ESKİŞEHİR TEKNİK ÜNİVERSİTESİ BİLİM VE TEKNOLOJİ DERGİSİ
B- TEORİK BİLİMLER

Eskişehir Technical University Journal of Science and Technology B- Theoretical Sciences

2019, 7(1), pp. 81 - 93, DOI:10.20290/aubtdb.407794

ASSESSMENT OF GEO-SPATIAL PROXIMITY AND MAGNETIC POLLUTION FROM 132KV AND 330KV POWER TRANSMISSION LINES TO INFRASTRUCTURES IN OSOGBO, NIGERIA

Rahmon Ariyo Badru [1, *], Oluwatosin Iyanu Akinwale [2], Ayodeji Olalekan Salau [3], Kayode Olorunyomi [2], Joshua Alwadood [1], Abimbola Atijosan [1]

[1] Cooperative Information Network (COPINE), National Space Research and Development Agency, Obafemi Awolowo University, Ile-Ife, Nigeria.
[2] African Regional Centre for Space Science Education in English (ARCSSTEE), Obafemi Awolowo University, Ile-Ife, Nigeria
[3] Department of Electrical/Electronics and Computer Engineering, Afe Babalola University, Ado-Ekiti, Nigeria

ABSTRACT

Urbanization and development within cities has made people to build houses, workshops, religious centres, schools and farms close to or under transmission power lines. Meanwhile, transmission power lines produce electromagnetic fields which are harmful to humans. This study practically examines the magnetic field component of electromagnetic field generated around a transmission line using Osogbo as case study. Measurements were taken with a gaussmeter at a vertical distance of 1.04 meters at the center, right and left side of a selected number of power transmission lines respectively. The results were evaluated with the standard limit of exposure established by International Commission on Non-Ionizing Radiation Committee (ICNIRP). This paper also carried out a survey research with the use of GIS analysis, using the satellite image of osogbo in ARCGIS environment in order to map out the power lines and infrastructures close to the transmission power line in osogbo. A buffer of 500 m interval was created along the power lines, this was used to measure the distance from the power lines from the nearest infrastructure. The Power Holding Company of Nigeria (PHCN) regulations, Lagos State Urban and Regional Planning (LSURP) regulations and Occupational Health and Safety Code (OHSC) regulations were used to assess the infrastructure close to the power lines to determine the infrastructures violating the regulation and those which could expose inhabitants to health hazards which result from exposure to electromagnetic radiation.

Keywords: Power transmission lines, Remote sensing, ICNIRP, Magnetic flux pollution, Occupational and general public exposure

1. INTRODUCTION

High population growth coupled with a corresponding increase in infrastructural development around or under power transmission lines (PTL) has caused numerous adverse effects to humans resulting from electromagnetic radiation emitted from the transmission lines. These effects include damage to the body tissues, cardiovascular disorders, low sperm counts and many other effects on live-line workers who regularly service the lines [1]. Also, proximity of these PTL cause destruction of lives and property in the advent of the tranmission lines falling on close-by infrastructure. This is because eletric and magnetic fields are generated around an electric power transmission line. Although, the amount of power transmitted during the transmission and distribution reduces with increase in the distance. Thus reducing the electromagnetic radiation being received by the object as it moves further away from the transmission lines.

Futhermore, because of the need for electric power to be distributed to distant locations, there is a need to increase the overhead power transmission thus leading to a high voltage overhead so as to satisfy the electric consumers at far distance. The high voltage technology ensures that the line voltage is held relatively constant over time while currents are permitted to rise and fall with power demand. Magnetic fields are generated due to the moving current in the PTL. From previous research carried out, magnetic fields have been stated to be capable of penetrating into inner organs of human body because they are

*Corresponding Author: ayodejisalau98@gmail.com
Received: 19.03.2018 Accepted:14.02.2019

made up of conducting particles [2]. Magnetic field intensity reduces with distance, therefore at large distances away from the transmission lines, the magnetic field intensity might be zero.

Although, the magnetic fields produced by high voltage power transmission lines are in the extremely low frequency (ELF) range of the electromagnetic spectrum, they still can cause serious health effects if concentrated on the human body for a long period of time.Several problems arising from exposure of humans to electromagnetic radiation from PTL makes humans easily vulnerable to the health hazards. Numerous epidemiological research works have been carried out on the magnetic field created around the wire by the flowing current. These works have shown that it has adverse biological effects on humans like neurological, cardiovascular disorders and low sperm count in live-line workers [2, 3].

The remainder of this paper is organized as follows. The related works is presented in Section 2. Section 3 explains our proposed method in detail. Section 4 presents and discusses the results, and the paper is finally concluded in Section 5.

