International Journal of Engineering Research and Advanced Technology (IJERAT)

DOI: 10.31695/IJERAT.2020.3628

E-ISSN : 2454-6135

Volume.6, Issue 8
August -2020

Assessment of Carbon Emissions for the Construction of Buildings Using Life Cycle Analysis: Case Study of Lagos State

[1]Adekunle A., [1]Osagie Ibhadode, [2]A.P Ibhadode and [1]Shawon Msughter Caesar

[1]Nigerian Building and Road Research Institute (NBRRI)

(Federal Ministry of Science and Technology)

[2]The Delft Institute of Water Education, Delft, the Netherlands

Cintojon Company (Nigeria) Limited, Ota-Lagos, Nigeria.

ABSTRACT

Environmental impacts associated with construction, use, and end-of-life of buildings have become a great concern to all and sundry especially as it concerns the health of people. This study aims to evaluate and ascertain the level of carbon emissions for the construction of a case residential building using life cycle analysis. In an attempt to determine carbon emissions at different stages, the following areas were considered: materials consumed during formwork construction, materials for structure, transportation of materials from factory to site, energy consumed by tenants, carbon emission removals and disposal of debris. Emission factors were obtained from local sources to have cognitive and representative results. The results therefore established that the total carbon emission throughout the life cycle of the case building is 1,212 ton of CO_2e which was found to pose minor threat to the environment according to standard. It was also deduced that carbon emission due to energy consumed by tenants emerged the most significant with 47% followed by materials for structure (36%), materials consumed during formwork construction (8%), materials based on demolition (7%) while transportation of materials from factory to site and debris to disposal site emerged as the least significant with just 1% each. Overall, findings suggest that sufficient reduction of carbon emissions in building construction starts from the extraction, processing and manufacturing of building materials. Hence, law makers and professionals in the built industry should enforce implementable policies that will encourage designs of low carbon and sustainable residential edifice.

Keywords: *Carbon emission, Residential building, Life cycle analysis.*

1.0 INTRODUCTION

Of late, climate alterations around the globe have shown extraordinary challenge for mankind. A recent statistics show that on average, over 1.5 Pico ton of carbon emissions ($PtCO_2^e$) was experienced from 2010 to 2019 [1-3]. This occurrence is predominant because of the kind of activities people engage in. Such activities include cement production [4], deforestation [5], burning of fossil fuel and the likes. The urgent need to ascertain the level of emission in our environment cannot be overemphasized. Global warming [6] effects would eventually become calamitous, except adequate reduction strategies of greenhouse gases are put in place. These gases trap the heat from the sun and cause a gradual rise in temperature of the earth's atmosphere [7]. At present, the built environment shows the highest emitter of greenhouse gases [8-10]. As a result, the built environment has an undeniable part to play as buildings are responsible for more than two-thirds of the carbon emissions across the globe [11-12]. Residential buildings have also been found to take up a major portion of energy consumption [13] with carbon emissions resulting from energy used for construction and demolition of buildings [14]. The increase in residential buildings and continuous growth in

***Corresponding Author:** casio2022002@gmail.com

population [15], are expected to make energy consumption and carbon emission increase exponentially with time except reduction schemes are in place.

An essential decision by relevant authorities is to establish a practical and implementable policy that will assist the built environment to reduce greenhouse gas emissions as much as possible. These emissions are common in densely populated urban cities because renewable energy like solar or wind energy are somewhat limited. Many countries including China have begun campaign on how to reduce energy level by half by year 2030 [16-18], especially in both residential and public buildings as records show in 2009 that 0.7 million kWh of energy or 6 million tons of CO_2^e was consumed [19-21]. Many research works have been carried out to measure the impacts of carbon emissions on buildings. For instance, [22-24] recommended in their study that greenhouse gas emissions should be considered as a major factor when evaluating environmental performance of buildings. A study on carbon emissions [25-27], for two hundred and fifty completed buildings due to the number of structural materials applied without putting the entire life cycle into consideration. They succeeded in developing a model that assesses the environmental impacts [28] of the building construction [29]. A study was conducted by [30] on environmental performance of three different kinds of buildings in Germany based on types of construction material, heating energy and transport adopted. His results show that heat energy is responsible for majority of carbon emission generated in buildings. The aim of this research therefore, is to evaluate and ascertain the level of carbon emissions for the construction of a residential building using life cycle analysis while the specific objectives are: to estimate carbon emissions of the building from cradle to grave based on these six areas namely: 1) materials consumed during formwork construction 2) materials for structure 3) transportation of materials from factory to site 4) energy consumed by tenants 5) carbon emission removals 6) disposal

