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Joaquim Nabuco Avenue, No. 1950. Center. Manaus, Amazonas. Brazil.
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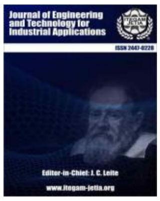

RESEARCH ARTICLE OPEN ACCESS

DETERMINANTS OF E-PROCUREMENT ADOPTION BY INSTITUTIONS IN KENYA AND TANZANIA DURING COVID-19 ERA

Enid Kebby Ernest*[1]

[1] Department of Procurement & Logistics Management, Tanzania Institute of Accountancy (TIA), Mwanza, Tanzania, Box 5247, Tanzania.

[1] http://orcid.org/0000-0002-4533-7753

Email: *eniernest@hotmail.com

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ABSTRACT

Electronic procurement (E-procurement) is one of the rapidly expanding digital form of procurement in both public and private institutions in Kenya and Tanzania. E-procurement is used by most public and private institutions to strengthen buyer-supplier relationships, cut transaction costs, eliminate maverick purchases, increase organizational coordination, and supply chain performance. It is perceived that most of the business operations were automated during the COVID-19 era to minimize the spread of novel corona virus. Therefore, this study intended to do a thorough empirical literature review on the determinants of E-procurement adoption in Kenyan and Tanzanian institutions during the COVID-19 era.

I. INTRODUCTION

Information and communication technology (ICT) will inevitably be used in both public and private institutions in the modern, globalized world. One of the most recent technologies used by institutions to expedite their procurement processes is E-procurement. Through the use of e-procurement platforms, numerous nations all over the world has earned competitive edge in their institutional operations [1].

Developed countries such as Japan, United Kingdom (UK) Australia, United States of America (USA) and Singapore have effectively deployed E-procurement systems and are now reaping the benefits. However, E-procurement systems are not fully utilized in many countries since they are seen as intimidating to adopt. The benefits of E-procurement include saving time, less paper work, minimize cost, quick ordering and reduction of maverick [1,2].

In order to reduce corruption and have a substantial economic impact, Sub-Saharan African nations, have indicated interest in adopting E-procurement. Moreover, these confront a number of E-procurement implementation obstacles that, if not resolved, may delay the process and discourage committed leaders from E-procurement implementation in various institutions [2].

Tanzanian government has decided to fully utilize innovation and ICT to execute public operations through deploying various systems such as Planning and Reporting System (PLANREP), government payment system (MUSE), Government e-Payment Gateway (GePG) and, Tanzania National e-Procurement System [3].

A pilot study of chosen vendors and experts from various public organizations across Tanzania was conducted in support of the adoption of e-procurement. The pilot program aimed to change participants' perceptions on the benefits and performance of TANePS. Surprisingly, just 63.4% of the participants were unable to implement the system, and 60% did not fully understand how it operated. The primary issues with this phenomenon have not been addressed by the available empirical studies [4-7]. Since most transactions were automated during the COVID 19 era, it is still important to understand what determinants led to the adoption of E-procurement in Tanzanian institutions as this era was characterized by automation of most of business transactions

In Kenyan context, public procurement has proven to be a time consuming and challenging process. The public procurement system has shown to be expensive for procuring entities and suppliers, a hub for corruption, and rife with problems that result in substantial losses of public funds. The government has adopted E-procurement to sustain the essential principles of Kenyan good governance, including transparency, accountability, and integrity [8]. Moreover, Kenyan Vision 2030 also acknowledges Small and Medium Enterprises (SME's) as key players in developing a revolutionary industrializing and high middle-income nation. In essence, SME's can lower Kenya's high unemployment rate and raise the Gross Domestic Product (GDP) of the country. Unfortunately, the failure rate of SME's is high across the globe, including Kenya. This could be caused by a variety of obstacles, such as a lack of adoption of E-procurement technology and an entrepreneurial culture [9].

It is worth noting that the application of technology was inevitable during the COVID-19 era as most of the business activities were negatively impacted and communities were put on lockdown, and businesses were forced to close in the quest of dealing with the spread of the novel corona virus [10-12].

Times for any country avoiding the technological changes being seen around the world have passed. The discovery of novel corona virus only served as a warning to create digital platforms in all institutional undertakings. One of the technologies that makes it possible to complete procurement duties electronically and streamline the entire procurement process is e-procurement. In order to source empirical literature on the determinants of E-procurement adoption in Kenya and Tanzania during the COVID-19 era, this paper used a desktop technique of literature review. As a result, secondary data was recorded and used for data analysis.

The researcher chose the aforementioned countries in East Africa because after a thorough literature review across several databases with the restriction of the COVID -19 period (2019–2022), Kenya and Tanzania had more empirical results than other East African countries namely Burundi, Democratic Republic of Congo, Rwanda, South Sudan and Uganda. Since it is perceived that most of business operations were automated during COVID-19 pandemic, the researcher sought to identify the determinants of E-procurement adoption during that time frame. By understanding these determinants, the researcher hopes to hasten the adoption of E-procurement by Kenyan and Tanzanian institutions that are currently lagging behind.

II. THEORY UNDERPINNING THE STUDY

A number of theories, such as Resource-Based View (RBV), Innovation Diffusion Theory (IDT), Technology Acceptance Model (TAM), Technology Adoption Theory (TAT) Institutional Theory (IT), Theory of Reasoned Action (TRA), Theory of Planned Behavior (TPB), Stakeholders' Theory (ST), Unified Theory of Acceptance and Use of Technology (UTAUT), Information Systems Success Theory (ISST), Disruptive Innovation Theory (DIT) , Theory of Human Service Delivery (THSD), and Technological-Organizational-Environmental (TOE) model have been used to various empirical studies related to E-procurement adoption [13-15]. However, most research have relied on RBV, IDT, and TAM [8-9], [14], [16,17].

Due to potential inconsistencies in one theory or model, it is advised that for clarity and consistence to be achieved researchers ought to use at least two theories in a study to gain a broader knowledge of technology adoption in an institution [18]. The adoption of E-procurement is said to be impacted by organizational, environmental, technological, and personal variables. Since the Technological-Organizational-Environmental (TOE) model explains technology adoption in the context of technology, organizations, and environments, while the Unified Theory of Acceptance and use of Technology (UTAUT) supplements by adding the individual context, this study adopted both models as they were applied by [19].

TOE described the adoption and implementation of technology by a company is influenced by technological, organizational and environmental context. Technological context includes technological tools, processes, external and internal technologies that are pertinent to the firm. Organizational context refers to the features and assets of an organization, such as managerial structure, human resources, level of slack resources, size, connections between employees, level of formalization and centralization. Size and structure of the industry, organizational competitors, macroeconomic climate, the firm's competitors, and the regulatory environment are part of the environmental context [20].

Furthermore, UTAUT attempts to illuminate user motives to use technology and subsequent usage patterns. Four essential constructs—effort expectancy, social influence, performance expectancy, and facilitating conditions—have an impact on likelihood of adoption of new technology by people. The first three are factors that affect user behavior and usage intention, while the fourth factor affect user behavior. Gender, age, experience, and voluntariness all act as moderators to the impact of the four dimensions on usage intention and user behavior [21].

II.1 E-PROCUREMENT ADOPTION IN VARIOUS INSTITUTIONS

Determinants for the adoption of E-procurement in different institutions have been the subject of numerous researches undertaken worldwide. For instance, [22] found that top management support, supplier readiness, employee knowledge and skills, compatibility, relative advantage, and complexity were the factors that strongly influenced the adoption of E-procurement in Sri Lankan public sector organizations. Similar to this, [23] conducted research on critical success factors for Ghana's adoption of electronic government procurement. The most important success element for the adoption of E-procurement was identified by the results as being quick, reliable and inexpensive internet services. In addition, the study found that organizational support for human factors, infrastructure setup, system features, management and control influence the adoption of E-procurement.

Utilizing Technology Acceptance Theory (TAT), [13] carried research on determinants of electronic procurement system adoption in Tanzania. They discovered that employee skill, education, organizational structure, and collaboration promote adoption of E-procurement in public institutions whereas employee age, education, motivation, and teamwork have the opposite effect in private institutions. In order to explore the factors that influence the adoption of an E-procurement model for green procurement in Tanzania, [4] used the Unified Theory of Acceptance and Use of Technology (UTAUT) and Technological-Organizational-Environmental (TOE) models. Results showed that while attitude has a direct impact on E-procurement adoption, legal framework, relative advantage, and performance expectancy have an indirect effect. Additionally, [24] applied Resource-Based View Theory (RBV) and the Technology Acceptance Model (TAM) to conduct a study on technological factors impacting vendors' involvement in the public electronic procurement system in Ilala, Tanzania. Data security, system integration, data quality and management, information transparency, originality, and innovation were discovered to be technological elements that had an impact on the adoption of e-procurement by vendors.

On other hand, [9] conducted research on influence of technological factors on E-procurement adoption in small and medium size enterprises (SMEs) Kenya's Nyeri county. Findings were supported by the Resource-Based View (RBV) theory showed that, SMEs' adoption of E-procurement is impacted by technological factors such as the lack of E-procurement software, a lack of technical know-how, a lack of IT infrastructure, and concerns about information security and confidentiality. Similarly, [16] did a study on organizational attributes and adoption of E-procurement in Tororo district in Kenya. The study was anchored on technology acceptance model (TAM) and findings indicated that ICT proficiency, employee competence and managerial decision had a positive correlation with the adoption of e-procurement. On top of that, [25] applied a Resource Based View theory to perform a study on influence of internal organizational factors on e-procurement adoption in small and medium sized enterprises in Kenyan Nyeri county. The results concluded that size of the organization, staff retention, manager's perception, trust on technology, and employee knowledge are internal organizational factors influence adoption of e-procurement to SMEs.

The conclusions on the determinants of E-procurement in various institutions are not comparable based on the empirical literatures examined above although the observed results based on technological, organizational, environmental and individual context. This disparity inspired the researcher to use the TOE model and UTAUT theory which takes into account the technological, organizational, environmental context (TOE), and individual context (UTAUT) to undertake study on the determinants of E-procurement adoption in Kenyan and Tanzanian institutions during the covid 19 era.

III. METHODS

This paper is based on an empirical study of the literature and consolidated key researches on determinants of E-procurement adoption in Kenyan and Tanzanian institutions during COVID19 era. The selection papers were guided by inclusion and exclusion principles. The literatures were chosen based on applicability and relevance of the research topic and quantitative technique was applied whereby descriptive analysis was adopted. Twenty (20) literatures were reviewed from Kenya and Tanzania in order to identify the determinants of E-procurement adoption with highest frequency during the COVID 19 era. The researcher used 20 literatures to source study variable since other researchers like [26] drew conclusions from 20 literatures in African perspective while [27, 28] compiled their findings using 12 literatures.

III.1 SOURCES OF DATA

Published and unpublished literatures were used as the source of data by using different electronic data bases and search engine which include Google, Google Scholar, Emerald, Science Direct, Google Books, Wiley Online, Sage Publications, AJAR Taylor and Francis and many others.

III.2 SEARCH KEYWORD

Keywords used for searching the study topic were; ("E-procurement" OR "Internet procurement" OR "Online procurement" OR "Web procurement" OR "Digital procurement") AND ("Tanzania" OR "Kenya" OR "East Africa" OR "Developing countries") AND ("2019" OR "2020" OR "2021" OR "2022").

III.3 INCLUSION AND EXCLUSION PRINCIPLE

Only English-language research papers were included in the search of the literature. The literatures were confined to Kenyan and Tanzanian institutions that had adopted E-procurement. This study includes E-procurement articles from the COVID 19 era, which ran from 2019 to 2022. This is because numerous studies such as [10-12] have shown digitalization of institutional processes during the latter era.

III.4 STUDY VARIABLES AND SAMPLE SIZE

Due to the fact that some studies, such [26], used 20 sources of information while [27, 28] used 12 sources for the compilation of their conclusions, sample of 20 literatures, of which 10 were collected from Kenya and Tanzania, was deemed sufficient for statistical analysis. However, the condition that the study variable must appear more than once from the reviewed research was applied.

III.5 DATA ANALYSIS

Data from the reviewed literature were analyzed by using descriptive statistics. The determinants that contributed to the adoption of E-procurement were tallied and given frequencies. The percentage was calculated by taking total frequencies of each E-procurement determinant divided by two (the number of countries) and multiplied by 100. The determinants were deemed significant if they had a score of 50% or above [26]. Clustered column charts were then used to summarize the findings.