2. RELATED WORKS

Several studies have been carried out on the effects of magnetic and electric field pollution from transmission power lines on lives and property. This section provides an overview of related works in this area. More recently, authors in [4] have presented an evaluation of electric field pollution from 132 kVA power transmission lines (PTLs) in Ibadan using the PHCN, LSURP, OHSC and the ICNIRP standard to determine the safest distance of proximity of infrastructures to power transmission lines. From their findings, they obtained that 12.5% of the infrastructures assessable complied with the PHCN regulation, 56.85% complied with the LSURP regulation and 78.12% compiled with the OHSC regulation. Authors in [5], presented an evaluation of the magnetic field produced by a 132kV and a 330kV high voltage transmission line (HVTL) at mid-span with horizontal and vertical configuration in Akure, South Western Nigeria using analytical methods from electromagnetic field theory. They obtained that power lines are being violated as buildings exist less than 15m and 25m away from the 132kV and 330kV transmission lines respectively. The 132kV power line and 330kV transmission line are both maintained by the Transmission Company of Nigeria (TCN). Similarly, authors in [6] carried out an analysis of smart grids using 132/33kV sub-transmission lines for power transmission in rural areas in Bangladesh. In their work, an assessment of the geo-spatial proximity and magnetic pollution from 132kV power transmission lines (PTLs) in Osogbo was carried out. Authors in [7], presented a study of the overvoltages due to the energisation of a 132 kV underground cable was analyzed using simulation studies using MATLAB. MATLAB simulations were carried out to obtain the overvoltage values at the sending and receiving end. These values are seen to vary between approximately 1.8 p.u. to up to 2.1 p.u. Furthermore, [8] presented an exposure assessment of live-line workers exposed to electric and magnetic fields from power transmission line for the Saudi Electricity Company (SEC). They obtained that the levels of safety workers exposures to extremely low frequency (ELF) electromagnetic field fall well below the recommended international standards limits.

This paper presents an assessment and evalution of the geo-spatial proximity and magnetic pollution from 132kV and 330kV power transmission lines to infrastructures in Osogbo, Nigeria.

2.1. Power Transmission Lines

Power transmission lines (PTL) are used for distribution of electricity from where it is generated at power stations by electromechanical generators to electrical substation and distribution centres. High-voltage direct-current (HVDC) technology is used for efficient transmission of electric power over very long distances like hundreds of miles away. Electricity is transmitted at high voltages to reduce the energy loss which usually occurs in long-distance transmission. Therefore, overhead power lines are commonly used to transmit power. The Voltage varies from 11kV to 765kV and radiates powerful

electromagnetic fields (EMFs). However, high voltage power transmission lines supply electrical energy to our cities and the strongest magnetic fields are usually emitted from high voltage transmission lines [9]. These transmission lines are major sources of electromagnetic field which pollutes the immediate environment with extremely low frequency [10]. There are various researches that identified the dangers of this pollution to life in our environment. Some epidemiologic residential and occupational studies have suggested a weak relation with a few types of cancer in humans, particularly leukaemia in children as well as brain and breast cancer in adults, while others reported no consistent evidence of relations between magnetic field exposure and any type of cancer [11]. International Commission on Non-Ionizing Radiation Protection (ICNIRP) gives recommendations on limiting exposure of radiation; it develops and publishes guidelines, statement and reviews used by regional, national and international radiation protection bodies such as World Health Organisation [12].

2.2. Power Line Configuration

The geometric configuration of a power transmission line (PTL) is shown in Figure 3 and a picture of the PTL is shown in Figure 1. The phase conductors are represented with A, B and C, and the vertical distance between them is represented with *av*, while *ah* is the separation between the phase conductors of the horizontal geometry and *Ht* is the distance of the lowest conductor from the ground at the tower. It is important that the towers of the two lines are not co-located in order to reduce/eliminate the combined magnetic field strength underneath the lines. Although in this work, we assumed their mid-span are in the same region for worst case scenario.

2.3. Interaction of Human Body with Electric and Magnetic Fields of Power Lines

Electric and magnetic fields generated by electric power transmission lines are harmful to the human body. Expose to these field cause damages to the body tissues. For the electric field generated, Ohm's Law relates the current density (J) and electric field (E) [13] as shown in (1):

$$J = \sigma E \tag{1}$$

A study of the effect of electric field exposure on human beings was presented in [14]. They observed that at certain distances human are mostly likely to experience these health treats: the ground (0 m), exposure of the heart (1, 5m) and brain exposure (1.8m). The reference level of the allowed magnetic field exposure is shown in Table 1.

Table 1. Reference levels of magnetic field exposure [15].

Exposure characteristic	Frequency range	Magnetic field (μH)	Magnetic field at 50Hz (mG)
Occupational exposure	0.025 – 0.82kHz	25/ f	5000
General public exposure	0.025 – 0.82kHz	5/ f	1000

2.4. Regulatory Agencies

The responsible regulatory agencies have layed down guidelines and technical specification to determine the permissible exposure limit of human beings to magnetic and electrical fields [16]. Most regulatory agencies have contributed to this standard. The agencies include, the International Commission on Non-Ionizing Radiation Protection [13], the Council for European Union [15], World Health Organisation [12], Lagos State Urban and Regional Planning (LSURP), PHCN [18] and Institute of Electronic and Electrical Engineers [17], have recommended permissible limits to exposure of electric and magnetic fields.

3. MATERIALS AND METHOD

Primary and secondary data were collected for this research work. The global positioning system (GPS) coordinates (Longitude, Latitude and Height) of the spatial locations were obtained using a GPS receiver with following characteristics; model GPSMAP 78 Series and error margin of 3metres. GPS values of strategic points were taken, such as the infrastructure closest to the left and right side of the power line tower and GPS points under the power line tower. The mid-span magnetic field distribution in the vertical plane with minimum ground clearance was considered, in case there are regions where the two power lines are close to each other in Osogbo.