Table 1: Carbon emission standards for residential buildings [30]

Carbon emission (C_{em}), tons of CO_2	Consequence
$C_{em} \leq 1000$	no threat
$1000 \leq C_{em} \leq 4000$	minor threat
$4001 \leq C_{em} \leq 8000$	severe threat
$C_{em} \geq 8001$	extreme threat

2.0 METHODOLOGY

This study employed life cycle analysis for assessing the carbon emissions of the residential building under consideration. This technique allows assessment of environmental impacts of buildings. Carbon emissions from extraction of raw materials to disposal after demolition of building was considered in this study. The carbon emission calculations was done by assessing the greenhouse gases metrics as defined by [31] for Standard organization of Nigeria (SON) and international standard organization (ISO). These carbon emissions are converted into $kgCO_2$ emissions using the Inter-governmental Panel report on Climate Change 80-year global warming coefficients [32]. It must be stated that conducting an environmental assessment of the entire building is complex due to the differences in materials [33], associated transportation, and various considerations at the use stage, end-of-life of the building and lifespan of the building. Although this study has attempted to include all these in the assessment, several limitations cannot be avoided. This study did not consider the contributions of non-structural materials. Waste material generated during the construction and end-of-life stages were not considered in this assessment. During the use stage of building, actual energy consumed by tenants was not accessible. Thus, average energy consumption data was collected from the nearest electricity distribution company. This study only focused on carbon emission assessment and excluded other impact categories. A four bedroom, two-storey modern building as shown in Figure 1 was considered for this study. This building is located at 2, Adebimpe crescent Isolo, Lagos. This design has a total floor area of $176m^2$ which can be built with a minimum lot frontage of 11.3 meters and minimum lot size of 156 m^2. The carbon emissions over this building's life cycle were estimated based on their sources and components. The estimation of carbon emissions of the building from cradle to grave were based on six areas namely: 1) materials consumed during formwork construction 2) materials for structure 3) transportation of materials from factory to site 4) energy consumed by tenants 5) carbon

DOI : 10.31695/IJERAT.2020.3628

emission removals 6) disposal as shown in Table 2. The guidelines provided by ISO standards [33], [34] were employed to derive Equations (1) to (6) in this study.

Figure 1: Design of the considered residential building

Table 2: Study scope for carbon emission evaluation

Aspects	Sources of carbon Emissions
Materials used up during construction	Steel formwork for superstructure, Timber formwork for superstructure, Steel formwork for substructure, Timber formwork for substructure
Materials for structure	Steel for superstructure, Timber for superstructure, Steel for substructure, Timber for substructure
Transportation of materials from factory to site	-
Energy expended by tenants	Lighting, Television, air-condition, ironing, cooking, refrigeration, washing machine, pumping machine, electrical distribution, electric fan., computer
Carbon emissions removal	Tree planting
Demolition and disposal	Dismantling of building, transportation of building debris from site to disposal site.

DOI : 10.31695/IJERAT.2020.3628

2.1 Carbon emission due to formwork and structure construction

This involves key building materials expended during formwork and structure construction including concrete, steel, timber and formwork. For the sake of calculating carbon emissions, the quantities of concrete, steel and timber were actually obtained from the tender documents as well as the drawings. Table 3 gives the greenhouse gas emission factors as retrieved from local sources. The carbon emission for steel production was taken out from inventory of carbon and energy gathered by [34] Concrete production was according to [34] .Timber production was according to [34]. The local emission factors employed was necessary to produce representative results. Equation (1) gives the carbon emissions from formwork and structure constructions, where Cem_{CSF} is the total carbon emissions of concrete, steel and formwork in $kgCO_2e$, m_i is the amount of building material *i* (m^3) and f_i is the carbon emission factor for building material *i* ($kgCO_2e/m^3$)

$$Cem_{CSF} = \sum_{i=0}^{n} m_i * f_i \qquad (1)$$

Table 2: Carbon emission factors/standards for building materials ($kgCO_2e/m^3$)