IV. RESULTS AND DISCUSSIONS

Teamwork, individual age, individual education, staff pressure, staff awareness, staff competency, organizational size, attitude, performance expectancy, legal framework, compatibility, complexity, IT infrastructure, perceived benefits, management support, user involvement, security, capital, supplier capability, system integration, internet connection, staff training, and user acceptance were discovered to be determinants of e-procurement adoption of various institutions in Tanzania and Kenya. The determinants of e-procurement adoption in Tanzania and Kenya are listed in Table 1.

Table 1: Determinants of e-procurement adoption in Tanzania and Kenya (2019-2022).

S/NO	Author	Country	Determinants/Findings
1	[13]	Tanzania	Individual education, individual age, staff competency, organizational structure and team work
2	[4]	Tanzania	Attitude, performance expectancy, relative advantage, legal framework
3	[29]	Tanzania	Compatibility, complexity, technological infrastructures, perceived benefits, organizational size, management attitude, user involvement, coercive pressure, mimetic pressure, normative pressure, value addition
4	[30]	Tanzania	Legal framework, employee competency, technological infrastructure and data security
5	[14]	Tanzania	Stakeholders' awareness, management involvement, financial resource, staff competency
6	[15]	Tanzania	Top management commitment, supplier capacity and technological infrastructure
7	[24]	Tanzania	Information transparency, creativity and innovation, data quality and management, system integration, data security and IT literacy

S/NO	Author	Country	Determinants/Findings
8	[31]	Tanzania	Technological infrastructure, reliable internet service, system compatibility, management support, public procurement regulations, staff training, computer literacy, user acceptance, perceived benefits
9	[32]	Tanzania	Legal framework, Enterprise Resource Planning, supplier compatibility, internet connectivity, management support, infrastructure, funds, security and staff mind set
10	[33]	Tanzania	Perceived benefits, technological infrastructure, complexity, compatibility, organizational size, management support, user involvement, staff competency, performance expectancy
11	[34]	Kenya	E-security, staffing, user acceptance, top management support
12	[35]	Kenya	Stakeholders involvement, technology infrastructure, staff skills, top management support
13	[25]	Kenya	Employee knowledge, size of the organization, staff retention, trust on technology, perceptions of managers
14	[9]	Kenya	Security, confidentiality, IT infrastructure, system integrations, proper needs assessment, IT experts, unavailability of e-procurement software
15	[17]	Kenya	Capital, IT infrastructure, system compatibility, unstable internet connections, staff training, top management support
16	[36]	Kenya	IT infrastructure, staff competence, top management support, management involvement
17	[37]	Kenya	Staff training, staff involvement, supplier adoption, IT experts, Top management support
18	[38]	Kenya	Staff competency, management support, IT infrastructure, security, training, system integration
19	[8]	Kenya	IT infrastructure, staff training, top management support, supplier capability
20	[16]	Kenya	Top management support, procurement planning, capital, IT infrastructure, internet accessibility, internet reliability and affordability, staff competency, staff willingness

Source: Authors, (2022).

The rule that determinants must appear more than once guided the selection of the 18 determinants of E-procurement adoption. Each determinant was then utilized as a header in a table that had been prepared. The findings from two countries were organized under each heading based on their similarity. As a result, table 2 compiles the determinants of e-procurement adoption based on their similarities.

Table 2: Summary of determinants of e-procurement adoption.

Author	SC	OS	ATT	PE	LF	COMP	COMPL	ITF	PB	MS	UI	SE	CP	SUC	SI	INT S	ST	UA
[13]	x	x																
[4]			X	X	X				X									
[29]		X				X	X	X	X	X	X							
[30]	X				X			X				X						
[14]	X									X			X					
[15]								X		X				X				
[24]	X											X			X			
[31]	X				X	X		X	X	X						X	X	X
[32]			X		X	X		X		X		X	X			X		
[33]	X	X		X		X	X	X	X	X		X						
[34]	X									X		X						X
[35]	X							X		X	X							
[25]	X	X								X		X						
[9]	X							X				X			X	X	X	
[17]						X		X		X			X					
[36]	X							X		X	X							
[37]	X									X		X		X			X	
[38]	X							X		X		X			X		X	
[8]								X		X				X			X	
[16]	X		X					X		X			X			X		

Source: Authors, (2022).

Key: (1) SC – Staff competency (2) OS – Organizational Size (3) ATT – Attitude (4) PE – Performance Expectancy (5) LF – Legal Framework (6) COMP – Compatibility (7) COMPL –Complexity (8) ITF – IT Infrastructure (9) PB – Perceived Benefits (10) MS – Management

Support (11) UI – User Involvement (12) SE – Security (13) Capital (14) SUC- Supplier Capability (15) SI – System Integration (16) INTC – Internet Connection (17) ST – Staff Training (18) UA – User Acceptance

Additionally, the frequencies of the E-procurement determinants were constructed based on the results of table 2, and the percentage was determined. Three of the 18 determinants were significant out of the total because they received a score of 50% or above, while the remaining determinants were not. Therefore, throughout the COVID 19 era, management support (75%), staff competency (70%) and IT infrastructure (65%) were the key determinants of E-procurement adoption by institutions in Kenya and Tanzania. Table 3 lists the frequencies and percentages for the determinants of E-procurement adoption.

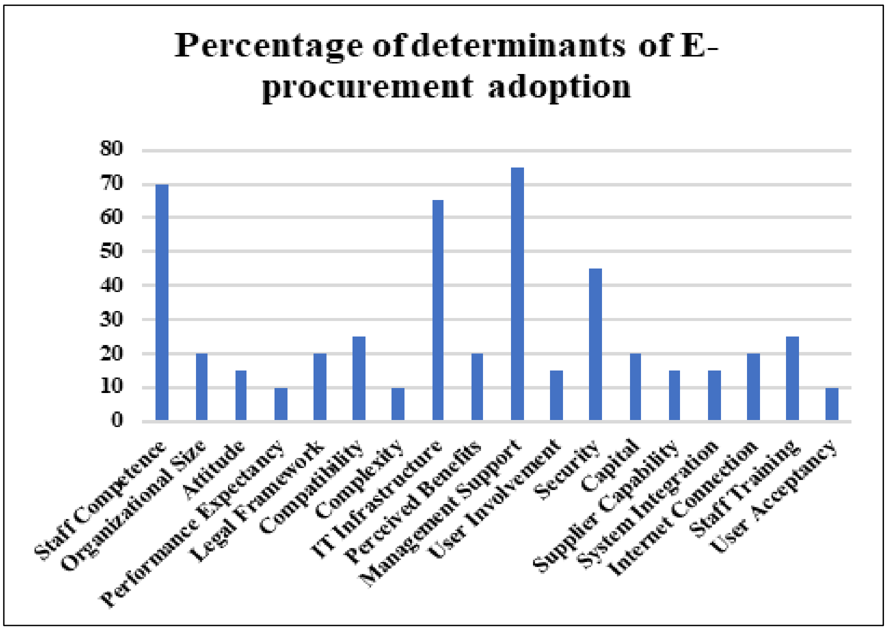

Figure 1: Percentage of determinants of E-procurement Adoption.
Source: Authors, (2022).

The adoption of E-procurement in any institution is easily implemented provided that the staff involved have the right attitude, knowledge, abilities, and competencies in relation to computers, IT, internet, and E-procurement systems. This view is fully supported by [34], they observed that staff competence is an obstacle in e-procurement adoption hence continuous training is necessary to overcome it and ought to be put into practice. Findings are aligned by both TOE model and UTAUT theory. According to TOE framework staff competence is grouped under human resources, which is under organizational variables influencing the adoption of technology while UTAUT theory paved that, adoption of technology is easily attained if individuals will find easy to use the system (effort expectancy) through having enough knowledge, skills and practice of the system.

Furthermore, [39] argued that the adoption of E-procurement at Temeke Regional Referral Hospital in Tanzania depends on staff competence and expertise on E-procurement systems. However, [24] showed that computer and IT skills have a big impact on vendors' participation in public e-procurement systems in Ilala Tanzania. In a similar vein, [25] and [9] discovered that staff knowledge, technological expertise, and competency have influence in E-procurement adoption to SME's in Nyeri County, Kenya.

The adoption of E-procurement has also been observed to be significantly impacted by IT infrastructure. IT infrastructure according to [30], consists of hardware, software, internet connectivity, network security, and system integration. The results have been supported by both TOE model and UTAUT theory. TOE model clarified that an organization's adoption of technology is dependent on the technological context, which includes technological tools, procedures, and relevant internal and external technologies while UTAUT commented that the adoption of technology by individual is influenced by technical infrastructure supporting the application of the system (facilitating condition). The results are corroborated by those of [33], who found that IT infrastructure is a key for e-procurement adoption to public procuring entities in Tanzania. The results also support those of [36] who found a substantial correlation between the adoption of E-procurement projects by the Kenya Revenue Authority and the availability of information technology infrastructure. Additionally, [15] and [35] identified that IT infrastructures in Tanzania and Kenya, respectively, is a reason for effective implementation of electronic procurement in public institutions.

The use of E-procurement at institutional level is aided by management support provided through the organizational culture, staff training, collective commitment, allocation of resources and responsibilities. Findings are affiliated by both TOE model and UTAUT theory. TOE model clustered management support under connection between employees which is within organizational factors influencing institutional to adopt technology while UTAUT described that individuals will easily adopt technology if management (facilitating condition) will provide support on the use of the technology through in-house and out-off job trainings. This contention is supported by the research conducted by [14], who discovered a significant correlation between senior management support and E-procurement adoption in Tanzania's public institutions. Similarly, [32] found that top management support is one of the biggest obstacles to adoption of E-procurement in Mwanza Urban Water Supply and Sanitation Authority (MWAUWASA) in Tanzania. Additionally, [17] and [8] described that top management support had a positive effect on the implementation of e-procurement in Kenya at Murang'a county and northern eastern region county respectively. Moreover, [31] and [38] identified that senior management support in Tanzania and

Kenya, respectively, is a crucial success factor for the implementation of e-procurement in the ministry of finance.

V. CONCLUSIONS

Technology is increasingly being incorporated into every aspect of modern life in an effort to boost institutional performance and competitiveness. In this situation, it is impossible to dispute the use of technology by organizations around the world. Novel corona virus was just a wakeup call for a creation and embracing of digital platforms in all business undertakings. Thus, in this study the key determinants of E-procurement adoption in Kenyan and Tanzanian institutions during the COVID 19 era were management support (75%); staff competency (70%), and IT infrastructure (65%). The observed determinants were supported by both TOE model and UTAUT theory.

V1. RECOMMENDATION AND IMPLICATIONS

The study suggests that Kenyan and Tanzanian institutional decision-makers, policy-makers, and IT specialists should concentrate on the observed determinants of E-procurement adoption because it is perceived that during the COVID-19 era most of business operations were automated in order to avoid physical contact and minimize the spread of novel corona virus. In that case the observed determinants will speed up the adoption of E-procurement in institutions of Kenya and Tanzania which are lagging behind. The adoption of e-procurement will improve institutional performance, competitiveness, cost reduction, less paperwork, avoid maverick purchases, profit maximization and allow institutions to concentration on strategic procurement.

VI. STUDY LIMITATIONS AND FURTHER STUDIES

This study reviewed literatures during the COVID 19 era (2019 – 2022) to determine the determinants of e-procurement adoption by institutions in Kenya and Tanzania. The study constraint was restricted database to view the empirical literature that might include information pertinent to the study and determination the validity and reliability of data. To provide more robust results, additional study on the adoption of e-procurement by institutions in East Africa and Africa may be carried out by conducting empirical literature studies or collecting primary data.

V. AUTHOR’S CONTRIBUTION

Conceptualization: Enid Kebby Ernest.
Methodology: Enid Kebby Ernest.
Investigation: Enid Kebby Ernest.
Discussion of results: Enid Kebby Ernest.
Writing – Original Draft: Enid Kebby Ernest.
Writing – Review and Editing: Enid Kebby Ernest.
Resources: Enid Kebby Ernest.
Supervision: Enid Kebby Ernest.
Approval of the final text: Enid Kebby Ernest.