Secondary data was collected and was used to identify infrastructures that were located around the power lines in the study area and also to extract the road network. ARCGIS environment was used to map out Osun State from the map of Nigeria. Thereafter, Osogbo which is the study area of this research work was mapped out as shown in Figure 2. The GPS sample points of the transmission towers were plotted on the satellite image of Osogbo in ARCGIS environment in other to map out the power lines. A buffer of 500 m interval was created along the power lines as shown in Figure 4. This was used to measure the distance from the power lines from the nearest infrastructure. After the distances were recorded, a waveform of the spatial location's distance (metres) to nearest infrastructure from the 330 kVA transmission lines was plotted and another waveform showing the spatial location's distance (metres) of nearest infrastructure from the 132 kVA transmission lines was plotted. Afterwards, a table was created to show the types of infrastructure located under and near the power lines. The tables comprise of the list infrastructure found at the left and right side of the power line, the frequency of the structures and the total number of infrastructures observed. A graph showing the frequency and percentage of different Infrastructure located close to power lines was plotted. Questionnaires were used to obtain other required information from residents and users of the pathway. All measurements were taken at one metre (1.04m) from the ground surface. The magnetic flux density was obtained using Field Test Meter with following characteristics: model 3120-EN-00 and measuring Capacity from 0.01μT to 19.99 μT. Magnetic field strength of strategic points was taken at the infrastructure closest to the left and right side of the power line tower and under the power line tower itself. All measurements were taken at one metre (1.04m) from the ground surface. The measurements were recorded into a spread sheet on Microsoft Office Excel. Afterwards, waveforms were generated from the results on the table using Microsoft Excel tools. The comparative analysis of the results of Magnetic Flux Density at nearest infrastructure to Right, Left and Under the Tower were recorded into a spread sheet on Microsoft Office Excel. Afterwards, the waveforms were generated from the results on the table using Microsoft Excel tools. There are different regulatory standards on limits of human exposure to magnetic field resulting in the guidelines of minimum distance which an infrastructure can be located close to power lines. The results of the magnetic field measured were compared with these standards. The regulatory agencies include, the Power Holding Company of Nigeria (PHCN), Institute of Electronic and Electrical Engineers (IEEE), Lagos State Urban and Regional Planning (LSURP), Occupational Health and Safety Code (OHSC) and International Commission on Non-Ionizing Radiation Protection guidelines (ICNIRP). Waveforms were plotted to show the comparative analysis of all the measurement of magnetic field recorded around the power line based on the guidelines of PHCN, LSURP, OHSC and ICNIRP.

Figure 1. Automobile mechanical workshop under 330/220 kVA power transmission line in Osogbo

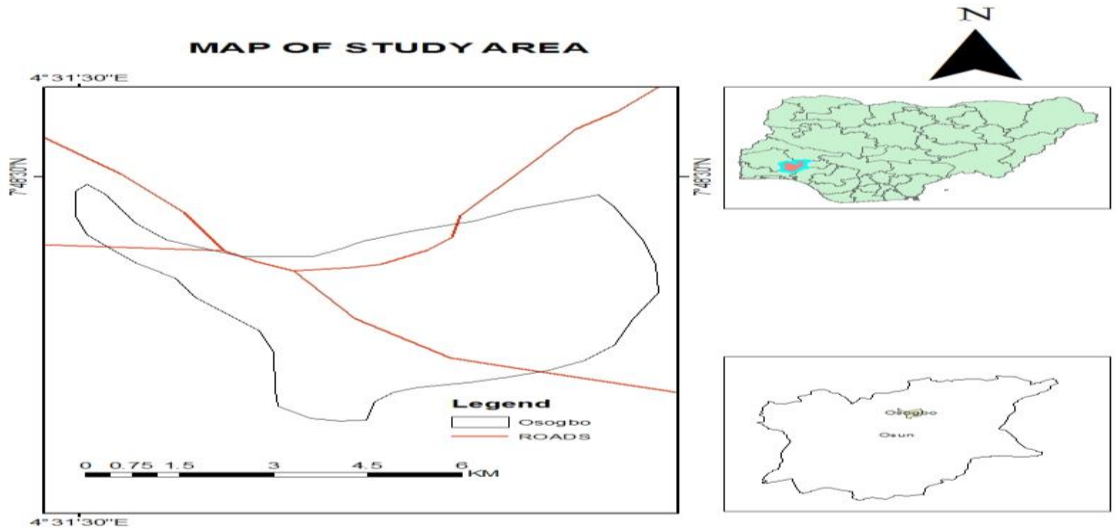

Figure 2. Map of the study area (Osogbo)

