Assessment of Extremely Low Frequency Magnetic Fields Associated with Industrial Sewing Machines

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Abstract – This study assess the level of extremely low frequency magnetic fields associated with industrial sewing machines using the Trifield Metre, and the exposure of tailors was assessed in accordance with the American Congress of Industrial Hygienists (ACGIH) and International Commission on Non-Ionizing Radiation Protection (ICNIRP).The formulation used in this survey is the current density which is an important factor to evaluate the biological effects associated with exposure to extremely low frequency magnetic fields. In this paper a standard of the human femur is considered. Data analyses were conducted and the maximum arithmetic mean of the magnetic fields from the survey was found to be 10μT and a value of 0.43μT was the minimum. In none of the situations does exposure of tailors to ELF-MF exceed the threshold limits recommended by ACGIH. While the maximum induced current density around the human femur bone from the survey was computed to be 64.3 nA/m^2 and the value of 2.8 nA/m^2 was the minimum current density. The maximum computed value for induced current density for the human femur bone was found to be far less than the recommended reference value of 10 mA/m^2 set by ICNIRP.

Key words – Magnetic Fields, Extremely Low Frequency, Human Bone Marrow Stromal Cells/ Human Skeletal Stem Cells, Industrial Sewing Machines and Trifield ^{TM}100XE Metre.

I. INTRODUCTION

The wearing of clothing is exclusively a human characteristic and is a feature of most human societies. It is not known when human began wearing of clothes but anthropologists believe that animal skins and vegetation were adapted as protection from weather conditions. Clothing and textiles have been important in human history. They reflect the material available in different civilisation at different times. They also reflect upon the technologies that had been mastered in due course of time [6].Sewing (the craft of fastening or attaching objects using stitches made with a needle thread) for thousands of years have been done by hand, where the first needles were made from bones or animal horns and the threads made from animal sinew. The invention of sewing machines in the 19th century and the rise of computerisation in the 20th century led to mass production and export of industrial sewing machines across the globe [9].

As demonstrated by environmental assessments, the range of potential biological effects from electromagnetic field (EMF) is broad. In June 2001, the International Agency for Research on Cancer (IARC), which classifies environmental agent in terms of the likelihood that they are a cause of cancer, delivered a finding about extremely low frequency or power frequency field, using its standard approach that weighs human, animal and laboratory evidence, classified extremely low frequency magnetic field (ELF MF) as possibly carcinogenic to humans [14].More recently, women garment workers were considered a possible target population for studying breast cancer in relation to magnetic field exposure. With respect to the latter investigations, sewing machine operators were initially identified as a potential high exposure group for magnetic fields and an occupational group where women made up the majority of the workforce and could be more efficiently studied for female-specific health outcomes such as breast cancer [8]. Living bodies do not possess significant ferromagnetic properties, and thus, they do not distort the magnetic field by their presence. In other words, magnetic fields interact weakly with living bodies by inducing internal current. Many characteristics of biological system influence the interaction between (ELF-MF) and living bodies [1]. Exposure to exogenous stimuli such as an EMF can promote differentiation of human bone marrow stromal cells (hBMSCs)/human skeletal stem cells (hSSCs) via ion dynamics and small signaling molecules. Studies show specific EMF frequencies enhances hSSC/BMSC adherence, proliferation, differentiation, and viability all of which play a key role in the use of hSSCs/BMSCs for tissue engineering [13].

The magnetic field is the pollution of concern in this study. AC electric and magnetic fields induce surface charges on human bodies and weak current flows in these bodies. This is one reason why there is a potential for electric and magnetic fields to cause biological effects[5]. Magnetic field may either be static (an electric or magnetic field whose intensity does not vary over time) or alternating with time such as (ELF-MF) and vocational workers may be expose to these field in place of work[7].

