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Assessing the Health Risk Due to Exposure to Non-ionizing Radiation in the Form of Magnetic Field from Electrical Power Lines

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Abstract

We are all exposed to electromagnetic fields from electrical appliances, electric power transmission lines, distribution lines and power substations. This study was focused on investigating the possible risks to human health due to exposure to extremely low frequency varying magnetic fields from 330 kV, 132 kV, 33 kV and 11 kV power lines in southeastern Nigeria. To determine the risks, a magnetic field meter was used to take measurements of magnetic flux from these power lines. From which, the induced current density due to exposure to varying magnetic fields was obtained using a model of the human body known as the prolate spheroid model. The maximum mean magnetic field and current density induced as obtained from the study were 4.79 µT and 0.042 mA/m^2, which were obtained from the 330 kV power line. The study results are well below the reference levels of the International Commission for Non-Ionizing Radiation Protection, which are used for comparison, indicating that there is very low exposure risk to people living near these electric power transmission lines.

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Introduction

Interest in the study of radiation that cannot knock off electrons from an atom (non-ionizing radiation), especially in the form of 50/60 Hz frequency electric and magnetic fields and its resulting adverse health effects on humans increased recently [1-7]. We are all exposed to electromagnetic fields (EMF) from electrical appliances [8, 9], electric power transmission lines, distribution lines [7] and power substations [10]. The determinants of the level of this exposure are location, size and distance from the source [11]. In 2016, the World Health Organization (WHO) reported that most studied subjects are exposed to less than 0.1 µT of extremely low frequency (ELF) magnetic field, with a very small percentage exposed to more than 0.3 µT [12]. Various researchers have reported that there is a likely relationship between human exposure to ELF-EMF and health conditions as cancer in children living near electric transmission lines [13], tumors in the brain, sterility, congenital defects, abortion, and so on [14-18]. ELF magnetic fields have been classed by the International Agency for Research on Cancer (IARC) as possibly carcinogenic, *i.e.*, group 2B on the IARC scale of risk to humans due to carcinogenic sources [19] and thus raising further concerns about the adverse health effects.

Because of the increasing evidence of the adverse health risk of ELF-EMF exposure on humans, various regulatory bodies such as the International Commission for Non-Ionizing Radiation Protection (ICNIRP) and the Institute of electrical and electronics engineering (IEEE) [20, 21] have set up exposure limits for EMF for both public and occupational exposures. Protection from the likely risk due to exposure to these fields requires that these standards are adhered to. The most widely used standard is the ICNIRP standard. According to these standards, for occupational situations of exposures to 50 Hz fields, the reference levels are set at 10 kV/m for electric fields and 500 µT for magnetic fields [20] and for public exposure, the reference levels are 5 kV/m and 100 µT, respectively [20]. For the current density, the basic restriction of the ICNIRP guidelines for 50 Hz fields is 10 mA/m^2 [20]. The reference levels for current density are set to help mitigate the effects of exposure to these fields on the nervous system [20, 22].

In Nigeria, there are no country-specific regulations for exposure to ELF-EMF and few studies have been reported with respect to the level of exposure to ELF fields [23-25], hence, the motivation for this work. There is currently no study that has been reported with respect to induced current density due to exposure to magnetic fields from transmission lines in Nigeria using the prolate spheroid model. In this study, we investigated possible health risks due to exposure to magnetic fields from 330 kV, 132 kV, 33 kV and 1 1kV power lines within southeastern Nigeria and calculated the resulting induced current density due to this exposure using the prolate spheroid model [1, 22].

Materials and Methods

To measure the magnetic fields from the lines, the TENMARS magnetic field meter (TM-191, TENMARS Electronics Co., Ltd., Taiwan) was used for the measurement of magnetic flux density. It is an easy-to-carry device of 130×56×38 mm dimensions and 170 g weight, which is designed to be used to measure safely magnetic flux density. It has a liquid crystal display (LCD) equipped with a single axis sensor for the measurement in one direction with a maximum reading of 1999. It measures magnetic field in units of µT or mG with a measuring range of 20/200 µT with the resolution of 0.01/0.1 µT and a sampling rate of 2.5 per second. It is powered by a 9V alkaline battery with an approximate life of 100 h. Each measurement was taken over a short period. All readings of magnetic flux density were taken one meter above the ground. The meter sensor was pointed towards the source of field and kept steady to avoid the display of false field value due to electrostatic charges. Magnetic flux values were taken directly underneath each power line (Epicenter) and then at successive 5m from the starting point to 50m. These measurements were repeated twice at different times of the day to ensure accuracy. Measurements were taken from a total of five power lines comprising 330 kV, 132 kV, 33 kV and 11 kV power lines within southeastern Nigeria (Fig. 1).