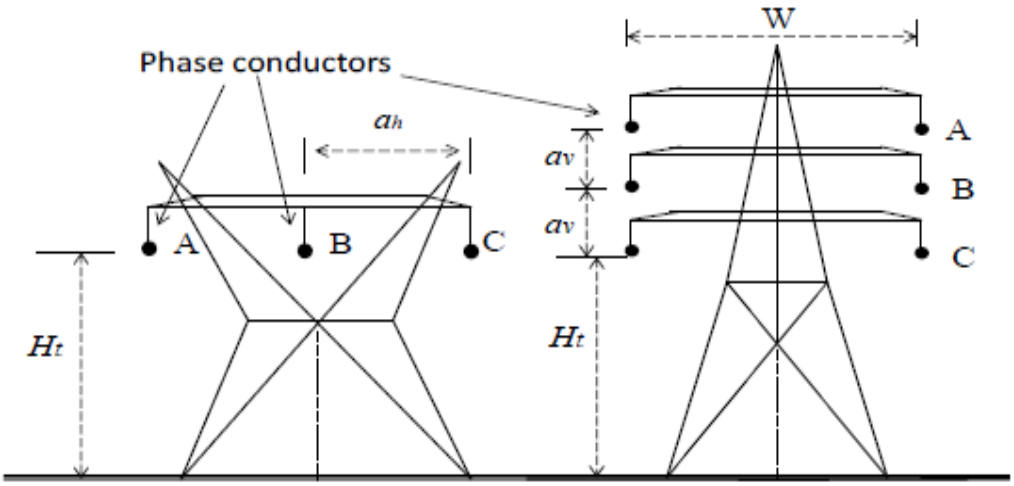

Figure 3. Schematic diagram of the configuration of a power line

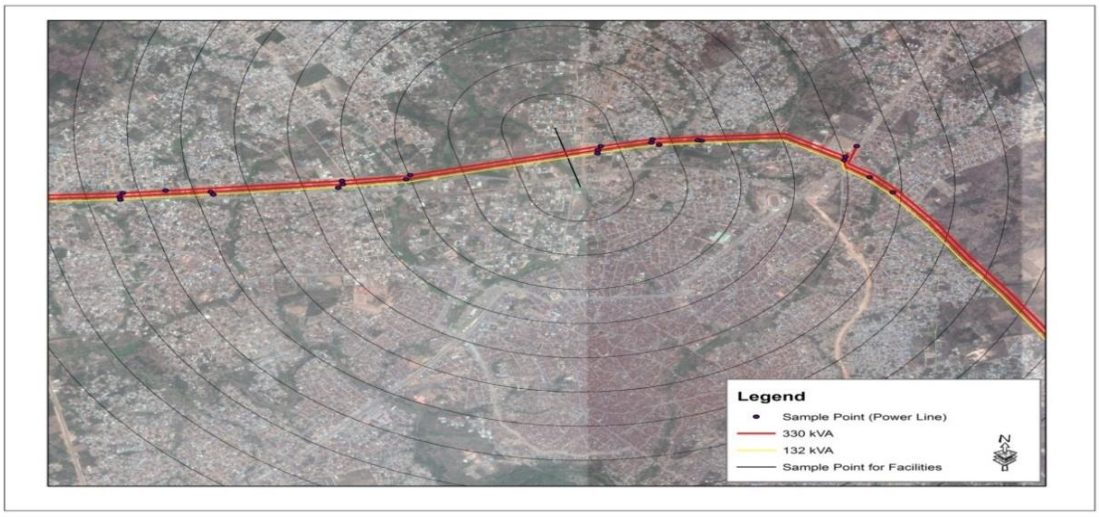

Figure 4. Buffering of 500 m along power lines along Osogbo

4. RESULTS AND DISCUSSION

From the plotted waveform of the magnetic field values recorded under the tower i.e. at the left and right side of the tower as shown in Figure 5, Figure 6 and Figure 7 respectively, and also the obtained values in Tables 4, 5 and 6 respectively. It is observed that the magnetic field is dense at the side lines of the transmission tower (TT) with high values obtained for point 23 (right side of the TT), point 3 (under the TT) and point 20 (left side of the TT) as shown in Figure 8, although less than the guide line of ICNIRP (about 100μT). This implies that infrastructures on both sides of the tower are exposed to the higher range of magnetic field. The Infrastructures found at the power line are workshop, shop, church, farm lands, residential houses, block industries and schools. Workshops and shops such as mechanic workshops, furniture workshop, are more frequently located near power lines. Block industries were also found frequently located, especially under the towers as shown in Table 2. Residential houses were located near the power lines. Meanwhile, most schools compiled to the guidelines set by International Commission for Non-Ionizing Radiation Protection on the exposure limit of human being to magnetic field, the results clearly show that the values are still very low and in a safe limit of exposure which is 100μT as shown in Figure 10.

However, the standards of the regulatory agencies along the power lines are being violated as buildings exist less than 15m and 25m away from the 132kV and 330kV lines respectively as shown in Figure 13 from the spatial distance between the nearest infrastructure and the transmission lines using Satellite. Work places for various occupations and makeshift structures exist directly below the power lines. The spatial distance of infrastructure is shown in Figure 9 and their related frequency is shown in Figure 10. The results as shown in Figure 10, clearly show that only schools and churches partially meet the requirement for spatial proximity of infrastructure to PTL. The encroachment of the proximity is higher using PHCN standard (about 42%) as shown in Figure 12. Block industries and workshops are more pronounced under the power line within Osogbo metropolis. Lastly, it was observed that many infrastructures violate the minimum distance that buildings should be away from power lines. From the field work, within the power line area covered, 57.89% infrastructure complied with the PHCN regulation and 78.95% complied with Lagos State Urban and Regional planning, while 89.47% complied with the OHSC regulation as shown in Table 3 and shown in the waveform in Figure 11. With the results obtained, there is need for regulatory/law enforcement agents to further ensure that the standards/regulations along the power lines are observed by the general public as a result of the thermal effects of prolonged electromagnetic pollution on human health.