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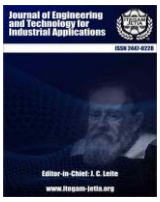

RESEARCH ARTICLE OPEN ACCESS

EFFECTS OF GRAPHITE ADDITION ON THE MECHANICAL PROPERTY AND WEAR RESISTANCE OF 60/40 BRASS

Chiedozie Valentine Oluigbo*[1], Johnson Olumuyiwa Agunsoye[2] and Joseph Babalola Agboola[3]

[1] Department of Welding and Fabrication Engineering Technology, Federal Polytechnic, Ilaro, Ogun State, Nigeria.
[2, 3] Department of Metallurgical and Materials Engineering, University of Lagos, Akoka, Lagos State, Nigeria.

[1] http://orcid.org/0000-0002-8900-2883, [2] http://orcid.org/0000-0002-8773-0051, [3] http://orcid.org/0000-0002-1359-7841

Email: *chiedozieoluigbo@gmail.com, jagunsoye@unilag.edu.ng, joeagboola@gmail.com

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ABSTRACT

Brass 60/40 is widely used in a number of industrial applications where wear due to friction is a major concern. A significant number of failures in components such as bushings, gears, bearings and machine parts are due to wear. This study investigates the effects of Graphite nano-particulate on the mechanical properties and wear rate of 60/40 Brass produced by sand casting with varying graphite reinforcement addition ranging from 0.4 - 2.0 wt. %. The produced castings were characterized using XRD, SEM and TEM. The XRD revealed the formation of new phases such as Cu_5Zn_8 and $CuZn_2$ and the presence of free carbon within the microstructure. The wear rate of the composite specimens was evaluated using a pin-on-disc wear testing machine under dry conditions at room temperature. Taguchi's technique and analysis of variance method were used to study the influence of applied load, sliding speed, time and weight % composition on the wear rate. The results revealed that nano-particulate graphite-reinforced brass composite containing 2.0 wt. % graphite has the best wear resistance and applied load is the dominating factor on wear rate.

I. INTRODUCTION

In the manufacturing industry, wear is a severe problem. As a result, several efforts are being made to develop more durable materials and procedures to reduce tool and component wear. Wear has an estimated cost which vary from 1 to 4% of GDP [1]. It also accounts for approximately 75% of component or machine part failure [2]. Wear is the gradual loss of material from a machine's operating surface as a result of relative motion between the surfaces, while the resistance to relative motion between two adjacent bodies, either solids, liquids, or gas molecules, is known as friction [3]. Wear and friction are experienced by moving equipment parts. Lubrication can be applied by the introduction of a friction-reducing film [4] and as well as the use of improved materials to minimize friction and wear between moving surfaces in contact.

Brass is a copper-zinc alloy whose proportions can be varied to achieve different properties. Brass with 40 % of Zn is heterogeneous alloy with ($\alpha + \beta'$) microstructure and it is also referred to as Muntz metal [5]. Most bearing materials are made of brass which eventually wears out over time and have to be replaced. Brass-based composites are now widely used in tribological engineering components, such as bearings and bushes. In this study, graphite powder in nanoscale is added to brass in order to improve its wear resistance property. Graphite is the most stable form of carbon under ordinary conditions. It also functions as a solid lubricant. Graphite's self-lubricating and dry lubricating properties are due to its crystal structure, and this makes it highly valued in industrial applications. Its usage as a brass alloy additive is also due to its low cost and environmental friendliness [6].

Composites are multiphase materials having desirable combinations of the best properties of the constituent phases. A Metal Matrix Composites (MMC) with nanoparticle reinforcement forms a Metal Matrix Nano-Composite (MMnC) [7]. Graphite brasses can be produced in different ways. Studies have shown that graphite brass can be prepared by graphitization annealing of cast brasses containing cementite particles, which were in-situ formed during the fasting process, and the graphite particles were formed by the decomposition of cementite particles in cast brasses [8]. In addition, graphite brass can be produced by powder metallurgy and studies by Imai *et al.* [6] has shown that the addition of 1 weight percent graphite particle in the powder metallurgy extruded brass significantly improved the machinability. A copper-graphite composite's performance in terms of friction and wear was investigated by Ma *et al.* [9]. According to the authors, a rise in sliding speed causes a dramatic rise in the friction coefficient for a powder material containing 5 weight percent graphite. According to Kato *et al.* [10], adding graphite to anti-friction materials greatly improves their usability. In particular, composites containing 40% graphite had a remarkably low friction coefficient of 0.15. Rajkumar *et al.* [11] pointed out that the morphology of the friction surface depends on the material's composition and that a copper matrix composite material with a composition of 5 - 10% graphite has higher wear resistance. Further studies were also carried out on the electro-deposition of graphite-brass composite coatings. It was shown that the presence of graphite particles improved anti-friction properties of the composite coatings and that the composite coating containing approximately 3.7 volume % graphite had the best tribological properties [12]. In this current study, sand casting technique through the liquid metallurgy route was adopted to produce a nano-particulate graphite reinforced brass composite.

II. MATERIALS AND METHODS

II.1 MATERIALS

The materials used in this work include Brass, Copper, Zinc, and Graphite. Graphite lumps were sourced from Saman-Burkono in Ningi Local Government Area of Bauchi State, Nigeria. According to findings by Adeaoti *et al.* [13], Table 1 shows the results of the chemical analysis of the Saman-Burkono graphite head sample.

II.2 METHODS

II.2.1 Preparation of Graphite Nano-Particle

The Graphite lumps were crushed and ground to powder. It was later milled for 70 hours at 3,500 rev. per min. using laboratory ball mill of 1.11855 kilowatts, in order to reduce the ground graphite powder to nano-particulate size. The mechanical attrition was carried out at the Federal Institute of Industrial Research, Oshodi (FIIRO) in Lagos State, Nigeria. The graphite powder was analysed using the Transmission Electron Microscope (TEM).

II.2.2 Preparation of Brass Alloy

Commercial brass (60/40 brass) was gotten as scraps from Owode-Onirin, Lagos State, Nigeria. Pure Copper in bar and zinc scraps were also gotten from the same location, in order to supplement the masses of copper and zinc that will be lost by oxidation during melting of the brass. Table 2 shows the results of the compositional analysis of the brass.

In this research, the nano-particulate graphite reinforced brass composites were fabricated using the Liquid Metallurgy route via the sand-casting technique. Wooden patterns of cylindrical and rectangular shapes were constructed for this purpose. Melting of materials were done in a crucible furnace. The production of the composites was done with varying graphite reinforcement addition between 0.4 - 2.0 wt. %.

The characterization of the microstructure of the cast samples were carried out using X-Ray Diffraction (XRD) and Scanning Electron Microscope (SEM). Compositional analysis of the control sample was carried out using an S7 - Metal Lab Plus - Optical Emission Spectrometer. The samples' surfaces were ground and polished before the analysis.

II.3 MECHANICAL PROPERTY TESTING

II.3.1 Tensile Test

Tensile test was carried out according to ASTM D636, on the Universal Testing Machine, Model: SAUMYA D2. A load was applied continuously throughout on the test coupons with nominal dimension of 80 x 15 x 4 mm at a loading rate of 60 mm/min.

II.3.2 Hardness Test

Hardness test was carried out in accordance with ASTM A956 using a Brinell Hardness Testing machine. The test coupons were indented on the surface with a pin at different locations and the average of the results were taken from the display of the tester.

II.3.3 Impact Test

The impact energy test was carried out on Hounsfield Balanced Izod Impact Machine, Serial No: 3915 in accordance with ASTM D6110-10. The test coupons were prepared and inserted, then the hammer was thrown smartly and the readings were observed from the pointer, the impact energy were determined by taking the average of 2 coupons each per filler loading.

II.4 WEAR TEST

Wear test was done using Pin-On-Disc wear testing machine. It was conducted on the control sample as well as the 1.2% and 2.0% samples. The test was carried out in dry conditions and in accordance with ASTM G99 standard. Using an arm and weights attached to it, the pin specimen was pressed against the disk at a specific load. The parameters selected for the experiments were applied load, sliding speed, time and weight % reinforcement. The amount of wear was calculated by weighing the specimens both before and after the test. Volume loss in cubic millimeters was used to report wear results.

The experiments were conducted according to L9 Orthogonal array generated using Design of Experiments based on Taguchi's technique. The smaller-is-better (Signal to Noise ratio – S/N) performance characteristic was used to determine the wear rate (since the wear rate is expected to be minimized) as shown in equation 1. The experimental results were further analysed using Analysis of Variance to study the influence of each individual parameter on the response.

$$S/N = -10 * \text{Log}[\sum(Y^2)/n] \quad (1)$$

Where Y = responses for the given factor level combination.
n = number of responses in the factor level combination.

III. RESULTS AND DISCUSSIONS

III.1 MICROSTRUCTURAL ANALYSIS

Table 2 shows the results of the spectrometric composition of the brass control sample. In order to examine the structure of the graphite, XRD and TEM were carried out as shown in figures 1 and 2 respectively. The XRD was able to identify the phases present as carbon, silicon and silicon dioxide. The TEM confirmed that the graphite powder is in nano-particulate size of 100 nanometers.

Table 1: Chemical characterization of Saman-Burkono Graphite head sample.

Compound	Al_2O_3	SiO_3	SO_3	K_2O	CaO	TiO_2	FeO_3	MgO
Composition (Wt. %)	4.35	67.14	BDL	3.70	2.89	0.40	0.38	0.15
Compound	V_2O_3	Cr_2O_5	MnO	PbO	Na_2O	ZnO	BaO	P_2O_5
Composition (Wt. %)	0.38	0.06	0.86	0.19	BDL	0.92	0.86	BDL

Source: Adeaoti *et al.* [13].

Abbreviation: BDL=below detection limit.

Table 2: Spectrometric compositional analysis of 60/40 Brass.

Element	Cu	Zn	Sn	Al	Si	Fe	Ni
Wt. % Composition	59	38.35	0.3	0.05	1.6	0.4	0.3

Source: Authors, (2022).

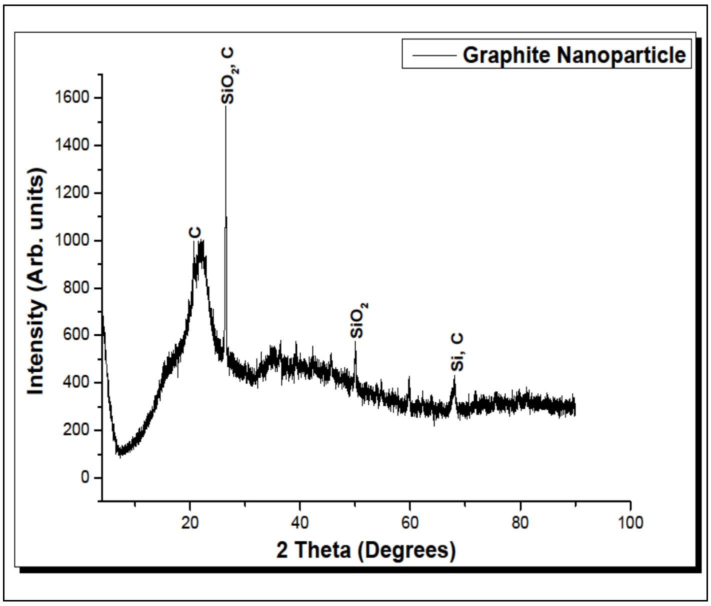

Figure 1: XRD of Graphite nanoparticles.
Source: Authors, (2022).

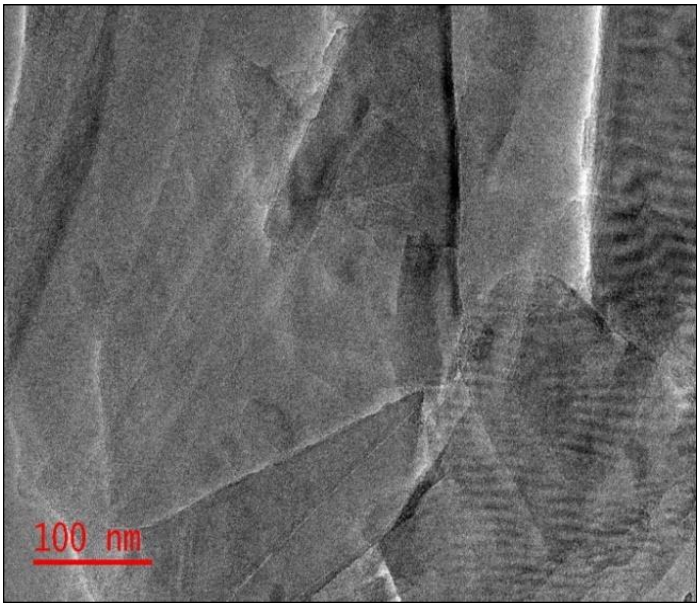

Figure 2: TEM of Graphite nanoparticles.
Source: Authors, (2022).