References	Timber	Steel	Concrete
Adetona and Richard, [34]	468	**15210**	317
	-	-	**426**
	962	-	-

2.2 Carbon emission due to transportation from factory to site

This emission was generated from the transportation of building materials from factory to site. The distance between the factory and site was obtained as 15km. Equation (2) gives the carbon emission generated from transportation of building materials to site where Cem_T is the total carbon emission due to fuel consumption of transportation of building materials in $kgCO_2e$, m_i is the amount of building material *i* transported in m^3 ($5m^3$ of loading limit per truck was assumed) , d_i is the diesel consumption in liter/km/truck (0.325L/km), x_i is the distance covered by transporting building materials *i* (15km assumed) and f_i is the emission factor for transporting by diesel truck ($2.62 kgCO_2e/liter$) (Michael, 2011)

$$Cem_{Transp} = \sum_{i=0}^{n} \frac{(m_i * d_i * x_i * f_i)}{5} \qquad (2)$$

2.3 Carbon emission due to energy expended by tenants

This stage involves carbon emissions due to electricity and heat consumed by tenants during the period. Equation (3) gives the total carbon emissions due to the energy expended over the 40-year building life cycle in $kgCO_2e$, where e_i and g_i are the yearly electricity and gas consumed for building services system *i* in kWh and gas unit (1unit =48MJ) respectively. Also, f_{e_i} and f_{g_i} are the emission factors of the energy consumed by electricity and gas respectively and given as 0.7 $kgCO_2e$ /kWh and 0.59 $kgCO_2e$ /unit of gas procured [34].

$$Cem_{Tenant} = \sum_{i=0}^{n} (e_i * f_{e_i} + g_i * f_{g_i}) * 40 \qquad (3)$$

DOI : 10.31695/IJERAT.2020.3628

The electricity end-use data for the period was obtained from Ikeja electricity Distribution Company while the gas use data was obtained from the landlord of the building.

2.4 Carbon emission removals

This helps to determine the amount of carbon emission removed during the period as a result of tree planting. A recent study by [34] shows that 23 $kgCO_2$ can be removed by each tree based on the height. Equation (4) gives the total carbon absorption over the 40-year building life cycle by tree planting in $kgCO_2e$, where t is the number of newly planted trees within the premises while f_t is the carbon emission removal factor and taken as 23 $kgCO_2$/tree/annum.

$$C_{absorption} = (t * f_t) * 40 \qquad (4)$$

2.5 Carbon emission due to pulling down of building

This stage is categorized into two stages namely: emission due to energy expended on demolition and emission due to transportation of building debris to disposal sites. Equation (5) represents carbon emission due to demolition and transportation, where m_{dem} is the amount of building materials dismantled or building debris, $5m^3$ load per truck is assumed, f_{dem} is the emission factor for dismantling a building, which is 17 $kgCO_2e$ according to [34], d_c is the diesel consumption, which is 0.325 L/km x_i is the total distance for transporting materials *i*, which is 15km according to and f_i is the emission factor for transporting by diesel truck.2.62 $kgCO_2e$ /liter.

$$Cem_{dem\&transp.} = m_{dem} * f_{dem} + \frac{(m_{dem} * d_c * x_i * f_i)}{5} \qquad (5)$$

2.6 Total carbon emissions over the buildings life cycle

$$Cem_{TOTAL} = Cem_{CSF} + Cem_{Transp} + Cem_{Tenant} - C_{absorption} + Cem_{dem\&transp.} \qquad (6)$$

3.0 RESULTS AND DISCUSSION

Table 4: Materials consumed due to formwork construction

	Type	Quantity (m^3)	Emission factor ($kgCO_2e/m^3$)	Total emission ($kgCO_2e$)
Materials consumed during construction	Steel formwork for superstructure	4.5	15210	68445
	Timber formwork for superstructure	28.92	962	27821.04
	Steel formwork for substructure	0	15210	0
	Timber formwork for substructure	0.68	962	654.16
	Sub Total			**96920.2**

Table 4 shows materials consumed due to formwork construction using Equation (1). Steel formwork for superstructure produced the highest carbon emission (68445 $kgCO_2e$) while steel formwork for substructure emerges the least (0). During this phase, steel remains the dominant building material not only in terms of quantities but also

DOI : 10.31695/IJERAT.2020.3628

the embodied carbon as seen above. The total carbon emission due to materials consumed during construction gives 96920.2 $kgCO_2e$.