In Maiduguri, Nigeria, many modern sewing machines like the mechanical, industrial, and a few computerised sewing machines are found almost everywhere in the metropolis. Due to the rising number of industrial sewing machine and magnetic field hazard associated with electricity, there is need to measure the fields that is emitted as a result of sewing machines usage and determine the limiting exposure to this field that will give a maximum protection on the established adverse effect of magnetic fields on tailors exposed to such field. The objectives of the study were to quantify the level of exposure to magnetic field and associated induced current density among tailors in the metropolis. The study has some limitation that should be pointed out. First, measuring the magnetic field exposure is particularly difficult, because the metre use was analog, and exposure misclassification arises because tailors using the same industrial sewing machine do not necessarily have the same exposure.

II. MATERIALS AND METHODS

The materials used during the field measurement of magnetic field exposure associated with industrial sewing machine is the hand heldTrifield™100XE metre, and 37 industrial sewing machines. This study was conducted in August 2019 for a period of 2 weeks during the preparation of Eid-Al-Adha Mubarak on intracity of Maiduguri Metropolis (Hausari) Borno State, Nigeria. First the authors recorded all available data about the industrial sewing machine on the nameplate; the horse power, revolution per minute (RPM), ampere current and model of the industrial sewing machine motor.The on state magnetic field and the operational state magnetic field was determined through measurement.

The assessment of exposure to the magnetic field was made through a measurement survey carried out among tailors while working. Measurement of exposure to magnetic fields were taken with a Trifield ™100XE Metre with a frequency range of 40 Hz – 100 kHz, which measures magnetic field of up to 100 mG, with a measurement accuracy of +/- 20% of reading. The metre was checked and calibrated before used. The metre was placed close to the thigh of the tailor seated opposite to the electric motor during full work. All measurements were carried out close to the sources of emission (motor) of the industrial sewing machine while working, and the authors recorded the on state magnetic field and the operational state magnetic field for at least four seconds.

The survey was carried out during a festive period (Eid-Al-Adha) when the industrial sewing machines are in maximum operation due to high demand of cloths. Technical problems were avoided such as zero errors in metre reading was ensured after each stage of measurement and no other source of magnetic field would interfere while taken the reading and the battery was replaced when down.

In total, measurements taken from 37 industrial sewing machines while working were used for estimating the exposure to magnetic fields that tailors experience. For better results, measurements were carried out with three replications, with two-minute interval on each industrial sewing machine, the distribution of magnetic field values recorded by the metre during the on state and operational states was cautiously observed. Data were analysed using the arithmetic mean of the operational states to summarise the magnetic field exposure of tailors. In the analysis the estimated induce current density in the thigh region at extremely low frequency, the average conductivity σ, of the cortical bone (that is, the thick outer surface of a typically long bone) is of the order of 3.5mS/m, while an average radius R of 11.7 mm of the induction loop are assume for the femur bone.

III. FORMULATION OF MAGNETIC FIELD MODEL

Exposure to time varying EMF results in internal body currents and energy absorption in tissues that depend on the coupling mechanisms and the frequency involved. The internal electric field and current density are related by microscopic ohm's law [12]:

$$J = \sigma E \quad 1.1$$

If the magnetic flux Φ through an area bounded by closed conducting loop changes with time, a current and emf are produced in the loop; this process is called induction. Faraday's law states that the magnitude of the emf induced in a conducting loop is equal to the rate at which the magnetic flux Φ through that loop changes with time [15]:

$$V_{emf} = -\frac{d\Phi}{dt} \quad 1.2$$

where $\Phi = \int \vec{B}\cdot d\vec{A}$, if $\vec{B}$ is perpendicular to the area and uniform over it, the flux is $\Phi = BA$. Using equation (1.2) and realising that only the field magnitude B changes in time (not the area A) Faraday's law can be rewriting as [15]:

$$V_{emf} = \frac{d(BA)}{dt} = A\frac{dB}{dt} = \pi R^2 \frac{dB}{dt} \quad 1.3$$