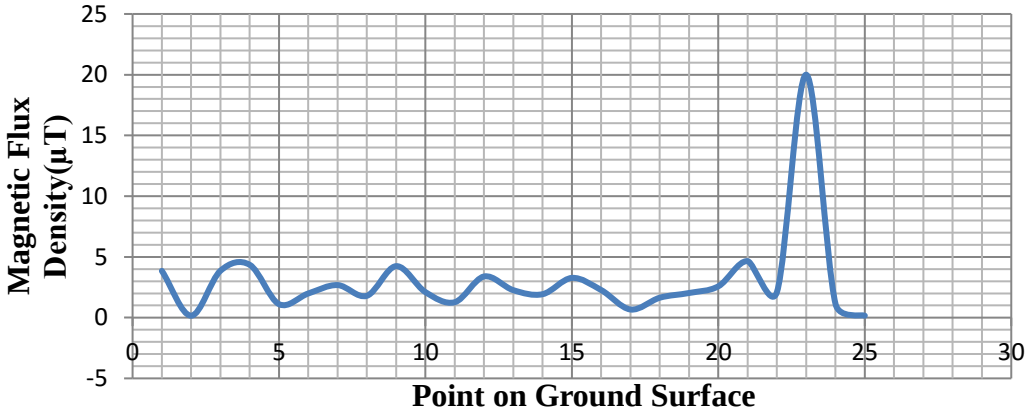

Figure 5. Waveform of the Magnetic field under the transmission Tower @ 1.04 m to ground surface

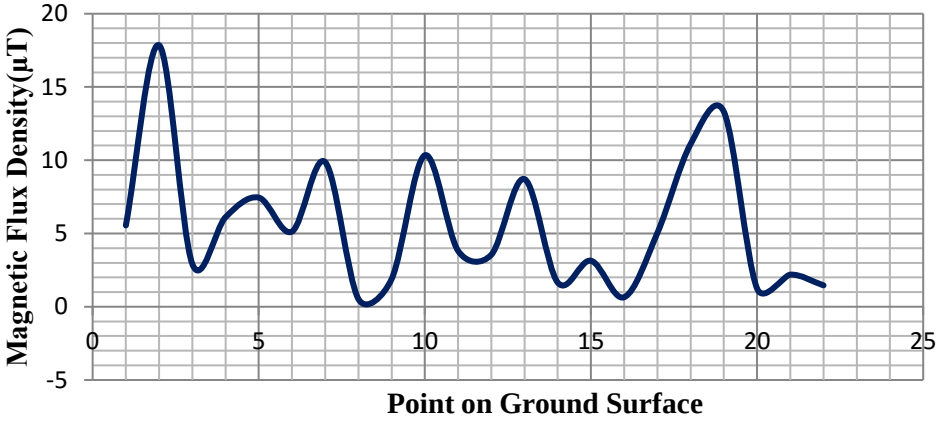

Figure 6. Waveform of the Magnetic field Left side of transmission Tower @ 1.04 m to ground surface

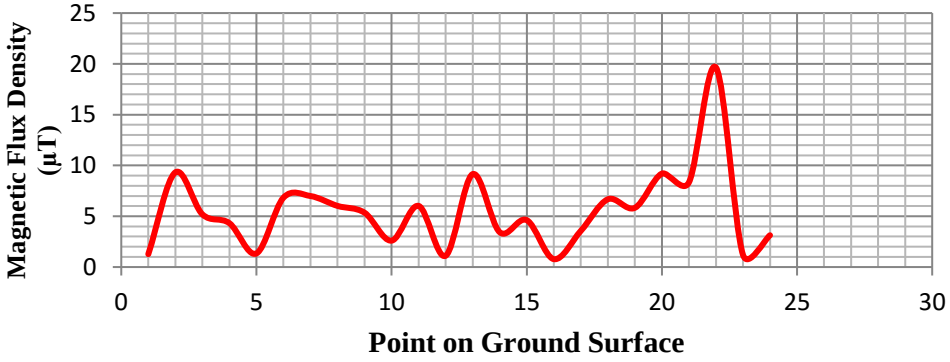

Figure 7. Waveform of the Magnetic field @ Right side of transmission Tower @ 1.04 m to ground surface