Table 5: Materials consumed due to structure

	Type	Quantity (m^3)	Emission factor ($kgCO_2e/m^3$)	Total emission ($kgCO_2e$)
Materials for structure	Steel for superstructure	8.6	15210	130806
	Concrete for superstructure	409	426	174234
	Steel for substructure	5	15210	76050
	Concrete for substructure	164	426	69864
	Sub Total			**450954**

Table 5 reveals the materials consumed due to structure using Equation (1). Concrete for superstructure recorded the highest carbon emission (174234 $kgCO_2e$) while concrete for substructure records the least (69864 $kgCO_2e$). The total carbon emission due to materials for structure gives 450954 $kgCO_2e$ **.**

Table 6: Transportation of materials

	Type	Quantity (m^3)	Distance from site (km)	Total emission ($kgCO_2e$)
Transportation of materials	Steel	123.5	15	316.1
	Timber	25.5	15	65.3
	Concrete	4771.8	15	12203.6
	Sub Total			**12585.0**

Table 6 represents carbon emission due to transportation of materials using Equation (2). Transportation of concrete records the highest carbon emission (12203.6 $kgCO_2e$) while timber records the least (65.3 $kgCO_2e$). The total carbon emission due to transportation of materials gives 12585.0 $kgCO_2e$ **.** This is an indication that concrete remains the most significant material during construction of structure hence the highest carbon emitter.

Table 7: Energy consumed by tenants

		Annual energy consumption (kWh)	Annual emission ($kgCO_2e$)	Total emission in 40 years ($kgCO_2e$)
Energy consumed by tenants	Lighting	39.6	332.64	13305.6
	Television	47.8	401.52	16060.8
	Air condition	56.4	473.76	18950.4
	Ironing	132	1108.8	44352
	Refrigeration	45.2	379.68	15187.2
	Washing machine	55.7	467.88	18715.2
	Standing fan	79.5	667.8	26712

DOI : 10.31695/IJERAT.2020.3628

	Home theatre	38.5	323.4	12936
	Electrical distribution	759.8	6382.32	255293
	Others	359.5	3019.8	120792
	Electric cooker	28.4	238.56	9542.4
	Pumping Machine	78.5	659.4	26376
	Sub Total			**578222**

Table 7 shows the energy consumed by tenants using Equation (3). This was generated due to several utilities used by tenants. From the entire utilities, electrical distribution shows the most significant in terms of carbon emission (255293 $kgCO_2e$) as well as ironing, electric cooker, electric fan and pumping machine. This reflects that carbon emitted are strongly dependent not only on the building and occupancy factors, but also on the source of energy.

Table 8: Carbon emission removals

Carbon emission removals	**Type**	**Quantity**	**Annual emission absorption ($kgCO_2e$)**	**Total absorption in 40 years ($kgCO_2e$)**
	Tree	22	506	20240
	Sub Total			**-20240**

Table 8 shows carbon emission removals due to tree planting using Equation (4). For the 22 trees planted for the 40 years life cycle, the total carbon removals recorded is 20240 $kgCO_2e$ **.** This shows that when more trees are planted then more carbons emission are removed.

Table 9: Carbon emission due to demolition and transportation of debris

Demolition	**Dismantling of building**	**Quantity (m^3)**	**Emission factor ($kgCO_2e/m^3$)**	**Total emission ($kgCO_2e$)**
		4792	17	81464
Transportation of debris	Transportation of building debris to disposal site	Quantity	Distance to disposal site (km)	Total emission ($kgCO_2e$)
		4792	15	12241.2
	Sub Total			**93705.2**
	TOTAL			**1,212,146 (1,212 tons co_2e)**

Table 9 shows carbon emission due to demolition of building and transportation of debris to disposal site using Equation (5). The total emission due to these two aspects is 93705.2 $kgCO_2e$ **.** Considering all the six aspects, the total carbon emission throughout the life cycle using Equation (6) and the assumptions is 1212 tons of CO_2e **.** This result shows that there is minor threat in this condition according to recommendations of International standard organization shown in Table 1.