A changing magnetic field induces an electric field $\vec{E}$, using the induced electric field we can write Faraday's law in its most general form as [12]:

$$\oint \vec{E}\cdot d\vec{S} = -\frac{d\Phi}{dt} \quad 1.4$$

and

$$\oint \vec{E}\cdot d\vec{S} = E\oint dS = E(2\pi R) \quad 1.5$$

Comparing equation (1.2) and (1.4)

$$V_{emf} = \oint \vec{E}\cdot d\vec{S} = E(2\pi R) \quad 1.6$$

The integral $\oint dS$ implies the circumference $(2\pi R)$ of the circular path. When the magnetic field is in the plane of the loop and the time rate of change of flux is a maximum. From equation (1.1) spatially uniform magnetic field will induce an electric field in the exposed body, according to Faraday's law, substituting the flux density $B = \sqrt{2}B_{rms}\cos\omega t$, where $\omega = 2\pi f$ and $\omega t = 270^{O}$ in equation (1.3) the resultant equation gives [10]:

$$V_{emf} = \pi R^2 \cdot \frac{d}{dt}\left(\sqrt{2}B_{rms}\cos\omega t\right) \quad 1.7$$

Solving equation (1.7) and substituting equation (1.6) we have

$$E(2\pi R) = 2\sqrt{2}\pi^2 R^2 f B_{rms} \quad 1.8$$

The resulting induced electric field is

$$E = \sqrt{2}\pi R f B_{rms} \quad 1.9$$

The value of surface current density is given by $J = \sigma E_{rms}$, where $E_{rms} = \frac{E}{\sqrt{2}}$.

This relation is frequently employed in estimating induced electric field in animal bodies and cell cultures but will give only approximate results because biological tissue is neither cylindrical nor electrically homogeneous [12].

For a pure sinusoidal field at frequency, f equation (1.1) becomes

$$J = \sigma \pi f R B_{rms} \quad 1.10$$

Equation (1.11) is referred to as Magnetic Field Model.

J= current density (A/m^2)

E = induced electric field strength (V_m)

R = radius of the induced loop for induction of the current (m) (usually up to 20cm)

σ = tissue conductivity field (S/m)

B = magnetic flux density (T)

f = 50 Hz ELF magnetic field (Hz)

IV. EMF MODE OF INTERACTION

EMF has been reported to be effective in the enhancement, formation and development of the bone (Osteogenesis) and cartilage (Chondrogenesis) of hSSCs/BMSCs with no documented negative effect [13]. When a body is moved across the lines of magnetic force it experience what is called an electromotive force; the two extremities of the body tends to become oppositely electrified, and an electric current tends to flow through the body. When the electromotive force is sufficiently powerful, and is made to act on certain compound bodies, it decomposes them, and causes one of their components to pass towards one extremity of the body and the other in the opposite direction [11].

When an EMF falls upon the body, then it partially penetrates into human body and is attenuated by human body tissues and its parts are absorbed by body tissues[2]. In living bone however small piezoelectric potentials are shielded. In physiology, mechanical stress-generated potentials are formed by mechanism such as: the entrainment of ion caused by fluid motion through the bone. The EMF caused by this reaction is able to penetrate tissue, and the MF component can induce electric currents in the bone or muscle tissue via Faraday's coupling, which state a form of inductance by which the current in one system induces a voltage in another [13].

For humans the bones, nerves and muscle are relatively resistant while the lymphatic tissues and bone marrow are relatively sensitive to effects by radiation. The susceptibility to radiation shows itself in a decrease in the level of white blood cells and later of red blood cells (anaemia), a long term result may be leukaemia which is an uncontrolled over production of the white blood cells [4].

Harmful effect of EMF exposure on living tissue depends primarily on the frequency (wavelength) and density of the field and on the exposure time [3]. For hBMSCs to differentiate, endogenous EMF frequencies which arises from the movement of muscles, tendons, and the actions of the musculoskeletal system will be entrained to follow exogenous EMF of the same frequencies. This entrainment via harmonic resonance is what influences the differentiation of hBMSCs, and there must be effective exogenous stimuli providing direction for their differentiation capabilities, one of such stimuli is sinusoidal low frequency EMF (0.3-100 Hz), which produces fields that are coherent, and produce regularly recurring signals that must be present for a certain minimum duration [13].