To obtain the induced current density, the prolate spheroid model was used. The prolate spheroid model is used to investigate the biological effects of electric and magnetic fields on humans. This model is used in approximating the interaction of the human body with electric and magnetic fields [1, 22]. The current density induced by the magnetic field is dependent on the larger loop, so it is maximum at the prolate spheroid surface (the

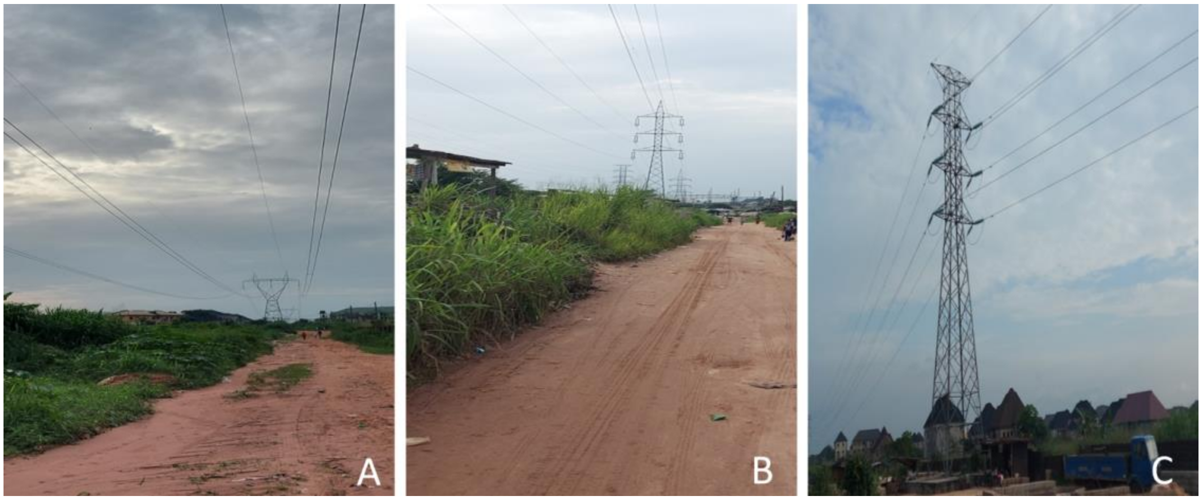

Fig. 1 Electricity transmission lines (A) 330 kV (B) 132 kV line 1 (C) 132 kV line 2.

largest loop) corresponding to "$r = b$" (maximum radius of the spheroid). Spiegel [26] derived an equation for the current density induced by a magnetic field on a prolate spheroid. The equation for obtaining the highest value for the current density *J*, at the surface of the prolate spheroid in a horizontal magnetic field of magnitude B is given below:

$$J = -j2\pi f\sigma bB_0 \quad \text{(eq. 1)}$$

Where f, b, B_0, σ are frequency, minor axis of the spheroid, external magnetic field, and tissue conductivity, respectively. Tissue conductivity and minor axis of the spheroid are 0.2 S/m and 0.14 m, respectively.

Results and Discussion

The results of the study are summarized in Tables 1-5 showing the mean values of the magnetic field from the power lines sampled in this study and the corresponding calculated values of the induced current density in the body due to these fields. In Table 1, the mean values of B and *J* are presented for the 330 kV transmission line. The maximum value for the magnetic field and the induced current are 4.790 µT and 0.04214 mA/m^2, respectively. The observed values are all below the ICNIRP exposure limits. The B and *J* values are about 4.79% and 0.42% the recommended limits for public exposure of 100 µT and 10 mA/m^2. Previously, Ukhurebor et al. [23] and Aliyu et al. [24] recorded maximum values of ~1.57 µT and ~4.5 µT (45 mG) for 330 kV power lines in Bauchi and Edo states, Nigeria, respectively, which are both lower than the values of this study. Ozen [28] also reported a maximum value of 3.3 µT and 2.86 µA/m^2 for 380 kV power line, which is also lower than the values reported in this study. This indicates that the risk to people living close to the power lines in this study is slightly greater. In comparison, the result of Helhel and Ozen [31] reported a maximum value of 70 µT for a 154/31.5 kV substation, indicating that the risk of health effects due to occupational exposure is significantly higher than public exposures from power lines.