DOI : 10.31695/IJERAT.2020.3628

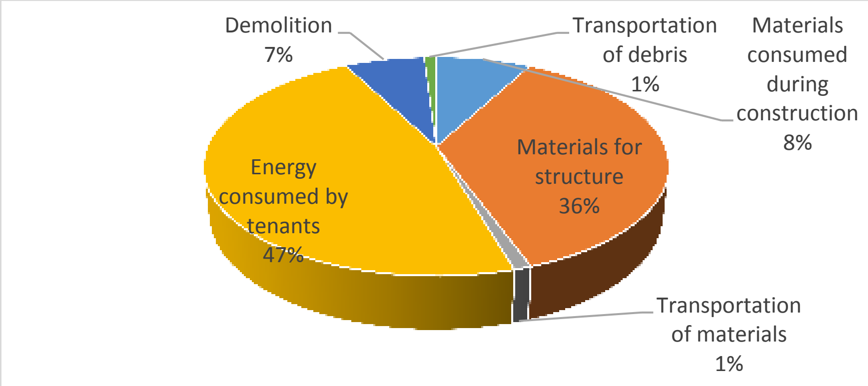

Figure 2: Contributions to carbon emission of the sampled building

The pie chart in Figure 2 shows the contributions of carbon emissions in various life cycle phases of the building. Carbon emission due to energy consumed by tenants emerged the highest with 47% while transportation of materials and debris to disposal site emerged as the least with just 1% each. This shows that majority of carbon emission in residential building come from the use of electricity and gas. It also means that the operating energy consumption by tenants is clearly impacting the environment the most. This corroborate a study by [34] where the use of heat and electricity produced the highest contribution to carbon emission in residential buildings.

4.0 CONCLUSION

In this study, we have discussed how to determine carbon emissions for construction of residential building. Different stages of construction considered are: materials consumed during formwork construction, materials for structure, transportation of materials from factory to site, energy consumed by tenants, carbon emission removals and disposal of debris. Emission factors were obtained from local sources based on the region and standards. This specific assessment was carried out not just to ascertain the level of emissions in building constructions but to also suggest ways of mitigating the impacts from buildings. Results show that the total carbon emission throughout the stages considered gives 1212 tons of CO_2e. Also, based on all the stages studied, **c**arbon emission due to energy consumed by tenants emerged the most significant with 47% while transportation of materials and debris to disposal site emerged as the least with just 1% each. This shows that majority of carbon emission in residential building come from the use of electricity and gas

5.0 RECOMMENDATIONS

Relevant authorities such as government, professionals in the built industry should as a matter of urgency enforce the following recommendations:

- Reducing the carbon content of concrete through the manufacturing process.
- Adopting recycled materials or materials with lower environmental impact such as pulverized fuel ash, granulated blast furnace slag, and silica fume in the concrete mixes can save significant amount of cement and the associated CO_2 emissions.
- Carbon emissions can be minimized by using environmentally-friendly materials or energy efficient appliances, lighting, heating, and cooling equipment
- Switching to low carbon fuels and utilizing renewable energy are considered effective in tackling the climate change problem.
- Reducing carbon emissions by sourcing sustainable materials and using low carbon materials.
- Planting sufficient trees for carbon emission removals

Acknowledgements

The authors would like to recognize the anonymous reviewers and the editor for their valuable comments and constructive suggestions to improve the quality of the paper.