XRD and SEM examinations were carried out on the cast samples for the extreme compositions (control sample and 2 wt. % composite) and intermediate composition (0.4 wt. % composite). Figures 3 to 8 shows the XRD peak properties and SEM micrographs of the respective materials. The XRD of the control sample showed that the predominant phases were free Zn, CuZn, $CuZn_2$ while the SEM showed the morphologies of these phases. The XRD results in 0.4 wt. % composite and 2 wt. % composite identified free carbon in the form of graphite and Cu_5Zn_8 which is an intermetallic compound, in addition to other phases present.

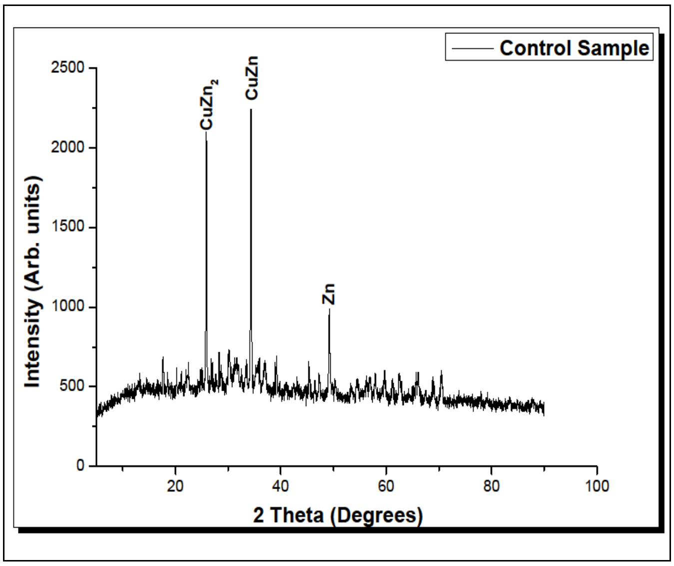

Figure 3: XRD of Control Sample.
Source: Authors, (2022).

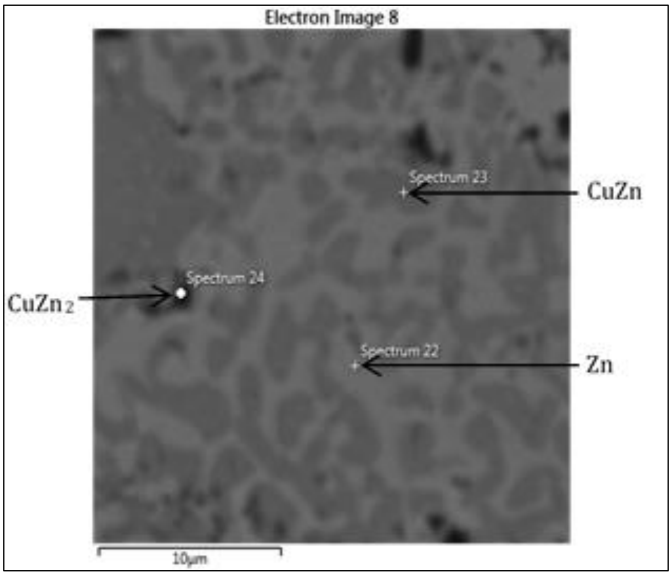

Figure 4: SEM Micrograph of Control Sample.
Source: Authors, (2022).

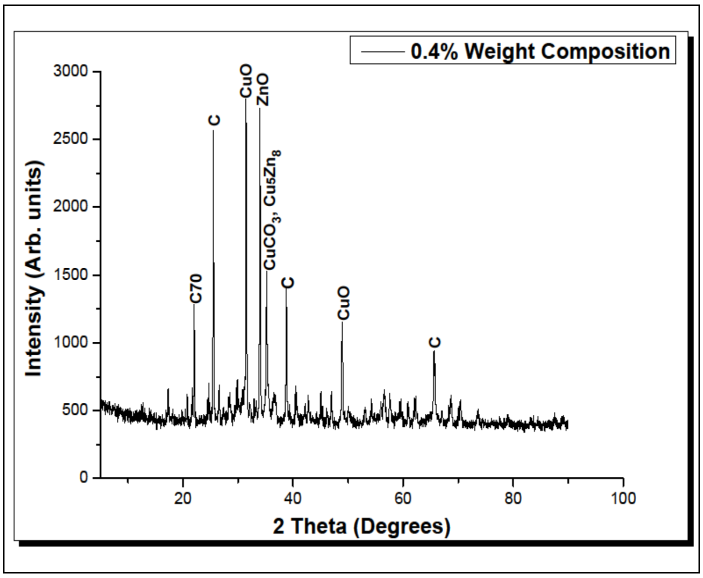

Figure 5: XRD of 0.4% sample.
Source: Authors, (2022).

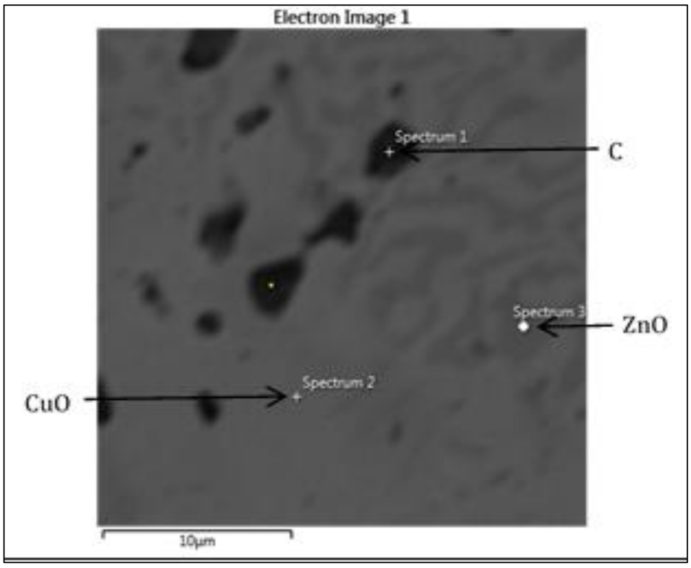

Figure 6: SEM Micrograph of 0.4% sample.
Source: Authors, (2022).

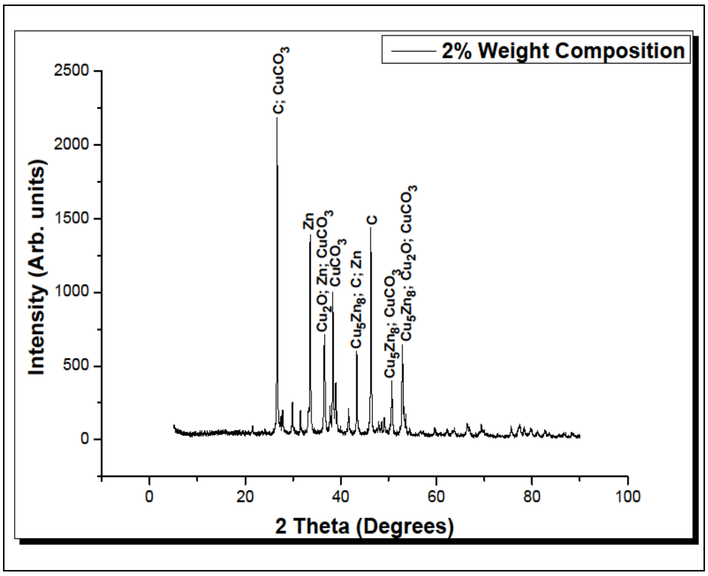

Figure 7: XRD of 2% sample.
Source: Authors, (2022).

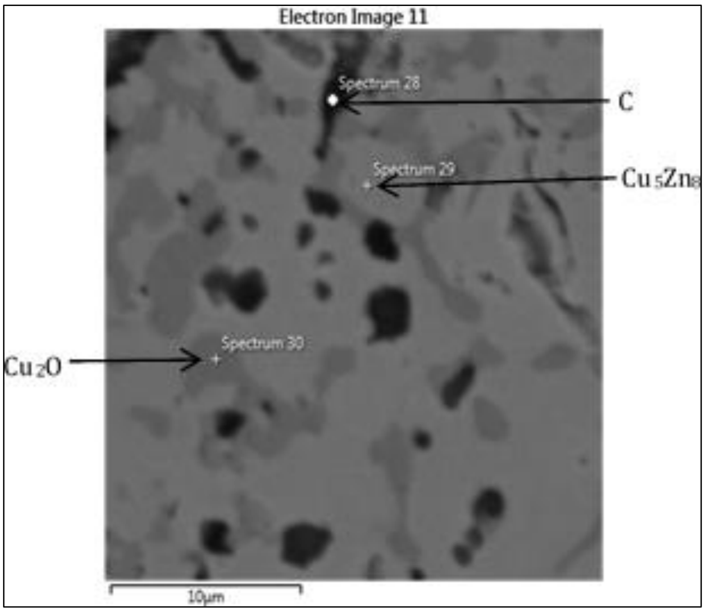

Figure 8: SEM Micrograph of 2% sample.
Source: Authors, (2022).

III.2 MECHANICAL PROPERTIES

The results of the mechanical properties of the brass reinforced composites are summarized in table 3.

Table 3: Mechanical Properties of Nano-Particulate Graphite Reinforced Brass Composite.

S (%)	UTS (MPa)	T (MPa)	E (MPa)	D (%)	I (J)	H (BHN)
Control	222.400	209.598	5728.500	13.555	18.460	19.900
0.4	238.930	157.836	6269.207	13.299	12.570	25.350
0.8	221.365	220.748	6550.185	12.076	11.820	25.900
1.2	232.474	142.296	6349.036	11.088	10.740	26.800
1.6	205.252	131.356	6119.281	9.802	10.480	26.600
2.0	268.775	243.990	7516.783	9.797	9.250	29.150

Abbrevation: S = Sample, UTS = Ultimate Tensile Strength, T = Tensile Strength at Break, E = Elastic Modulus, D = Ductility, I = Impact Energy, H = Hardness.

III.2.1 Toughness and Ductility

Figure 9 shows the relationship between the applied stress on the composite materials and the resulting strain (or elongation). It can be seen that the Control sample has the largest area under the stress-strain curve, hence has the highest toughness. The area under the stress-strain curve decreases as the weight percent addition of graphite nanoparticles in the brass matrix composite increase. It can also be seen from figure 10 that the Control sample has the highest ductility of 13.555% and it decreases as the weight percent addition of graphite nanoparticles in the brass matrix composite increase. This confirms the relationship between the toughness and ductility. It can be inferred that the addition of nano-particulate graphite reduced the toughness and ductility of brass matrix composite.

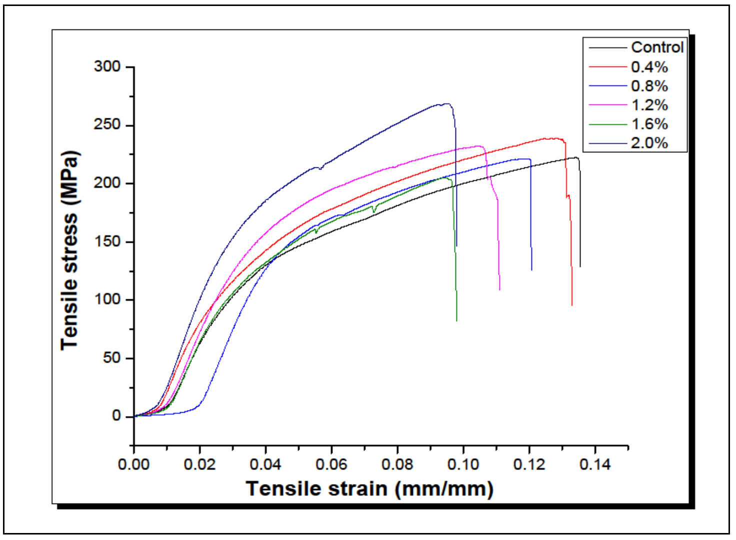

Figure 9: Tensile Stress against Tensile strain of the graphite nano-particulate reinforced brass composites.
Source: Authors, (2022).