Table 2 and Table 3 present mean values of B and *J* for the 132 kV transmission line 1 and line 2. The maximum values of B are 0.725 µT and 1.920 µT, respectively, *i.e.*, 0.73% and 1.92%, respectively, of the ICNIRP recommended limit. For the induced current, the maximum values are 0.00638 mA/m^2 and 0.01689 mA/m^2, *i.e.*, 0.06% and 0.17 %, respectively, of the recommended

Table 1 Mean values of magnetic field (B) and current density (*J*) for 330 kV transmission line (Alaoji-Onitsha).

Distance	B (µT)	*J* (mA/m^2)
0	4.790 ± 0.721	0.04214
5	3.445 ± 0.799	0.03031
10	2.180 ± 0.410	0.01918
15	1.395 ± 0.120	0.01227
20	0.835 ± 0.078	0.00735
25	0.720 ± 0.042	0.00633
30	0.400 ± 0.014	0.00352
35	0.395 ± 0.078	0.00348
40	0.285 ± 0.049	0.00251
45	0.250 ± 0.042	0.00220
50	0.140 ± 0.014	0.00123

SD: Standard deviation

Table 2 Mean values of magnetic field (B) and current density (*J*) for 132 kV transmission line 1 (Alaoji-Onitsha).

Distance	B (μT)	*J* (mA/m²)
0	0.725 ± 0.064	0.00638
5	0.440 ± 0.014	0.00387
10	0.200 ± 0.014	0.00176
15	0.040 ± 0.028	0.00035
20	0.015 ± 0.007	0.00013
25	0.015 ± 0.007	0.00013
30	0.015 ± 0.007	0.00013
35	0.015 ± 0.007	0.00013
40	0.010 ± 0.000	0.00009
45	0.010 ± 0.000	0.00009
50	0.010 ± 0.000	0.00009

SD: Standard deviation

Table 3 Mean values of magnetic field (B) and current density (*J*) for 132 kV transmission line 2 (Alaoji-Onitsha).

Distance	B (μT)	*J* (mA/m²)
0	1.920 ± 0.028	0.01689
5	0.865 ± 0.092	0.00761
10	0.605 ± 0.120	0.00532
15	0.535 ± 0.162	0.00471
20	0.475 ± 0.007	0.00418
25	0.370 ± 0.042	0.00326
30	0.300 ± 0.028	0.00264
35	0.220 ± 0.014	0.00194
40	0.150 ± 0.028	0.00132
45	0.125 ± 0.007	0.00110
50	0.100 ± 0.000	0.00088

SD: Standard deviation

Table 4 Mean values of magnetic field (B) and current density (*J*) for 33 kV transmission line (Owerri).

Distance	B (μT)	*J* (mA/m²)
0	1.035 ± 0.078	0.00911
5	0.875 ± 0.021	0.00770
10	0.420 ± 0.156	0.00369
15	0.235 ± 0.021	0.00207
20	0.150 ± 0.042	0.00132
25	0.015 ± 0.007	0.00013
30	0.010 ± 0.000	0.00009
35	0.010 ± 0.000	0.00009
40	0.010 ± 0.000	0.00009
45	0.010 ± 0.000	0.00009
50	0.010 ± 0.000	0.00009

SD: Standard deviation

limit. The observed values are all below the recommended ICNIRP values. Similar results were reported by Aliyu et al. [24], who recorded a maximum B value of 2.055 μT for 132 kV transmission line in Bauchi, Nigeria, which is above the maximum values reported in this study. Similarly, Ozen [28] also reported a maximum value of 4.3 μT and 3.728 μA/m² for 154 kV transmission lines, which is higher than the values of this study. This indicates that the risk from exposure to the fields in this study is lower based on the field values.

The summary of the results of 33 kV and 11 kV distribution lines is presented in Table 4 and Table 5, respectively. For the 33 kV line, the maximum B and *J* values are 1.035 μT and 0.00911 mA/m². These values are 1.04% and 0.09% of the recommended limit for B and *J*, respectively. For the 11 kV line, the maximum B and *J* values are 0.645 μT and 0.00567 mA/m², *i.e.*, 0.65% and 0.06%, respectively, of the ICNIRP limit for public exposure. It can be observed that there is an inverse relationship between the magnetic flux and the distance throughout the study, as the magnetic flux and consequently the induced current density are observed to decrease as we move away from the power lines. The maximum values of B and *J* for the whole study are recorded near 330 kV line. On the other hand, the lowest values are recorded near 11 kV line. This is due to the fact that a higher voltage translates to higher values of B and *J* and consequently greater risk to people living near these lines. The result of this study leads to the conclusion that the magnetic field decreases while moving away from the line conductors with the maximum intensity directly underneath the lines. These results are consistent with the results of Bidi [1], where a model is used to simulate the electric and magnetic fields from 400 kV transmission lines. Our results are also in line with those reported by other researchers [28–31]. It should be noted that although the results of this study are well below the reference level of the ICNIRP, the health risk to humans will be more significant, especially for long-term exposure mostly for those living near these power lines and substations [1, 30-31]. The values of induced current density due to the magnetic fields in this study are lower than the levels that could cause significant biological effects in humans. People living near the 11 kV and 33 kV line are at the least risk health-wise. It should be noted that the maximum values reported for this study for the 330 kV, 132 kV and 33 kV lines are higher than 1 μT, which should be a source of concern as it has been reported that there is an association between long-term exposure to ELF magnetic fields (~1 μT) and risk of Leukemia in children [32]. Thus, measures must be taken to mitigate the level of exposure to these fields even