DOI : 10.31695/IJERAT.2020.3628

REFERENCES

1. Adekunle A., Nwaigwe D.N, Nya Essang and Samuel P.O. "Application of Road Transportation System to Generate Electricity via Road Humps in Lagos State, Nigeria" ***International Journal of Advances in Scientific Research and Engineering (IJASRE)***, Volume 5, Issue 4 April (2019), 49-56
2. Osagie Ibhadode, A. A. Adekunle, S. O. Banjo, O. D. Atakpu (2019): Thermophysical, Electrical and Mechanical Characterizations of Normal and Special Concretes: A Holistic Empirical Investigation for Prequalification and Quality-Control of Concrete. *J. Phys.: Conf. Ser.* 1378 (2019) 042100. DOI: 10.1088/1742-6596/1378/4/042100
3. Osagie Ibhadode, Taofiq Bello, A. E. Asuquo, F. W. Idris, F. A. Okougha, I. I. Umanah, M. C. Ugonna, D. N. Nwaigwe (2017): Comparative-study of Compressive-strengths and Densities of Concrete Produced with different Brands of Ordinary Portland Cement in Nigeria, *International Journal of Scientific & Engineering Research*, 8(9), 1260-1275.(https://www.ijser.org/onlineResearchPaperViewer.aspx?Comparative-study-of-Compressivestrengths-and-Densities-of-Concrete-Produced-with-Different-Brands-of-Ordinary-PortlandCement-in-Nigeria.pdf)
4. Jibrin Sule, Sule Emmanuel, Ismaila Joseph, Osagie Ibhadode, Buba Y. Alfred, Farida Idris Waziri, Emeson Sunny (2017): Use of Waste Plastics in Cement-based Composite for Lightweight Concrete Production, International *Journal of Research in engineering Technology*,2(5),44-54.
5. Ogunro, A. S.; Apeh, F. I.; Nwannenna, O. C. and Ibhadode, O. (2018): Recycling of Waste Glass for Clay used in Ceramic Tile Production, American *Journal of Engineering Research*, 7(8), 272-278. (ajer.org/papers/Vol-7-issue-8/ZZG0708272278.pdf)
6. Azeta J., Ishola F., Akinpelu T., Dirisu J. O., Okokpujie I. P., Ibhadode O. (2019): Performance Evaluation of Developed Mathematical Models of Hot Air Balloon for Drone Application. *Procedia Manufacturing*, Elsevier, Science Direct, 35(2019), 1073-1078. DOI: 10.1016/j.promfg.2019.06.059
7. Osagie Ibhadode, I. T. Tenebe, P. C. Emenike, O. S. Adesina, A. F. Okougha & F. O. Aitanke (2018): Assessment of noise-levels of generator-sets in seven cities of South-Southern Nigeria. *African Journal of Science, Technology, Innovation and Development*, 10(2), 125135. DOI: 10.1080/20421338.2017.1400711
8. Ibhadode Osagie, Oyedepo O. S., Ogunro A. S., Azeta Joseph, Solomon O. Banjo, Umanah I. I., Apeh E. S., Ayoola A. R. (2018): An Experimental-assessment of Human Exposure-levels to Aircraft Noise-hazards in the Neighbouring-environments of four Nigerian Airports. *IOP Conf. Ser.: Mater. Sci. Eng.*, 413 (2018) 012080, DOI: 10.1088/1757-899X/413/1/012080
9. Ibhadode, O., Ajayi, O. O., Abioye, A. A., Ismaila, J., Adekunle, A. A. (2019): An evaluation of classroom-illumination: a critical requirement for effective designing and construction of naturally-illuminated schools in Nigeria. *Progress in Industrial Ecology – An International Journal*, 13(4), 342-372. DOI: 10.1504/PIE.2019.102849
10. ESEIGBE Akhere Pauline, IBHADODE Osagie, AYOOLA Abayomi Razzaq, SOSANOLU Omoniyi Moses (2018): An Experimental Determination of Drinking Water Quality in Abeokuta Metropolis, South-western Nigeria. *International Journal of Advances in Scientific Research and Engineering*, 4(12), 241-256. DOI: 10.31695/IJASRE.2018.33035
11. Ogbiye, A. S., Tenebe, I. T., Emenike, P. C., Diwa, I. D., Omole, D. O., Omeje, M., Ngene, U. B., Oyekweredike, O. K., Ibhadode, O. (2019): Preliminary Assessment of the Current Pollution Status of river Atuwara, Nigeria, Within an Industrial Site: A Bivariate Approach. *WIT Transactions on Ecology and the Environment*, River Basin Management 2019, 234(1), 209-219. http://library.witpress.com
12. Osagie Ibhadode, A. Adekunle, Y. K. Abimiku, N. M. Umeobika, (2019): Noise-level Characterization of Portable Electric-power Generators in North-Central Nigeria: A Brand-by-Brand Comparative-study. *International Journal of Engineering Research and Advanced Technology*, 5(4), 44-58. DOI: 10.31695/IJERAT.2019.3427
13. Ibhadode Osagie; Ibhadode Peter; Okougha, A. F.; Umanah, I. I.; Aitanke, F. O.; Fiyebo, S. A. B. (2016). Hazards Assessment Analyses of Fossil-fuel Generators: Holistic-study of Human Experiences and