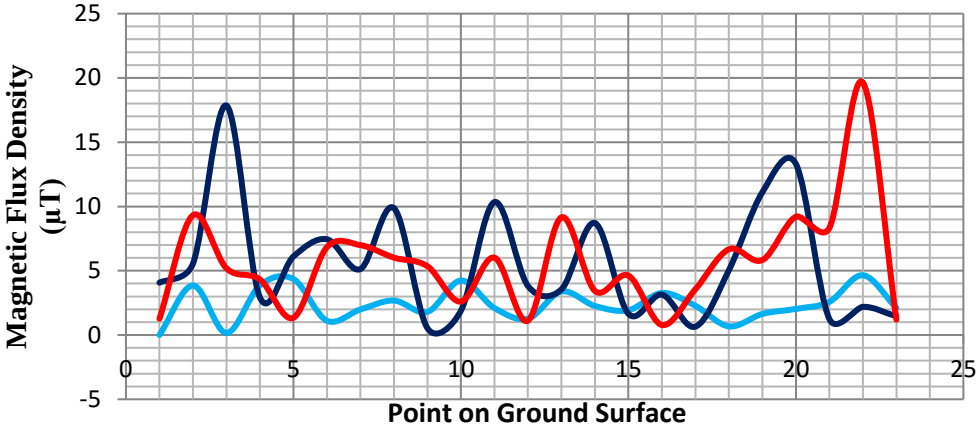

Figure 8. comparative analysis of values of the Magnetic field strength

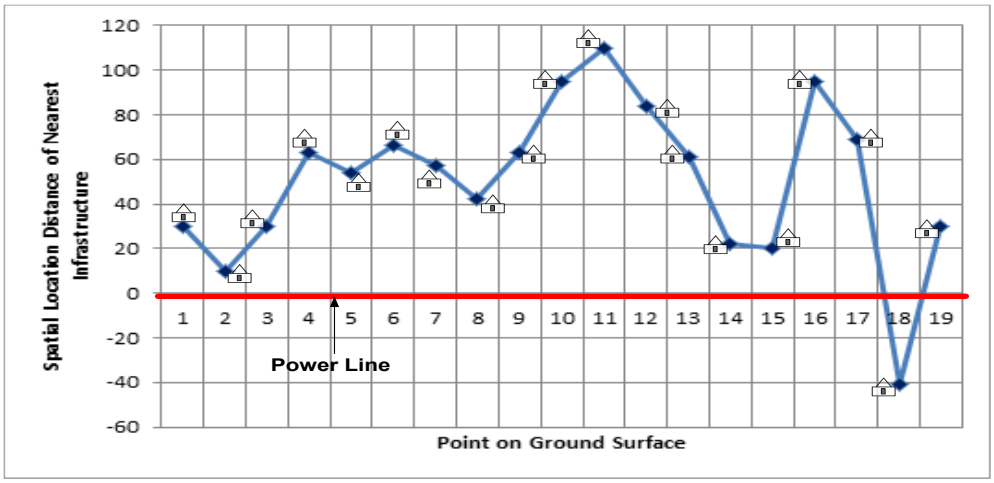

Figure 9. Spatial location's distance (m) to nearest infrastructure from the 330 kVA transmission line

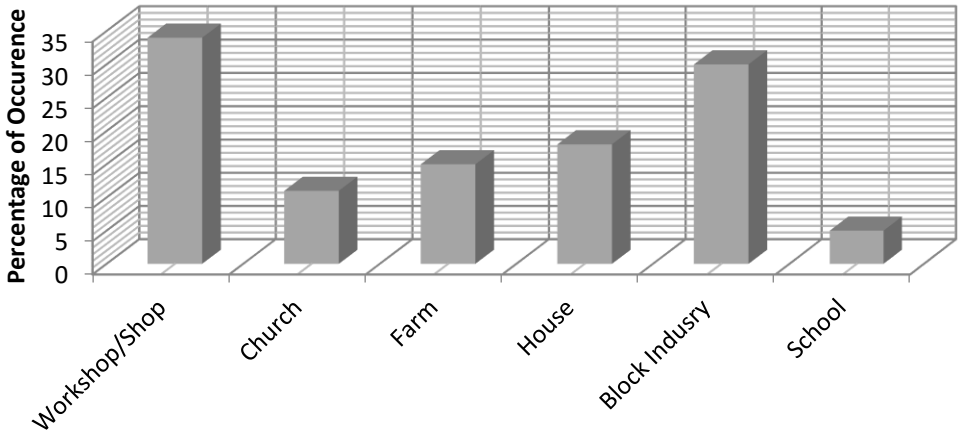

Figure 10. Percentage of the frequency of different infrastructure located close to power lines

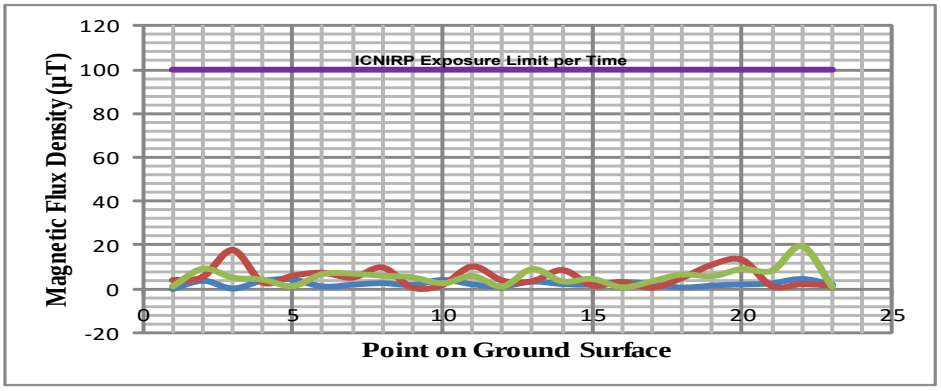

Figure 11. Comparative analysis of all the measurement of Magnetic field recorded around the power line based on ICNIRP

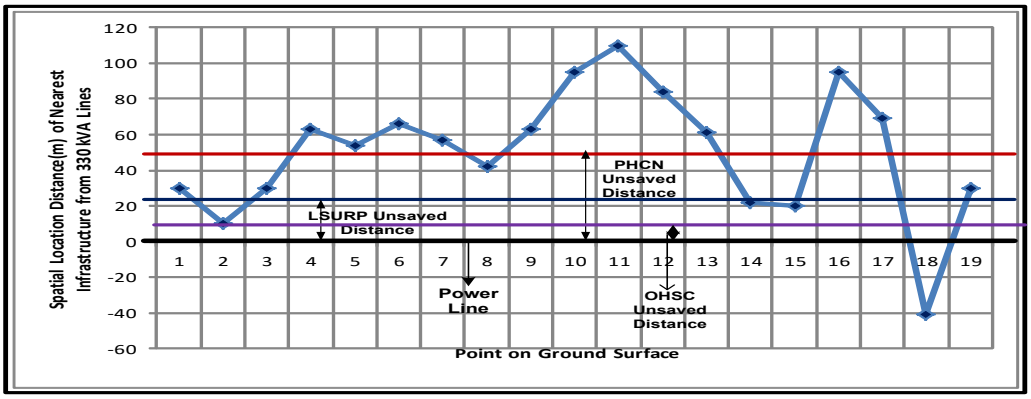

Figure 12. Comparative analysis of all the measurement of Magnetic field recorded around the power line based on power standard and regulations.

