion

It is difficult to deny that microwaves at low intensities can affect the white cells parameters and morphology in animals. However, data available suggest a complex reaction of white blood cells to microwave radiation, and the response is not likely to be linear with respect to intensity of the radiation. Other properties of microwaves exposure, such as frequency, duration of exposure, wave form etc. are all important determinants of biological responses. In order to understand the health effect of microwave radiation exposure on white blood cells more knowledge is needed on the interactivity of the cells at sub cellular level with low intensity directly from the mobile phones and its base-station. The service providers should be aware that the public is placed on radiation risk for their gain, therefore, they should avoid the mounting of base-stations in built-up areas and also their employees should be given adequate medical attention, intermittently. The regulatory body should be able to formulate guidelines and policies that will check incessant mounting of GSM base antennas in urban settlements and provide a platform so that radiation from antennae will be checked intermittently by microwave experts.

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