V. RESULTS

The survey of extremely low frequency magnetic fields associated with the industrial sewing machines is depicted in Table 1, which shows; Model of the Motor, Horse Power, Revolution per Minute, Current, On State Magnetic Fields, Arithmetic mean of the Operational State Magnetic Fields and the Current Densities. The ELF-MF was measured for 37 Industrial Sewing Machine.

TABLE 1: RESULTS OBTAIN FROM the SURVEY of EXTREMELY LOW FREQUENCY MAGNETIC FIELDS ASSOCIATED WITH INDUSTRIAL SEWING MACHINES.

S/N	Machine Type	Model of Motor	Horse Power	RPM	Current (A)	On State Magnetic Field (μT)	Operational Arithmetic mean (μT)	Mean Current Density (nA/m^2)
1	Sewing	DOL 12H	400W	3450	2.80	0.80	0.48	3.10
2	Sewing	RM1818-2	250W1/3HP	2850	1.88	1.50	1.40	9.00
3	Sewing	EM250A	1/3HP	2850	2.16-1.71	0.70	0.68	4.40
4	Sewing	DOL 121	250W	3450	2.00	1.50	1.27	8.10
5	Sewing	RM1818-2	1/3HP	2850	1.87	1.50	1.27	8.10

6	Sewing	DOL 12	250W	2850	2.00	10.00	0.43	2.80
7	Sewing	EM250+HB	1/3HP	2850	2.00	10.00	10.00	64.30
8	Sewing	DOL 13H	250W	2850	2.50	10.00	10.00	64.30
9	Sewing	DOL 12H	250W	2850	2.00	10.00	10.00	64.30
10	Sewing	DOL 12	250W	2850	2.00	10.00	10.00	64.30
11	Sewing	EM 250	1/3HP	2850	2.00	10.00	10.00	64.30
12	Sewing	DOL 13H	1/3HP	2850	2.00	10.00	10.00	64.30
13	Sewing	EM250A+HB	1/3HP	2850	2.16/1.71	10.00	10.00	64.30
14	Sewing	NS 312	250W	2850	2.10/1.90	10.00	10.00	64.30
15	Sewing	NS 312	250W	2850	2.10/1.80	10.00	10.00	64.30
16	Sewing	CL 12R1	250W	3450	2.00	10.00	10.00	64.30
17	Sewing	DOL 13H	250W	2850	2.50-2.00	10.00	10.00	64.30
18	Sewing	DOL 13H	250W	2850	2.50-2.00	10.00	10.00	64.30
19	Sewing	NS 312	250W	3450	3.80/1.90	10.00	6.17	39.70
20	Sewing	DOL 13H	250W	2850	2.50-2.00	10.00	10.00	64.30
21	Sewing	RM1818-2	250W	2850	2.00	10.00	10.00	64.30
22	Sewing	UNICORN	400W	3450	5.60/2.80	0.80	0.57	3.60
23	Sewing	VICTORY	250W	3450	3.80	10.00	10.00	64.30
24	Sewing	NS 312	250W	2860	2.00	5.00	3.17	20.40
25	Sewing	EM250+HB	1/3HP	2850	2.00	10.00	10.00	64.30
26	Sewing	DOL 13H	250W	2850	2.50-2.00	10.00	10.00	64.30
27	Sewing	DOL 13H	250W	2850	2.00	10.00	10.00	64.30
28	Sewing	3012S	250W	3450	1.80	10.00	10.00	64.30
29	Sewing	3012S	250W	3450	1.80	10.00	10.00	64.30
30	Sewing	NS 312	250W	2860	2.10/1.90	10.00	10.00	64.0
31	Sewing	RM1818-2	250W	2850	1.87	10.00	10.00	64.30
32	Sewing	NS 312	250W	2860	2.00	5.00	4.07	26.20
33	Sewing	RM1818-2	250W	2850	2.00	10.00	8.50	54.70
34	Sewing	DOL 250	250W	2850	2.00	2.50	2.10	13.50
35	Sewing	DOL 250	250W	1430	2.00	3.50	2.43	15.70
36	Sewing	DOL 13H	1/3HP	2850	1.87	10.00	10.00	64.30
37	Sewing	R31221	1/2HP	2850	2.90	10.00	10.00	64.30