Table 2. Infrastructures under and close to the power lines

S/N	Infrasructure	Under Lines	Left to Lines	Right to Lines	Frequency	Percentage
1	Workshop/Shop	5	3	5	13	34
2	Church	0	2	2	4	11
3	Crop Farm	0	1	1	2	5
4	House	2	2	3	7	18
5	Block Indusry	1	4	7	12	30
6	School	1	0	0	1	5
					39	100%

Table 3. Percentage of Compliance to Regulations and Standards

S/N	Organisation	Power Transmission Rating	Regulation and Standards	Compliance
1.	PHCN	330kVA	50 m pathway proximity	57.89%
2.	LSURP	330kVA	22.5m pathway proximity	78.95%
3.	OHSC	230kVA, 500kVA	5 – 7 m pathway proximity	89.47%

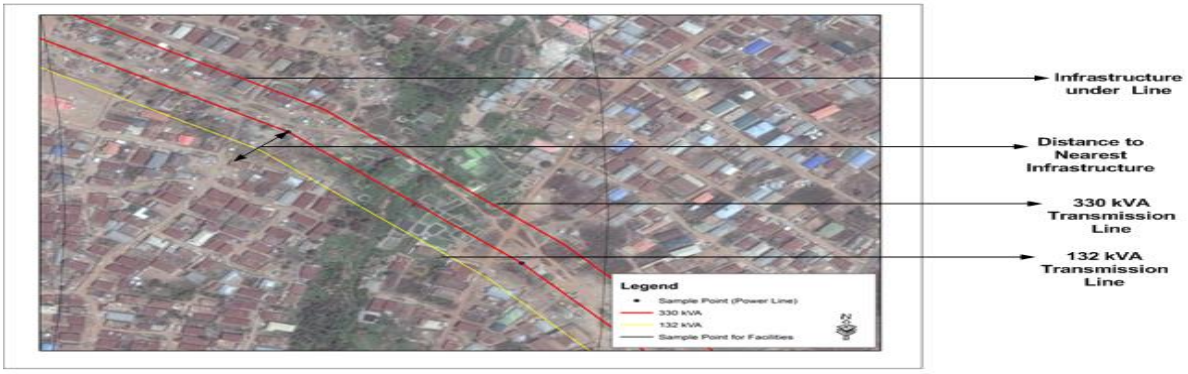

Figure 13. Results on spatial distance between the nearest infrastructure and the transmission lines using Satellite based system

Table 4. Results of magnetic flux density under transmission Tower @ 1.0 m to ground surface

Point on Ground Surface (P)	Magnetic Field @ Infrastructure B_T (μT)	GPS Values @ Towers X_{UT} (N)	Y_{UT}(E)	Z_{UT}(m)	Range (m) R_{UT}(m)
1	3.68	674256	862165	344	0(Ref. Pt)
2	3.85	674471	861944	330	308.65
3	0.16	674133	862620	356	351.49
4	3.86	674029	862464	357	375.63
5	4.35	674018	862414	353	384.57
6	1.11	672685	862697	335	1658.67
7	1.99	672649	862706	333	1675.16
8	2.68	669960	862196	319	1689.27
9	1.8	669324	862111	334	1696.81
10	4.24	669332	862063	331	1773.35
11	2.1	669289	862012	333	2087.05
12	1.27	672225	862719	326	2249.06
13	3.39	672213	862670	332	1409.20
14	2.26	672287	862637	325	2983.19
15	1.93	671742	862618	339	2998.63
16	3.27	671715	862563	340	2096.30
17	2.27	671711	862515	336	1862.16
18	0.67	669921	862134	315	1515.11
19	1.64	668121	861911	321	4368.75
20	2.03	668096	861953	321	4413.11
21	2.58	667275	861933	335	4535.54
22	4.65	667245	861880	332	4640.50
23	2.11	667254	861835	330	4759.26
24	20	665450	861718	329	1535.00
25	1.12	667676	861970	323	1577.07
26	0.16	665452	861662	329	1788.61

Table 5. Results of magnetic flux density at nearest infrastructure to Left side of Tower

Point on Ground Surface	Magnetic Field	GPS Values @ Towers			Range (m)
	B_{LT} (μT)	X_{LT} (N)	Y_{LT}(E)	Z_{LT}(m)	R_{LT}(m)
1	4.07	674631	861861	347	0(Ref.Pt)
2	5.55	674339	862232	338	472.21
3	17.85	673334	862701	345	1545.25
4	2.92	674028	862467	342	854.90
5	6.11	674029	862406	352	812.07
6	7.45	669940	862171	317	4701.32
7	5.13	669322	862093	333	5314.08
8	9.87	669334	862047	331	4701.32
9	0.53	669286	861997	335	5314.08
10	1.89	672228	862709	329	5300.29
11	10.34	672224	862654	332	5346.74
12	3.82	672274	862646	327	2548.30
13	3.55	671744	862604	339	2534.31
14	8.71	671724	862544	338	2484.36
15	1.65	671728	862506	338	2887.01
16	3.14	669917	862151	316	2973.80
17	0.65	668113	861892	318	4723.01
18	5.04	668084	861968	321	6547.93
19	11.11	667272	861951	336	7359.55
20	13.31	667251	861864	335	7380.0
21	1.24	667262	861826	331	7369.1
22	2.19	667682	861946	320	6949.57
23	1.46	665454	861676	331	9178.88

Table 6. Results of magnetic flux density at nearest infrastructure to Right side of Tower.