DOI : 10.31695/IJERAT.2020.3628

Perceptions in South-Southern Nigeria, *Journal of Sustainable Development Studies*, 9(2), 153-242. (infinitypress.info/index.php/jsds/article/view/1318)

14. O. S. Adesina, D. A. Agunbiade, O. Ibhadode, (2019): Adaptive Models for Tail of Distributions. *International Journal of Statistics and Economics*, 20(2), 123-134.
15. Osagie Ibhadode, A. A. Adekunle, C. O. Nwafor, I. I. Umanah (2019): Interference Mitigation Among Indoor Phone Subscribers in LTE Based Heterogeneous Networks Using Fast Response Frequency Reuse Technique. *J. Phys.: Conf. Ser.* 1378 (2019) 032019. DOI: 10.1088/1742-6596/1378/3/032019
16. S. O. Banjo, Bukola O. Bolaji, Oluseyi O. Ajayi, Babalola P. Olufemi, Ibhadode Osagie, Anthony O. Onokwai (2019): Performance enhancement using appropriate mass charge of R600a in a developed domestic refrigerator. *IOP Conf. Ser.: Earth Environ. Sci.*, 331 (2019) 012025, DOI: 10.1088/1755-1315/331/1/012025
17. Osagie Ibhadode, A. A. Adekunle, J. Azeta, Y. K. Abimiku (2019): An Investigation of the Influence of Femtocells Network on a Small Size Indoor Environment Using ITU-R and WINNER II Path Loss Models. *J. Phys.: Conf. Ser.* 1378 (2019) 032020. DOI: 10.1088/17426596/1378/3/032020
18. S. O. Banjo, B. O. Bolaji, Ibhadode Osagie, O. S. I. Fayomi, O. B. Fakehinde, P. S. Olayiwola, S. O. Oyedepo, N. E. Udoye (2019): Experimental analysis of the performance characteristic of an eco-friendly HC600a as a retrofitting refrigerant in a thermal system. *J. Phys.: Conf. Ser.* 1378 (2019) 042033. DOI: 1088/1742-6596/1378/4/042033
19. Nwafor Christiana O, Abimiku Yohanna, Ibhadode Osagie, Annune Eric J. (2019): Experimental Evaluation of Radiological Hazards in Ceramic Tiles Used in the Jos-South, Area of Plateau State, Nigeria. *International Journal of Advances in Scientific Research and Engineering*, 5(12), 1-8. DOI: 10.31695/IJASRE.2019.33571
20. Osagie Ibhadode, F. A. Okougha, C. O. Nwafor, Nya Essang (2017): An Experimental-study on Ventilation of Public Schools in Akure, Oshogbo and Ado-ekiti Cities in South-western Nigeria, *IOSR Journal of Mechanical and Civil Engineering*, 14(5), 34-43. DOI: 10.9790/1684-1405013443
21. Peter Ibhadode, A. P. Ibhadode, Osagie Ibhadode, O. M. Sosanolu (2020): Post-Project Environmental Impact Evaluation of Ota Industrial Housing Estate on the Localized Environment and Environs in Ogun State, Nigeria, *International Journal of Engineering Research and Advanced Technology*, 6(1), 9-28. DOI: 10.31695/IJERAT.2020.3597 Journal of Engineering, Science and Technology. 2011; 3(3):160-166.
22. Adekunle A., Asaolu G.O., Adiji K., Kasheem Umar A (2019) Improvement of Channel Capacity in a Multiple Input Multiple Output LTE Radio System for GSM-Users Using Ideal Power Distribution Technique. (IJASRE, E-ISSN: 2454-8006, Vol.5 Issue 9, September 2019, DOI: http://doi.org/10.31695/IJASRE.2019.33494)
23. Adekunle A.; Adewale A.K.; Olaifa O.A; Ukoh S.N.B. (2019).Statistical Study on Types, Causes, Effects and Remedies of Corrupt Practices in Construction Industries in Nigeria (IJASRE, E-ISSN: 2454-8006, Vol.5 Issue 4, April 2019, DOI: http://doi.org/10.31695/IJASRE.2019.33493)
24. Adekunle A., Abimiku Y.K., Umeobika N.M., Ameh E.E (2018). Radio wave detection using cost 231-Hata model for wireless network planning; a case study of senate building environs of Unilag, Nigeria.(IJASRE, E-ISSN: 2454-8006, Vol.4 Issue 12, December 2018, DOI: http://doi.org/10.31695/IJASRE.2018.32992)
25. Adekunle A., Umanah I.I., Adewale A.K., Egege C.C (2018). Analytical study of casualties in the construction industry in Nigeria with a view to provide remedial measures: case study of Lagos state. (IJERAT,E-ISSN: 2454-6135, Vol.4 Issue 8, August 2018, DOI: http://doi.org/10.31695/IJERAT.2018.3293)
26. Adekunle A., Umanah I.I., Ibe K.E., Imonikosaye M. Rukewe (2018). Statistical Analysis of Fire Outbreaks in Homes and Public Buildings in Nigeria: A Case Study of Lagos State (IJERAT, E-ISSN:2454-6135, Vol.4 Issue 8, August 2018, DOI: http://doi.org/10.31695/IJERAT.2018.3294)
27. Adekunle A., Asaolu G.O., Adiji K., Bamiduro H.A (2016). Impacts of electrical hazards on Nigerian construction industries with a view to provide safety measures(JSDS,ISSN 2201-4268, Vol.9, Number 2,2016,267-289 https://infinitypress.info/index.php/jsds/article/download/1365/612)
28. A. Adekunle, A. Asuquo, N. Essang, I.I.Umanah, K.E. Ibe, Ayo Bamidele Alo (2016). Statistical analysis of electrical fire outbreaks in buildings: case study of Lagos state, Nigeria(JSDS,ISSN2201-4268,Vol.9,Number1,2016,76-92 https://infinitypress.info/index.php/jsds/article/view/1288)