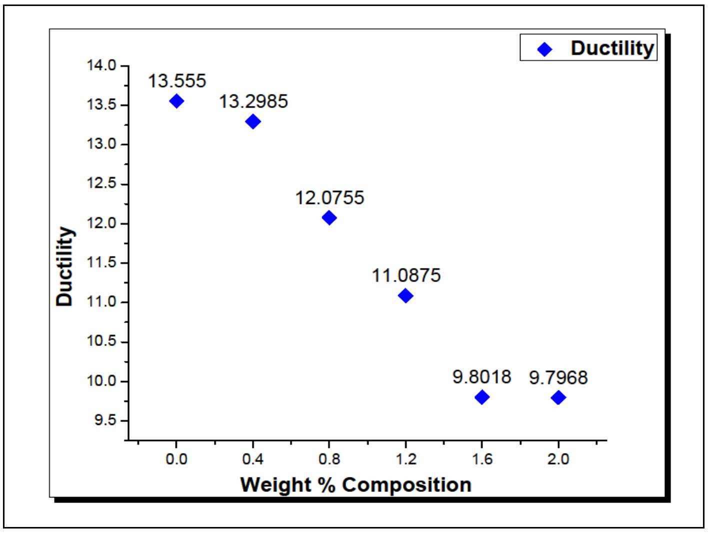

Figure 10: Ductility of the graphite nano-particulate reinforced brass composites.
Source: Authors, (2022).

III.2.2 Impact Energy

Figure 11 shows that the control sample has the highest impact energy and there was steady decrease in the impact energies as the weight percent addition of graphite nanoparticles in the brass matrix composite increased.

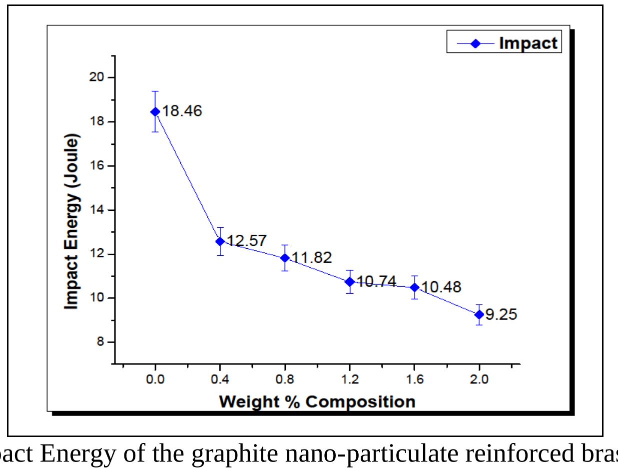

Figure 11: Impact Energy of the graphite nano-particulate reinforced brass composites.
Source: Authors, (2022).

III.2.3 Hardness

Figure 12 shows that the control sample has the lowest hardness value and this increases steadily as the weight percent addition of graphite nanoparticles in the brass matrix composite are increased.

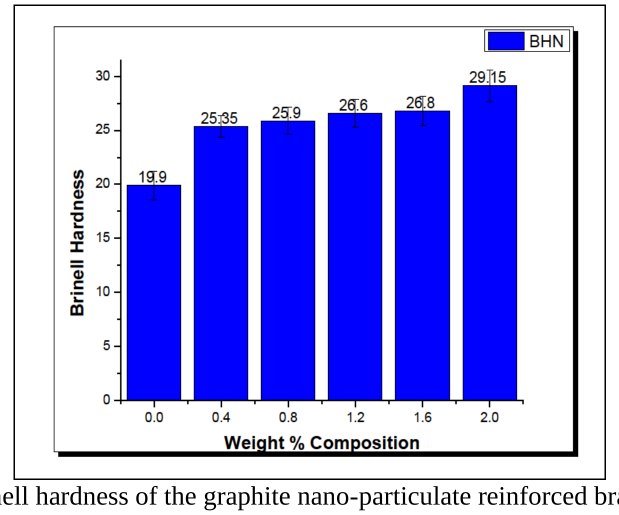

Figure 12: Brinell hardness of the graphite nano-particulate reinforced brass composites.
Source: Authors, (2022).

III.3 WEAR RATE ANALYSIS

III.3.1 Taguchi Analysis

Taguchi method was used to analyse the wear rate at low speed of 1.25m/s and high speed of 2.5m/s. Table 4 shows the wear process parameters and their values at different levels, while the wear rate values and S/Ns are displayed in Table 5. The S/N response table generated shows the influence of each parameter on the wear rate (Table 6 and Table 7). The strongest influencing parameter on the wear rate is determined using the delta value from these tables. The delta value gives the difference between the maximum and minimum value of each parameter level. The higher value of delta denotes that, the particular parameter has the strongest influence on the wear rate. From the delta value, it is noted that, load is the dominating factor on the wear rate followed by weight % composition and then time, for both the low speed and high speed.

Table 4: Process parameters and their values at different levels.

Process parameter	Low (1)	Medium (2)	High (3)
Load (N)	1.45	2.27	2.68
Time (Sec)	60	180	300
Material (Wt. %)	0	1.2	2.0

Source: Authors, (2022).

Table 5: Results of the wear rate and S/N ratios.

L (N)	T (S)	Wt. %	Low Speed (1.25m/s)		High Speed (2.5m/s)	
			W(g/m)	S/N	W(g/m)	S/N
1	1	1	0.039	48.18	0.0063	44.01
1	2	2	0.0024	52.40	0.016	35.92
1	3	3	0.0064	43.88	0.020	33.97
2	1	2	0.0026	51.70	0.0044	47.13
2	2	3	0.0083	41.62	0.0026	51.70
2	3	1	0.0019	54.43	0.0034	49.37
3	1	3	0.00085	61.41	0.0052	45.68
3	2	1	0.0015	56.48	0.0024	52.39
3	3	2	0.0027	51.37	0.0076	42.38

Source: Authors, (2022).
Abbreviation: L = Applied load, T = Time, W = Wear rate.

Table 6: Response Table for Signal to Noise Ratios at speed of 1.25m/s (Low speed).

Level	Load (N)	Time (Sec)	Wt. %
1	48.15	53.76	54.03
2	49.25	50.16	51.82
3	56.42	49.89	48.97
Delta	8.27	3.87	4.06
Rank	1	3	2

Source: Authors, (2022).

Table 7: Response Table for Signal to Noise Ratios at speed of 2.5m/s (High speed).

Level	Load (N)	Time (Sec)	Wt. %
1	37.97	45.61	48.59
2	49.40	46.67	41.81
3	46.82	41.91	43.79
Delta	11.43	4.76	6.78
Rank	1	3	2

Source: Authors, (2022).

Figures 13 and 14 show the main effect plot for SN ratio and mean respectively, at low speed. The slope of the line which connects between the levels clearly shows the power of influence of each control factor. In Figure 13, it is observed that optimal level for low wear rate is achieved by keeping the load at maximum level while the time and wt. % of reinforcement at minimum levels. The wear rate variation for each parameter when it changes from level to level is graphically represented in Figure 14.

In Figure 15 below, the lighter region shows low wear mass loss, that is, maximum wear resistance and the darker region shows high wear mass loss, that is, minimum wear resistance. Figure 16 shows the surface plot of wear rate against load and time at low speed.

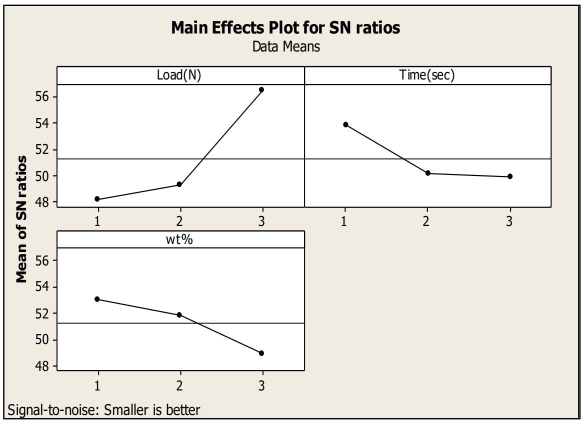

Figure 13: Main effect plots for SN ratio - Wear rate at low speed.
Source: Authors, (2022).

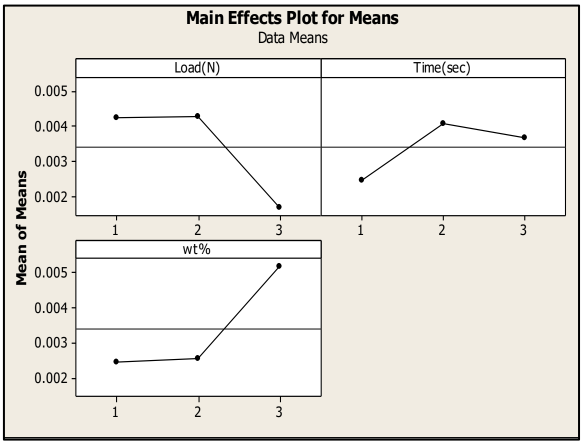

Figure 14: Main effect plots for means - Wear rate at low speed.
Source: Authors, (2022).

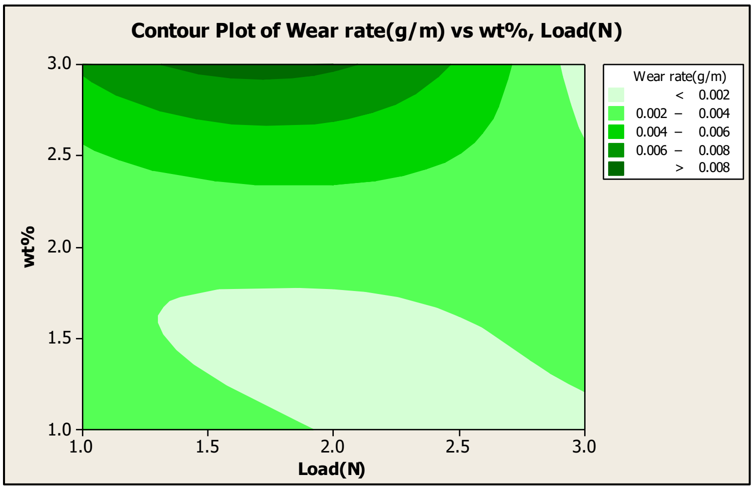

Figure 15: Contour plot of wear rate against weight % and load at low speed.
Source: Authors, (2022).

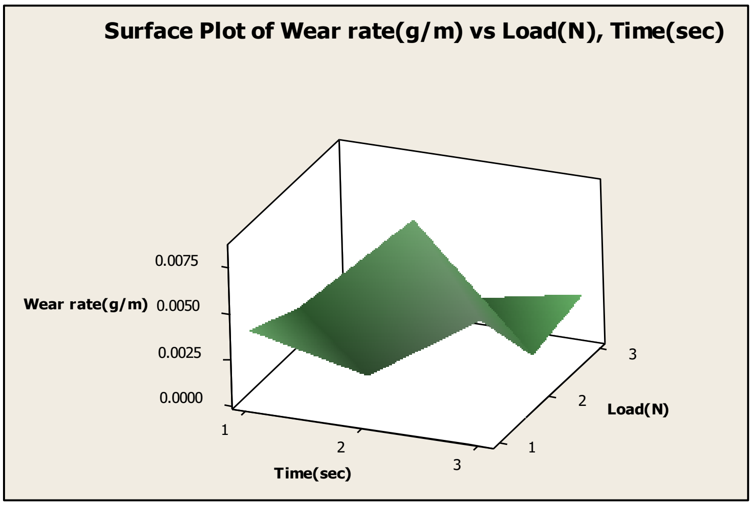

Figure 16: Surface plot of wear rate against load and time at low speed.
Source: Authors, (2022).

Figures 17 and 18 show the main effect plot for SN ratio and mean respectively, at high speed. In Figure 17, it is observed that optimal level for low wear rate is achieved by keeping the load and time at level 2 while the wt. % of reinforcement at minimum level. The wear rate variation for each parameter when it changes from level to level is graphically represented in Figure 18. The slope of the line which connects between the levels clearly shows the power of influence of each control factor.

Figure 19 shows the contour plot of wear rate against weight % and load at high speed while Figure 20 shows the surface plot of wear rate against load and time at high speed.