Point on Ground Surface	Magnetic Field	GPS Values @ Towers			Range (m)
	B_{RT} (μT)	X_{RT} (N)	Y_{RT}(E)	Z_{RT}(m)	R_{RT}(m)
1	1.27	674317	862223	340	0 (Ref. Pt)
2	9.32	673570	862713	340	893
3	5.19	674033	862451	353	364.43
4	4.32	674025	862430	355	358.24
5	1.34	672650	862630	331	1715.99
6	6.83	669948	862208	319	4369.08
7	6.99	669331	862137	334	4986.75
8	6.02	669322	862085	336	4996.90
9	5.35	669283	862023	334	5037.97
10	2.6	672232	862728	331	2145.30
11	6.02	672222	862686	333	2145.56
12	1.11	672295	862621	327	2060.83
13	9.15	671727	862638	334	2623.04
14	3.43	671722	862591	340	2620.96
15	4.62	671725	862534	340	2610.59
16	0.78	669915	862129	317	4403.06
17	3.56	668132	861892	318	6193.89
18	6.67	668116	861931	321	6207.90
19	5.83	667274	861914	336	7049.77
20	9.2	667271	861965	334	7050.72
21	8.33	667255	861834	333	7072.71
22	19.64	665455	861706	331	8877.07
23	1.2	667692	862007	328	6628.53
24	3.13	665455	861659	330	8879.93

5. CONCLUSION

In this study, we present an assessment of the geo-spatial proximity and magnetic pollution from 132 kVA and 330 kVA power transmission lines for the general public and also the allowed occupational exposure level. The results show that that 57.89% of the infrastructure complied with the PHCN regulations, 78.95% compiled with Lagos State Urban and Regional Planning (LSURP) regulation and 89.47% compiled with Occupational Health and Safety Code (OHSC) regulation. These results are compared with the ICNIRP standard.

REFERENCES

[1] Aliyu OI, Ali H. Analysis of magnetic field pollution due to 330kva and 132kva transmission lines. Abubakar Tafawa Balewa University Bauchi, Nigeria. Journal of Technology and Educational Research 2011; 4(20): 87-93.

[2] Nafar M, Solookinnejad G, Jabbari M. Magnetic field calculation of 63kv transmission lines. International Journal of Recent Research and Applied Studies 2013; 17(2): 218.

[3] Siaka M. Highlighting the dangers of living under high tension cables. Business day Newspaper 2010.

[4] Badru RA, Olorunyomi KP, Salau AO, Akinwale OI, Alwadood J, Atijosan AO. Evaluation of electric field pollution from 132 kva power transmission lines to proximity of ınfrastructures in Ibadan, Nigeria. Bilge International Journal of Science and Technology Research 2017; 1(2): 46-58.

[5] Akinlolu P, Kazeem A. Assessment of human exposure to magnetic field from overhead high voltage transmission lines in a city in south western Nigeria. American Journal of Engineering Research 2015; 4(5): 154-162.

[6] Hasan ASM, Habibullah Md. Analysis of smart grid with 132/33 kv sub-transmission line in rural power system of Bangladesh. American Journal of Electrical Power and Energy Systems 2013; 2(4): 106-110. doi: 10.11648/j.epes.20130204.12

[7] Daud MZ, Ciufo P, Perera S. Statistical analysis of overvoltages due to the energisation of a 132 kv underground cable. In: 6th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON) 2009; 54-57.

[8] Habiballah IO, Abdel-Galil TK, Dawoud MM, Belhadj CA, Arif Abdul-Majeed M, Al-Betairi, TA. ELF electric and magnetic fields exposure assessment of live-line workers for 132 kv transmission line of SEC. IEEE PES Transmission and Distribution Conference and Exposition, Latin America, Venezuela 2006; 1-6.

[9] Neuert MR. Possible safety distances to consider for emf sources. Neuert Electromagnetic Services 2012. [Online], available from: http:www.emfinfo.org.

[10] Ozovehe A, Ibrahim M, Hamdallah A. Analysis of magnetic field pollution due to 330kv and 132kv transmission lines. Journal of Trainee Teacher Educational Research 2011; 4(2): 87-93.

[11] Forseen UM, Feychting M. Rutqvist LE, Floderus B, Ahlbom A. Occupational and residential magnetic field exposure and breast cancer in females. Epidemiology 2000; 11(1): 24 – 29.

[12] World Health Organization (WHO). Electromagnetic fields and public health; physical properties and effects in biological systems. Fact sheet number 1998; 182.

[13] ICNIRP. Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields, quantities and units. Health Physics 1998; 74: 494–522.

[14] Rachedi BA, Babouri A, Berrouk F. A study of electromagnetic field generated by high voltage lines using COMSOL multıphysıcs. In: International Conference on Electrical Sciences and Technologies in Maghreb, Tunis 2014; 1-5.

[15] European Commission: Report on the implementation of the council recommendation on the limitation of exposure of the general public to electromagnetic fields (0 Hz – 300 GHz) 2008; 1-110. [Online], available from:https://ec.europa.eu/health//sites/health/files/electromagnetic_fields/docs/bipro_staffpaper_en.pdf

[16] Yu H, Baodang B, Dexin X. The electromagnetic field distribution in the human body under the ultra-high voltage transmission line. IEEE 2002; 2243-2246.

[17] Institute of Electrical and Electronics Engineers (IEEE). Safety levels with respect to human exposure to electromagnetic fields, 0–3 kHz. IEEE New York 2002.

[18] Taboola P. PHCN warns against building structures under Power lines. Vanguard 2012. [Online], available from http://www.vanguardngr.com/2012/07/phcn-warns-against-building-structures-under-power-lines/