Table 5 Mean values of magnetic field (B) and current density (*J*) for 11 kV transmission line (Owerri).

Distance	B (μT)	*J* (mA/m^2)
0	0.645 ± 0.007	0.00567
5	0.535 ± 0.007	0.00471
10	0.370 ± 0.084	0.00326
15	0.165 ± 0.091	0.00145
20	0.015 ± 0.007	0.00013
25	0.015 ± 0.007	0.00013
30	0.010 ± 0.000	0.00009
35	0.010 ± 0.000	0.00009
40	0.010 ± 0.000	0.00009
45	0.010 ± 0.000	0.00009
50	0.010 ± 0.000	0.00009

SD: Standard deviation

though they are low.

Conclusions

This paper assesses the potential risk to humans due to exposure to magnetic fields from electrical transmission and distribution lines within southeastern Nigeria. The resulting induced current densities due to these fields on the human body were also calculated using the prolate spheroid model. The results of the study show that all the measurements taken are below the ICNIRP reference levels, which were used for comparison, indicating that there is a very low exposure risk to people living near these lines. It should also be noted that although these values are low, there is potentially higher risk due to long-term exposure, especially for those living near these lines, most notably those living near the 330 kV lines. Hence, it becomes paramount for the relevant authorities to put in place regulations concerning exposure to the fields from these power lines to protect those living close to them better. Furthermore, it is pertinent that government enforces regulations that ensure that houses are not built near transmission lines and beyond a safe distance from the lines. Also, these kinds of measurements must be carried out in other parts of Nigeria to analyze the risk due to exposure to magnetic fields from power lines.

Conflict of Interest

The authors have no conflict of interest to declare with regards to the publication of this work.

References

[1] Bidi M. Biological risk assessment of high-voltage transmission lines on worker's health of electric society. Arch Elect Eng 2020; 69(1):57–68.

[2] Suri S, Dehghan SF, Sahlabadi AS, Ardakani SK, Moradi N, Rahmati M, et al. Relationship between exposure to extremely low-frequency (ELF) magnetic field and the level of some reproductive hormones among power plant workers. J Occup Health 2020; 62:e12173.

[3] Te neli NB, Te neli AY. Occupational exposure to electromagnetic fields of uninterruptible power supply industry workers. Radiat Prot Dosimetry 2013; 162: 289-298.

[4] Hosseinabadi MB, Khanjani N, Ebrahimi MH, Haji B, Abdolahfard M. The effect of chronic exposure to extremely low-frequency electromagnetic fields on sleep quality, stress, depression and anxiety. Electromag Bio Med 2018; 38(1):96-101.

[5] Gajšek P, Ravazzani P, Grellier J, Samaras T, Bakos J, Thuróczy G. Review of studies concerning electromagnetic field (EMF) exposure assessment in europe: low frequency fields (50 Hz–100 kHz). Int J Environ Res Public Health 2016; 13:875.

[6] Tognola G, Chiaramello E, Bonato M, Magne I, Souques M, Fiocchi S, et al. Cluster analysis of residential personal exposure to elf magnetic field in children: effect of environmental variables. Int J Environ Res Public Health 2019; 16:4363.

[7] Esmailzadeh S, Delavar MA, Aleyassin A, Gholamian SA, Ahmadi A. Exposure to electromagnetic fields of high voltage overhead power lines and female infertility. Int J Occup Environ Med 2019; 1:11-16.

[8] Marjanović AM, Pavičić I, Trošić I. Biological indicators in response to radiofrequency/microwave exposure. Arh Hig Rada Toksikol 2012; 63:407-416.

[9] Wdowiak A, Mazurek PA, Wdowiak A, Bojar I. Effect of electromagnetic waves on human reproduction. Ann Agric Environ Med 2017; 24(1): 13–18.