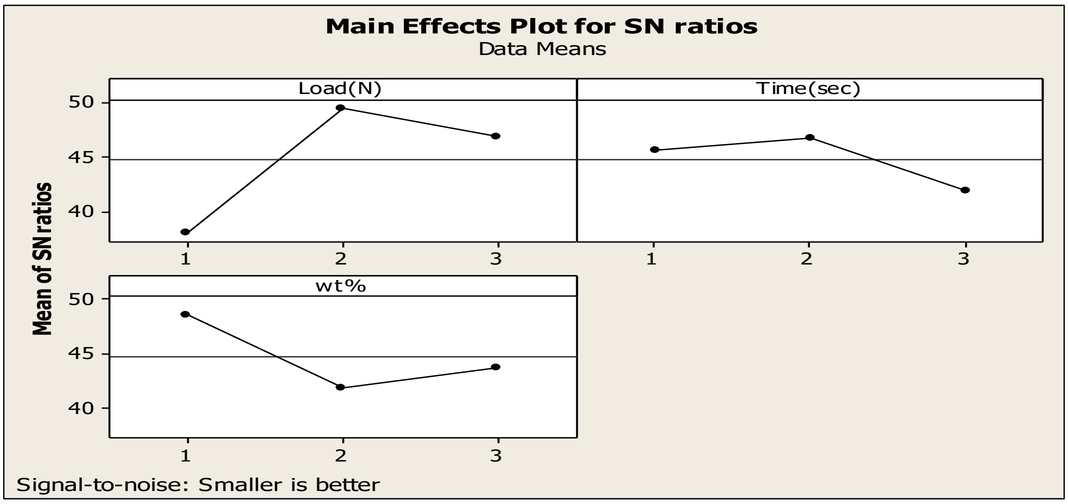

Figure 17: Main effect plots for SN ratio - Wear rate at high speed.
Source: Authors, (2022).

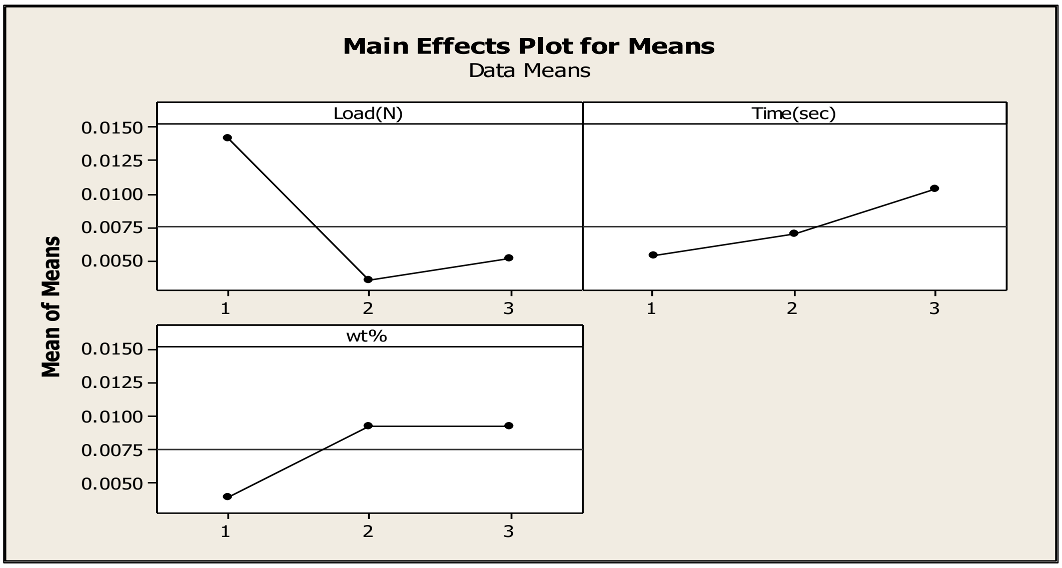

Figure 18: Main effect plots for means - Wear rate at high speed.
Source: Authors, (2022).

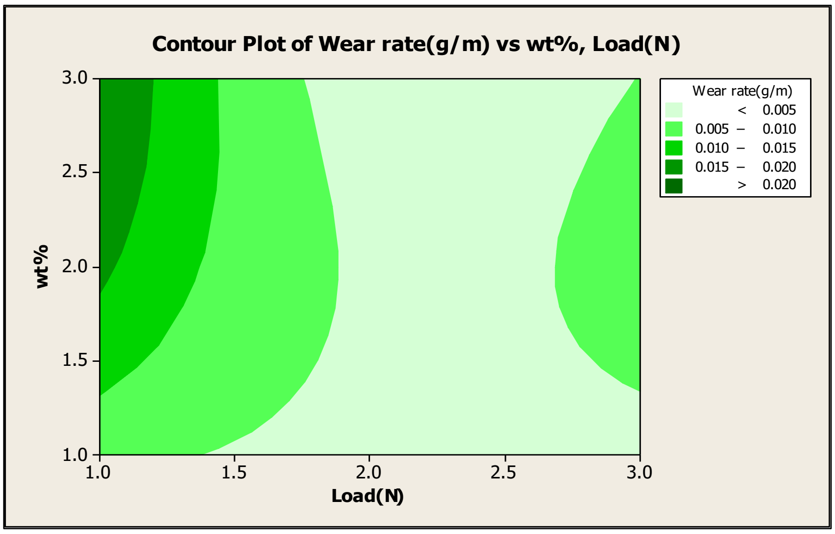

Figure 19: Contour plot of wear rate against weight % and load at high speed.
Source: Authors, (2022).

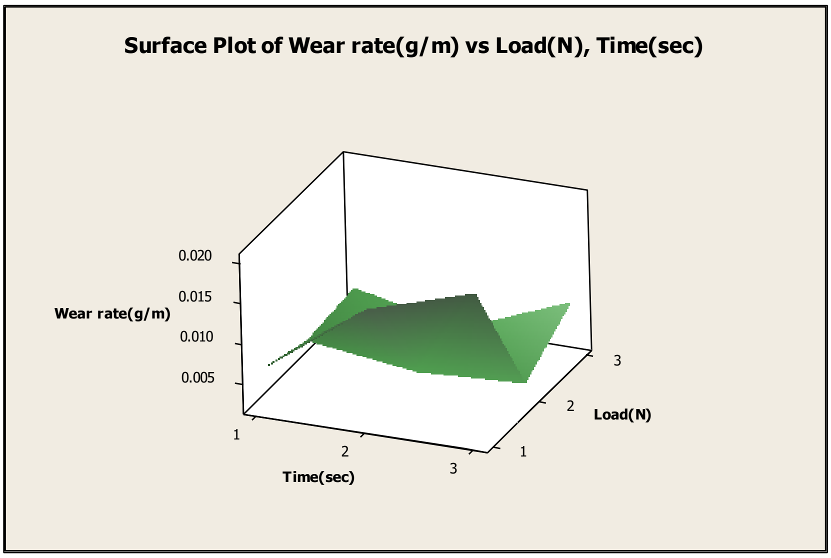

Figure 20: Surface plot of wear rate against load and time at high speed.
Source: Authors, (2022).

III.3.2 Analysis of Variance (ANOVA)

The percentage contribution of each parameter on the response was evaluated by using ANOVA. This analysis was carried out at a level of 5% significance with a confidence level of 95%. The results of the ANOVA on the wear rate at low speed are displayed in Table 8. It was observed that the applied load has a higher contribution of 69.01%, followed by the time with 16.20% and wt. % with 14.79%. Likewise, the results of the ANOVA on the wear rate at high speed are displayed in Table 9. It was observed that the applied load has a higher contribution of 66.12%, followed by the wt. % with 22.40% and time with 11.50%.

Table 8: Analysis variance results for low speed.

Source	DF	SS	MSS	F	P	% Contribution
Applied load	2	121.06	60.53	0.98	0.505	69.01
Time (s)	2	28.03	14.01	0.23	0.815	16.20
Wt. %	2	26.07	13.03	0.21	0.826	14.79
Error	2	123.62	61.81			
Total	8	298.77				

Source: Authors, (2022).

Table 9: Analysis variance results for high speed.

Source	DF	SS	MSS	F	P	% Contribution
Applied load	2	215.637	107.818	24.77	0.039	66.12
Time (s)	2	37.456	18.728	4.30	0.189	11.50
Wt. %	2	73.007	36.504	8.39	0.107	22.40
Error	2	8.706				
Total	*8*	*334.805*				

Source: Authors, (2022).

IV. CONCLUSIONS

The effects of Nano-particulate Graphite addition on the Tribological property of 6040 brasses for industrial applications was investigated. Based on the outcome of the research, the following conclusions are drawn from this study:

i. The nano-particulate graphite reinforced brass composites have been successfully produced by the stir casting route.
ii. The ductility, impact energy and toughness values of the brass matrix composite decreased with the increase in weight percent of graphite nano-particulate powder while the hardness values increased slightly with an increase in weight percent of graphite nano-particulate powder.
iii. At low speed of 1.25 m/s, the optimum process parameters which results in minimum wear rate are applied load of 2.68N, time of 60 sec and 2 wt. % of reinforcement. At low speed, load has the highest percentage contribution (69.01%) on the wear rate followed by time (16.20%) and wt. % of reinforcement (14.79%).
iv. At high speed of 2.5m/s, the optimum process parameters which results in minimum wear rate are applied load of 2.27N, time of 180sec and 2 wt. % of reinforcement. Hence, 2 wt. % of graphite reinforcement has the best wear resistance in the brass matrix composites. At high speed, load has the highest percentage contribution (66.12%) on the wear rate followed by wt. % of reinforcement (22.40%) and time (11.50%).

V. AUTHOR'S CONTRIBUTION

Conceptualization: Johnson Olumuyiwa Agunsoye.
Methodology: Chiedozie Valentine Oluigbo and Johnson Olumuyiwa Agunsoye.
Investigation: Chiedozie Valentine Oluigbo and Johnson Olumuyiwa Agunsoye.
Discussion of results: Chiedozie Valentine Oluigbo, Johnson Olumuyiwa Agunsoye and Joseph Babalola Agboola.
Writing – Original Draft: Chiedozie Valentine Oluigbo.
Writing – Review and Editing: Chiedozie Valentine Oluigbo, Johnson Olumuyiwa Agunsoye and Joseph Babalola Agboola.
Resources: Chiedozie Valentine Oluigbo and Johnson Olumuyiwa Agunsoye.
Supervision: Johnson Olumuyiwa Agunsoye and Joseph Babalola Agboola.
Approval of the final text: Chiedozie Valentine Oluigbo, Johnson Olumuyiwa Agunsoye and Joseph Babalola Agboola.

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RESEARCH ARTICLE OPEN ACCESS

DESIGN OF AN AUTOMATIC LICENSE PLATE READER

Matthew B. Olajide[1], Najeem O. Adelakun*[2], David S. Kuponiyi[3], Zaid O. Jagun[4] and Charity S. Odeyemi[5]

[1] Department of Electrical/Electronic Engineering, Olabisi Onabanjo University, Nigeria.
[2] Engineer/Researcher, Federal College of Education Iwo, Ogun State, Nigeria.
[3] Department of Electrical Electronics Engineering, Gateway (ICT) Polytechnic Saapade, Nigeria.
[4] Department of Computer Engineering, Olabisi Onabanjo University, Nigeria.
[5] Department of Electrical Electronics Engineering, Federal University of Technology Akure, Nigeria.

[1] http://orcid.org/0000-0001-8368-1427, [2] http://orcid.org/0000-0003-1749-7116, [3] http://orcid.org/0000-0002-3810-1267, [4] http://orcid.org/0000-0002-1544-0266, [5] http://orcid.org/0000-0002-1160-9394

Email: olajide.mathew@oouagoiwoye.edu.ng, *adelakunnajeem@gmail.com, david.kuponiyi@gaposa.edu.ng, jagun.zaid@oouagoiwoye.edu.ng, charityodeyemi@gmail.com

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ABSTRACT

The increase in the number of vehicles and the alarming rate of theft and defaulters daily prompts the need for sophisticated matching technology to curb car theft, reduce traffic offenders, and any other anomalies/irregularities affecting vehicles' smooth operation. This study deals with the design of an automatic license plate reader which automatically captures an image of the vehicle's license plate, transforms that image into alphanumeric characters using optical character recognition or similar high-tech software, and compares the plate number acquired to one or more databases of vehicles of interest to law enforcement and other agencies against those of stolen cars or people suspected of being involved in criminal activities. The automated capture, analysis, and comparison of vehicle license plates typically occur within seconds enabling the officer in charge to take appropriate actions.