DOI : 10.31695/IJERAT.2020.3628

29. Adekunle A., Ibe K.E., Kpanaki M.E., Umanah I.I., Nwafor C.O., Essang N (2015). Evaluating the effects of radiation from cell towers and high tension power lines on inhabitants of buildings in Ota, Ogun state (JSDS,ISSN 2201-7372, Vol.3, Number 1, 2015, 1-21 https://www.infinitypress.info/index.php/cas/article/download/872/494)
30. Adekunle A., Abimiku Y.K., Nwafor C.O., Nwaigwe D.N., Agbonkhese O (2015). High Voltage Transformers and Electromagnetic Emissions. (IISTE, ISSN 2225-0638, Vol.46,2015,16-25 https://iiste.org/Journals/index.php/APTA/article/download/24614/25216)
31. A.Adekunle, E.S.Ekandem, K.E. Ibe, G.N.Ananso, E.B.Mondigha (2014). Analysis of thermal and electrical properties of Laterite, clay and sand samples and their effects on inhabited buildings in Ota, Ogun state, Nigeria. (JSDS,ISSN 2201-4268, Vol.6,Number 2,2014,391-412 https://infinitypress.info/index.php/jsds/article/download/799/378)
32. Ekandem E.S., Daudu P.I., Lamidi R.B., Ayegba M.O., Adekunle Adebayo (2014). Spontaneous Settlements: Roles and Challenges to Urban Planning. Journal of Sustainable Development. (JSDS,ISSN 2201-4268, Vol.6, Number 2, 2014, 361-390 https://infinitypress.info/index.php/jsds/article/view/760)
33. Agbonkhese O., Agbonkhese E.G., Aka E.O., Joe-Abaya J., Ocholi M., Adekunle A. (2014). Flood menace in Nigeria: impacts, remedial and management strategies. (IISTE, ISSN 2225-0514,Vol.6,Number4,2014,32-40 https://www.iiste.org/Journals/index.php/CER/article/download/12140/12492)
34. Adekunle A. and Gbenga-Ilori A. (2020), Minimizing Interference in Ultra-Dense Femtocell Networks Using Graph-Based Frequency Reuse Technique, FUOYE Journal of Engineering and Technology (FUOYEJET) http://engineering.fuoye.edu.ng/journal/index.php/engineer/article/view/456.

DOI : 10.31695/IJERAT.2020.3628