[10] Barsam T, Monazzam MR, Haghdoost AA, Ghotbi MR, Dehghan SF. Effect of extremely low frequency electromagnetic field exposure on sleep quality in high voltage substations. Iranian J Environ Health Sci Eng 2012; 9:1-7.

[11] Leitgeb N, Cech R, Schröttner J, Lehofer P, Schmidpeter U, Rampetsreiter M. Magnetic emissions of electric appliances, Int J Hyg Environ Health 2008; 211: 69-73.

[12] World Health Organization. Environmental Health Criteria Monograph No. 238: Extremely Low Frequency Fields. http://www.who.int/peh-emf/publications/elf_ehc/en/. Accessed 21 December 2020

[13] Wertheimer N, Leeper ED. Electrical wiring configurations and childhood cancer. Am J Epidemiol 1979; 109: 273-284.

[14] Calvente I, Fernandez MF, Villalba J, Olea N, Nuñez MI. Exposure to electromagnetic fields (non-ionizing radiation) and its relationship with childhood leukemia: a systematic review. Sci Total Environ 2010; 408:3062-3069.

[15] Carpenter DO. Human disease resulting from exposure to electromagnetic fields. Rev Environ Health 2013; 28:159-172.

[16] Duan W, Liu C, Wu H, Chen C, Zhang T, Gao P, et al. Effects of exposure to extremely low frequency

magnetic fields on spermatogenesis in adult rats. Bioelectromagnetics 2014; 35: 58-69.
[17] Kheifets L, Monroe J, Vergara X, Mezei G, Afifi AA. Occupational electromagnetic fields and leukemia and brain cancer: An update to two meta-analyses. J Occup Environ Med 2008; 50:677-688.
[18] Hardell L, Sage C. Biological effects from electromagnetic field exposure and public exposure standards. Biomed Pharmacother 2008; 62:104-109.
[19] IARC Working Group on the Evaluation of Carcinogenic Risks to Humans. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. Non-ionizing radiation, part 1: static and extremely low frequency (ELF) electric and magnetic fields. IARC press, Lyon, France; 2002.
[20] International Commission on Non-Ionizing Radiation Protection (ICNIRP). Fact sheet on guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz-100 kHz). Health Phy 2010; 99(6):818–836.
[21] IEEE. C95.6-2002. Standard for safety levels with respect to human exposure to EMF 0 to 30 kHz, standards coordinating committee, 28, IEEE, NY, USA; 2006.
[22] Korpinen L, Isokorpi J, Keikk T. Calculation of induced currents in a human body represented by a spheroidal model, Transactions on Modelling and Simulation. WIT Press; 1999.
[23] Ukhurebor KE, Ushie PO, Ukagwu KJ, Acheme DI. Measurement of EMF from high voltage transmission lines in Edo. J Nigerian Ass Math Phys 2017; 39(1):341-346.
[24] Aliyu O, Maina I, Ali H. Analysis of magnetic field pollution due to 330 kV and 132 kV transmission lines. J Tech Educ Res 2011; 4(2):87-93.
[25] Aliyu O, Maina I, Ali H. Analysis of electromagnetic pollution due to high voltage transmission lines. J Energ Tech Pol 2012; 2(7):1-10.
[26] Spiegel RJ. Magnetic Coupling to a Prolate Spheroid Model of Man. IEEE Transactions on Power Apparatus and Systems. 1977; 1: 208–212.
[27] Internationa Commission for Non-ionizing Radiation Protection (ICNIRP). Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 GHz). Health Phys 1998; 74:494–552.
[28] Ozen S. Evaluation and measurement of magnetic field exposure at a typical high-voltage substation and its power lines. Rad Protect Dos 2008; 128(2):198–205.
[29] Carlak HF, Ozen S, Bilgin S. Low-frequency exposure analysis using electric and magnetic field measurements and predictions in the proximity of power transmission lines in urban areas. Turkish J Elect Eng Comp Sci 2017; 25:3994-4005.
[30] Ozen S. Low-frequency transient electric and magnetic fields coupling to child body. Rad Protec Dos 2008; 128(1):62–67.
[31] Helhel S, Ozen S. Assessment of occupational exposure to magnetic fields in high-voltage substations (154/34, 5 kV). Rad Protect Dos 2008; 128 (4):464–470.
[32] Ahlbom A, Day N, Feychting M, Roman E, Skinner J, Dockerty J, et al. A pooled analysis of magnetic fields and childhood leukaemia. British J Cancer 2000; 83:692–698.