I. INTRODUCTION

The increase in the number of vehicles daily prompts the need for matching technology to curb car theft, reduce traffic offenders, and any other anomalies/irregularities affecting vehicles' smooth operation. However, identifying a vehicle by its license plate (LP) is an imperative task that can be hindered by factors such as uneven lighting conditions, distortions of the license plate, varying sizes of the license plate, multi-plate detection, etc. in a varying environment when a proper detection technique is not put in place [1-2].

Consequently, license plate recognition is a form of automatic vehicle identification system with image processing technology used to identify vehicles by their number plates. However, government personnel mandate most vehicle owners to attach registration plates at the front and rear of a vehicle, while vehicles such as motorboats require only a single plate attached to the rear of the vehicle. They can use existing cameras, or ones specifically designed for the task. They are used by various security personnel as a means of automating toll collection, monitoring of traffic, and detection of vehicles crossing the speed, it is also useful for the identification of black-listed cars for speedy interception [3].

Due to the high crime rate in the nation most especially kidnapping, car theft, and also to reduce the number of citizens breaking traffic rules. Law enforcement agencies are increasingly adopting automatic license plate recognition/reader (ALPR). The two major types of Automatic License Plate Reader (ALPR) are: Stationary and mobile [4], the Stationary method has infrared (IR) cameras that are used at high fixed positions, while the Mobile uses vehicle-mounted IR cameras. Problems with the ALPR can be from Character Recognition (CR), Vehicle Capture Image (CI), License Plate Detection (LPD), and License Plate Segmentation [5–7]. An automated license plate readers (ALPR) is a high-tech device that captures computer-readable images of license plates and compares the information with what is available in the database [8].

Automatic license plate detection (ALPD) is a technique used in extracting a vehicle's license plate (LP) area from an image without human intervention [9]. Traditionally, automatic license plate recognition systems use machine learning techniques capable of capturing certain morphological attributes such as color, text, etc. and they are keen to complex background and image noise [10]. An Automatic Number Plate Recognition (ANPR) is an image processing innovation that adopts the use of optical character recognition on images to capture vehicle registration plates and translate them into machine-readable formats, which can then be processed and indexed into appropriate database [11–13], and it has three major sections: vehicle number plate extraction, character segmentation and Optical Character Recognition (OCR). License plate extraction is the stage where a vehicle license plate is detected.

Many advancements in Digital Image Processing have been used in a variety of sectors, as have advances in Optical Character Recognition Technology. In recent years, various ways of utilizing digital image processing have been created. OCR was made available as a service online in the 2000s (WebOCR) [14]. Early LPR systems had a poor recognition rate, which was lower than what actual systems required. External factors (sun and headlights, poor plates, a large number of plate kinds) combined with the low level of recognition software and vision hardware resulted in low-quality systems. Image enhancement is a critical approach that relies on filters to reduce noise and undesired light effects to obtain clear and readable images.

Over the last decade, many efforts have been made to solve the problem of detecting potential LP areas from an image or a video. Consequently, [15] proposed the installation of HD video cameras at an intersection to detect and capture vehicle images at every point in time. Hence, digital video recorders (DVR) are now integrated with Closed Circuit Television (CCTV) systems to store a large amount of data [16]. Sensors and other hardware peripherals are utilized to increase image acquisition and remove extraneous features, and for surveillance and forensic purposes, Manufacturing has improved the accuracy of LPR systems.

Sasi et. al proposed the usage of plate localization for edge detection in the study titled Automatic Car Number Plate Recognition which uses the Modified Ant Colony Optimization Algorithm. The Kohonen neural network is used to classify the location and dimensions of each character [3].

Similarly, [6] worked on Image Extraction from Number Plates that is based on an area extraction technique combined with morphological image processing using deep learning where a pre-trained Convolution Neural Network is used as a feature extractor (CNN)” The "Alex-Net" algorithm is employed, and SVM is used as a classifier. The algorithm is implemented in the C++ computer language for morphological image processing.

Jamtsho et. al opined on the need for the safety of the motorcyclists at all times using a single convolutional neural network deployed to automatically detect the License Plate (LP) of a non-helmeted motorcyclist from the usage of a video stream [17].

Satsangi et. al proposed “License Plate Recognition: A Comparative Study on Thresholding, OCR, and Machine Learning Approaches”, which examined license plate recognition using the Viola Jones algorithm. The primary focus of the study was on the classification and recognition of characters on license plates [18]. The photos were obtained with the help of a magnetic loop detector sensor. The identification of the license plate is accomplished in three steps: picture detection, number plate extraction, and image segmentation, the proposed algorithm's output is compared to the output of threshold and OCR technologies. The accuracy of all three implementations shows that the viola jones provides the best performance of 80 percent [18].

Omar et. al analysed several image process techniques using a cascaded deep learning approach and the results showed that the Automatic License Plate employs several preprocessing techniques with filtering and contrast enhancement capabilities suited for image processing [19].

Gao et. al use a quantitative approach to determine the privacy disclosure risk in an LPR data set based on the concept of k-anonymity, the study shows that there is a high possibility of anonymous individuals being re-identified, and the study concluded that five spatiotemporal records are enough to uniquely identify about 90% of individuals even the temporal granularity is set to be half of one day [20].

Selmi et. al proposed a Deep Learning System for Automatic License Plate Detection and Recognition. The author uses the pre-processing procedures to identify license plates and non-license plates in the work, which employs the first CNN model for LP detection, and the second CNN model is used for classification and recognition. The canny edge detection approach is used for character segmentation. Further character recognition is built on a tensor flow framework that employs a second CNN model with 37 classes. The datasets used in this study were obtained from the Caltech dataset and the AOLP dataset [21].

Shivakumara et. al proposed keyword spotting in the video, natural scene, and license plate images, which helps us to retrieve accurate and efficient information from large and diversified databases [22].

Wang et. al worked on a detection and tracking strategy for license plate detection in video, the study integrates the cascade detectors and TLD algorithm for detecting license plates in video sequences. The cascade detectors are applied to detect newly appearing license plates from the video sequences for TLD’s tracking and to detect the license plates with a higher degree of confidence for improving the shortcoming of an existing draft in TLD’s long-term tracking [23].

II. MATERIALS AND METHODS

In this study, our focus is on reducing the crime rate and increasing adherence to traffic regulations, this prompted the need for the development of an application that will provide access control through automated car plate recognition with the following objectives:

- Obtaining Nigerian plate number images through a solar camera
- Segmentation of plate numbers to extract the text on the number plate
- Build a database that will serve as a repository for car plate numbers already registered.

Automated License Plate Recognition (ALPR) can assist security personnel to identify a vehicle of interest associated with criminal activity, with the ability to read up to 1,000 plates an hour, this technology can improve results. Not only does the system read plates fast, but data are accepted only on vehicles displaying license plates that match the desired criteria and appear in the database. The ALPR detects crimes committed along the traffic highway and with an embedded system of data on a website. The offender can be sent a text message automatically by the officer in charge and be charged for particular misconduct.

This section shows an overview of how the system works and how the algorithms are created. The mathematical foundations as well as particular issues are discussed.

The application is intended to recognize number plates automatically based on the following characteristics:

- Nigerian Plate numbers
- Rectangle plates
- Single plate (One line of characters)
- Arrangement of letters and numbers

The resolution of a photograph entered into the software varies depending on the hardware. The size of the image is reduced to lower the required computational time. The lessen image is used in the processing until a certain ROI (Region of Interest) is established.

The initial processing step sequence is designed to locate and chop off a Region of Interest, which is thought to include the license plate. In this step, intensity detection will be used to obtain feature data from the image so that it can be modified.

II.1 ANPR

This is the main function where the output is a list that contains all numbers plate recognised by a set of previous functions. In this paper, the directory name 'image', contains a total of 50 pictures for the execution. All of them are realized within the community in Ogun State.

II.2 WEBSITE

A website that acts as the database for the registered license plate is built to assist traffic wardens in the tracking of vehicles via their plate numbers.

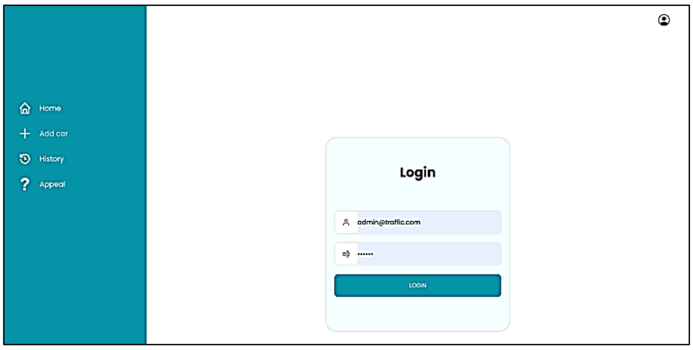

Figure 1: Login Page for Traffic Warden.
Source: Authors, (2022).

Figure 1 above shows a pictorial representation of the login page for different traffic wardens' details and locations each connected to different automatic license plate devices.

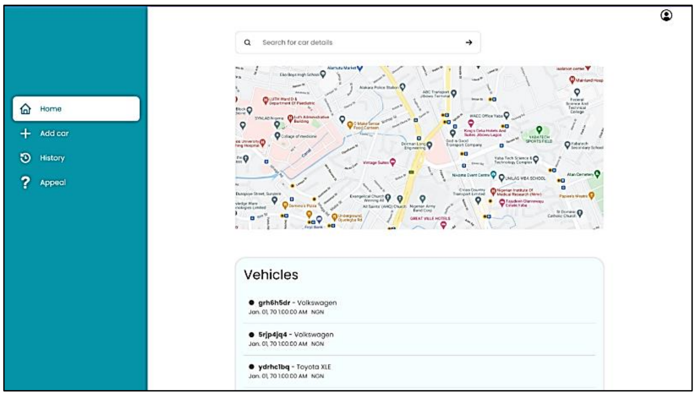

Figure 2: Home Page.
Source: Authors, (2022).

Figure 2 shows a pictorial representation of the homepage which contain different car details and location in different regions

Figure 3: List of Registered Cars.
Source: Authors, (2022).

Figure 3 shows a pictorial representation of the list of registered cars on the website.

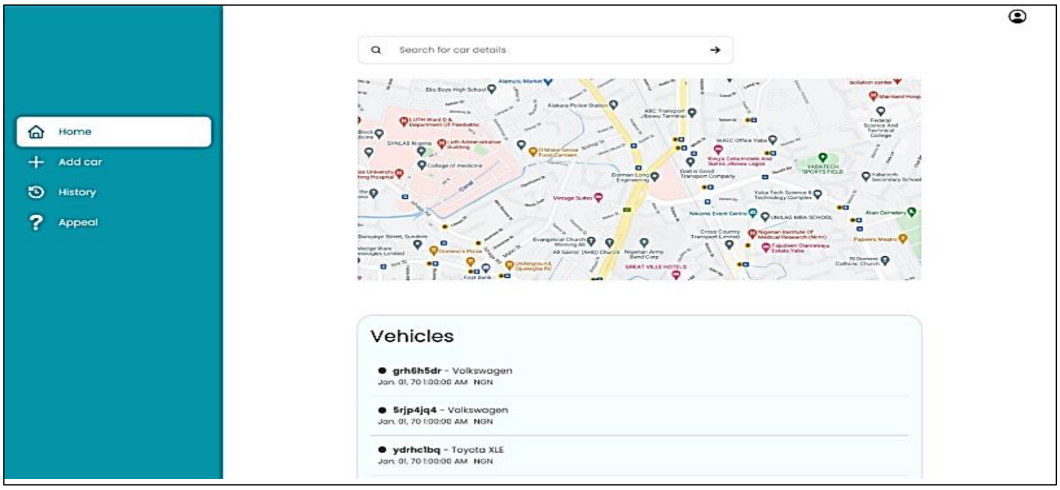

Figure 4: Details of Registered Cars.
Source: Authors, (2022).

Figure 4 contains the name, plate number, and model of the registered cars.

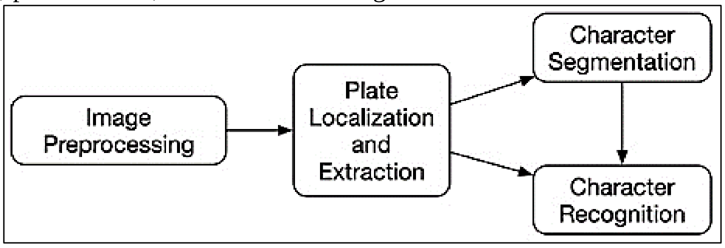

Figure 5: Flowchart for successful execution.
Source: Authors, (2022).