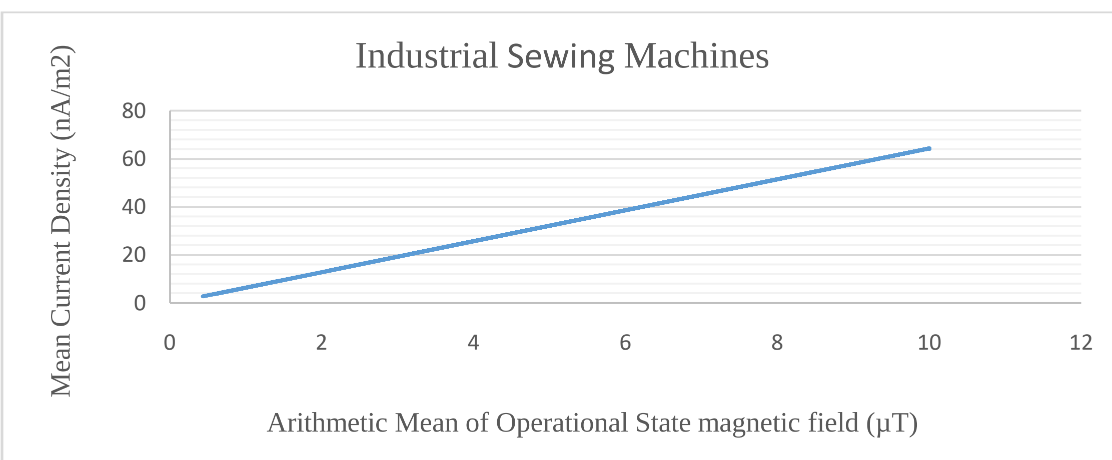

Fig 1: A plot of Mean Current Density (nA/m^2) against Arithmetic Mean Operational State Magnetic Field (μT) for an Industrial Sewing Machine obtain from Table 1

VI. DISCUSSION

Figure 1 indicates the relationship of the average mean current densities versus arithmetic mean operational state plotted as depict in Table 1. The chart shows that the current density is directly proportional with the mean operational state magnetic field, as stated in equation (1.11) that is, as the operational magnetic state increases so will the current density. The maximum computed mean magnetic field density is 10 µT while the minimum magnetic field is 0.43 µT obtain from the survey. Therefore the level of ELF MF associated with industrial sewing machine may not pose any known health risk to tailors. However more research work is recommended.

VII. CONCLUSIONS

The study evaluated in the current survey do find out that the maximum arithmetic mean of the magnetic field was 10 µT when the Trifield TM100XE metre was placed close to the thigh of the tailors seated opposite to the electric motor while working and a value of 0.43 µT was the minimum. In none of the situations, exposure of tailors to ELF-MF exceed the threshold limits recommended by ICNIRP. While the maximum induced current density around the human femur bone from the survey was found to be 64.3 nA/m^2 and the value of 2.80 nA/m^2 was the minimum current density. The maximum computed value for induced current density for the human femur bone was found to be far less than the recommended reference value of 10 mA/m^2 set by ICNIRP. This does not mean that these magnetic fields are safe and harmless because most tailors used this industrial sewing machine as a means of survival.

Based on the findings of this work, there is no convincing scientific evidence of the adverse health effect to ELF MF associated with industrial sewing machine. It is of the opinion of the authors that further research should be carried out on ELF MF with respect to industrial sewing machines.

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