III. RESULTS AND DISCUSSION

This section shows the results of the study with the interpretation of the data obtained.

Table 1: Displaying Results of Success and Failures of our algorithm.

Plate number	Discovered	Authenticity	Plate Number	Discovered	Authenticity
ISDYE	ISD1E	FALSE	06H-100G	06H-100G	TRUE
REP324FL	REP324FL	TRUE	AGE323674	AGE 323674	TRUE
FKJ259FC	FKJ259FC	TRUE	KSF-716HD	KSF-716HD	TRUE
ADK997JB	ADK997JB	TRUE	06H-100G	06H-100G	TRUE
SHM394AA	SHM394AA	TRUE	IJB-566FV	Nil	FALSE
APP456CV	APP456CV	TRUE	IKJ-234GA	32B-234GA	TRUE
THE CEO 1	THE CEO 1	TRUE	IKD-859MN	45G-859MN	TRUE
FKJ-160GP	FKJ-160GP	TRUE	ADK-543GH	ADK-543GH	TRUE
JJJ-267GV	JJJ-267GV	TRUE	BOSS 1Q	Nil	FALSE
LND-129EA	LND-129EA	TRUE	LND-345 BF	Nil	FALSE

Source: Authors, (2022).

Figure 6: Edge Detection.
Source: Authors, (2022).

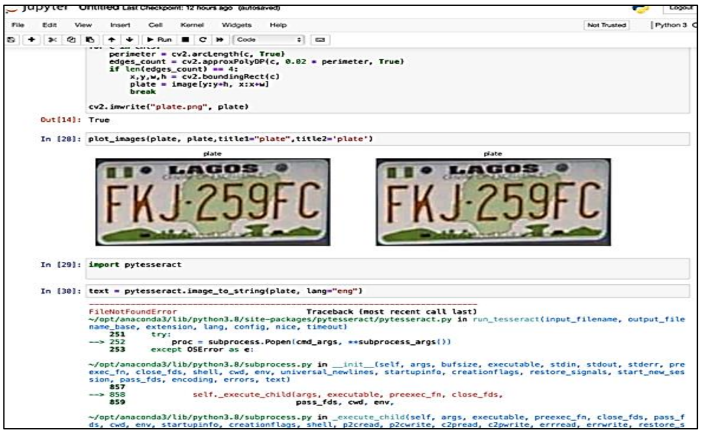

Figure 7: License Plate detected.

Source: Authors, (2022).

Figure 8: Car detection.

Source: Authors, (2022).

Figure 9: Image of a vehicle not successfully detected.

Source: Authors, (2022).

Table 2: Table of Results.

Total Images	Error	% Error	% Success
20	4	20	80

Source: Authors, (2022).

Location Plate mistakes

1. Locates the grids of the bonnet and not the plate of a similarity of shape, intensity, and color (two image failures).
2. Locates headlights of the car (one image failure).
3. Character attached to an impurity; the division does not remove invalid objects (one image failure).

Figure 10: Image of Vehicle.

Source: Authors, (2022).

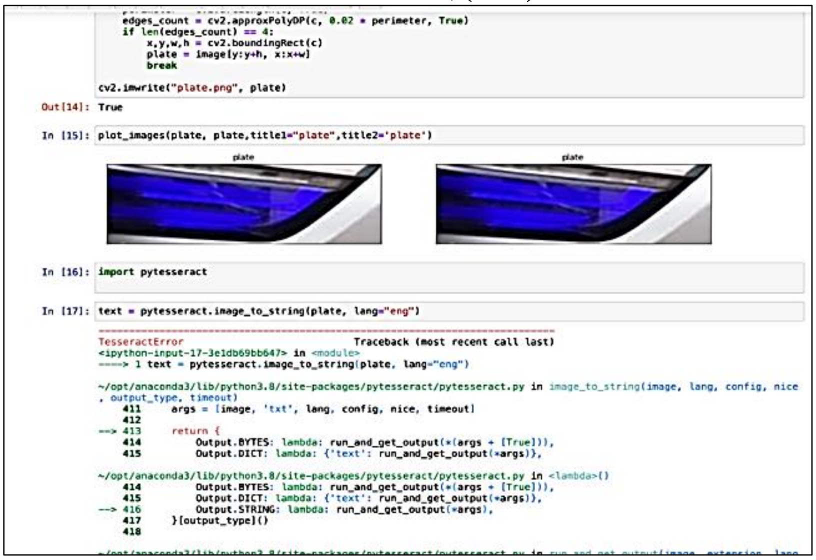

Figure 11: Poor detection.
Source: Authors, (2022).

IV. CONCLUSIONS

In this paper, a system that can obtain Nigerian plate number images through a solar camera was developed with the capability of extracting the text on the number plate, then send to a website (the database) to check for details of registered vehicles. The result from the data obtained shows that each 16 out of the 20 data were read correctly, this amount to an 80% success rate and 20% failure rate. The total elapsed time of recognition is 1561.36 seconds. The average time of recognition of each image is 5.80 seconds. The plate status, environmental conditions and the hardware used to capture the pictures are deterministic important factors for the proper functioning program. Good image preprocessing almost guarantees successful recognition. It is recommended that a proper adaptive mask of the picture should be employed to improve the choice of level to the threshold and not lose information about the shape of the characters found.

V. AUTHOR'S CONTRIBUTION

Conceptualization: Matthew B. Olajide, Najeem O. Adelakun, David S. Kuponiyi, Zaid O. Jagun and Charity S. Odeyemi.
Methodology: Zaid O. Jagun and Charity S. Odeyemi.
Investigation: Matthew B. Olajide and Najeem O. Adelakun.
Discussion of results: David S. Kuponiyi, Zaid O. Jagun and Charity S. Odeyemi.
Writing – Original Draft: Matthew B. Olajide and Najeem O. Adelakun.
Writing – Review and Editing: Matthew B. Olajide and Najeem O. Adelakun.
Resources: Matthew B. Olajide and Najeem O. Adelakun.
Supervision: Matthew B. Olajide and David S. Kuponiyi.
Approval of the final text: Matthew B. Olajide, Najeem O. Adelakun, David S. Kuponiyi, Zaid O. Jagun and Charity S. Odeyemi

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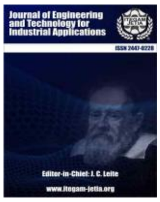

RESEARCH ARTICLE OPEN ACCESS

RADIOLOGICAL HAZARD LEVELS OF CONSTRUCTION ROCKS EXCAVATED FROM QUARRIES IN KERICHO COUNTY, KENYA

Chepngetich Betty[1], Fred Wekesa Masinde[2], Enoch Kipnoo Rotich[3] and Conrad Khisa Wanyama*[4]

[1, 2, 3] Department of Mathematics, Actuarial and Physical Sciences. University of Kabianga. P.O BOX 2030-20200 Kericho, Kenya.
[4] Department of Science, Technology and Engineering, Kibabii University, P.O BOX 1699-50200 Bungoma, Kenya.

[1] http://orcid.org/0000-0003-3555-9464, [2] http://orcid.org/0000-0002-5025-9534, [3] http://orcid.org/0000-0001-7203-6633,
[4] https://orcid.org/0000-0002-3624-7756

Email: bettymutai247@gmail.com, wekesamasinde@yahoo.com, ekipnoo@kabianga.ac.ke, *conradwanyama50@gmail.com

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ABSTRACT

The study determined the natural activity concentration levels of ^{40}K, ^{232}Th and ^{238}U in rocks used for construction from the 15 selected quarries in Kericho County, Kenya through Gamma-ray Spectrometric analysis at the Physical Sciences department of South Eastern Kenya University (SEKU). IAEA procedures were followed from sample collection, preparation, and measurement. Samples were collected, crushed, oven dried at 105℃, weighed and packed in sealed containers and kept for four weeks for secular equilibrium to be achieved between ^{226}Ra and ^{232}Th. The average activity concentration of ^{232}Th, ^{238}U and ^{40}K were 101 ± 5 Bq/kg, 56 ± 3 Bq/kg and 1100 ± 55 Bq/kg and ranged from 41 ± 2 to 138 ± 7 Bq/kg, 26 ± 1 to 116 ± 6 Bq/kg and 512 ± 26 to 1919 Bq/kg ± 96 Bq/kg respectively. The average external and internal hazard indices were 0.8 mSv/y and 0.9 mSv/y respectively. Radium equivalent ranged from 222 ± 11 Bq/kg to 366 ± 18 Bq/kg with an average value of 285 ± 14 Bq/kg which was below the permissible limit of 370 Bq/kg; therefore, the excavated rocks for construction from the selected quarries in Kericho county poses insignificant health risk to the general population and quarry workers.

I. INTRODUCTION

Mineral mining or the extraction of rocks exposes workers to ionizing radiation from the primordial radioisotopes found in the rocks [1]. The radioactive isotopes ^{238}U and ^{232}Th, as well as their decay products, as well as the radioactive isotope ^{40}K which are found in the earth's crust that is soil, rocks and water expose people to ionizing radiation at doses that are either outdoor or indoor [2]. Indoor exposure results from radiations emitted from the building materials such as soil, rocks and even the ground where the building is constructed. Radiations from the primordial radionuclides present in these construction rocks may pose a risk to miners, masons, transporters, the populace around the quarries and inhabitants of the houses built from these rocks if the radiation is beyond the permissible levels [3]. The annual effective dose rate (AEDR) in both the outdoor and indoor settings should not exceed 1mSvy^{-1}and the average radium equivalent (Ra_{eq}) should be less than the permitted maximum of 370 BqKg^{-1} in both the outdoor and indoor environments [4]. Natural radioactivity exposure arising from radiations depends on the geological conditions, and therefore the levels in rocks are different. Quite a few the building materials (soil and rocks) have natural primordial radioisotopes of ^{238}U and ^{232}Th series [5]. The decay series/chain of ^{238}U and ^{232}Th. Potassium-40 adds to the external and internal radiation exposure for residents of rock-built homes where gamma radiation is emitted from walls, ceilings, and floors when radon, thorium and progeny are ingested [6]. Ionizing radiations are emitted when an unstable nucleus decays to be stable [7]. The earth's crust is made of sedimentary rocks, metamorphic rocks, and igneous rocks [8]. Documentations from radiometric surveys show that igneous rocks have elevated levels of ^{40}K, ^{238}U and ^{232}Th [9]. Apart from inhaling radionuclides (radon gases and dust particles), these radionuclides get into our body systems through food uptake found in plants, notably ^{40}K. Human consumption of food grown in regions with potentially elevated levels of background radionuclides is at significant risk [10]. Radium, uranium, and thorium in their natural states and their decay products as well and potassium are examples of NORM materials that have not been altered by human action [11]. The combination of radiation from highly energetic particles, such as the sun and stars that enter the earth's atmosphere (cosmic radiations) and radionuclides, such as ^{238}U and ^{232}Th, their decay products, and the naturally occurring ^{40}K found on the earth's surface forms background radiation that exposes human beings either internally or externally to radioactive substances [12]. Because ^{40}K and ^{14}C are present in food, soil and water, they form internal radiations in human bodies [13]. The current research examined the hazard levels of ^{238}U, ^{232}Th, and ^{40}K on the construction rocks excavated within Kericho county.

II.1 STUDY AREA

The study took place in Kericho County's quarries. It is situated in the Great Rift Valley's southern rift region, $35^0$02` and $35^0$40` east longitude and the equator and latitude $0^0$23` south, with a height of roughly 2002m above sea level, it covers an area of 2111 square kilometres. The county has an estimated population of 901,777 per the 2019 Kenya population and housing census [14]. Samples were collected from the following quarries: Tunnel and Kimondui in Kipkelion West, Kedowa, Jagoror, Kipsirichet and United in Kipkelion East, Rockland, Kisumu Concrete and Rai cement in Soin-Sigowet, Kibingei in Kericho West, Laliat and Chepsetion in Kericho East, Agisiek, Kibugat and Maburo in Bureti sub-county. Figure 1 shows the map of the study area.

Figure 1: Map of Kericho County.
Source: [15].

The selected areas were chosen because most residents and others from neighboring counties source rocks used for construction from Kericho County. Therefore, there is a need for research to determine the safety of materials used for the building of either domestic or commercial houses.

II.2 SAMPLE PREPARATION

Two rocks' samples, each weighing 200g, were collected from each quarry using a 1000ml plastic container, packed and labelled using unique codes. The 30 collected samples were crushed, sieved in 1mm wire mesh, and dried up in an oven at a temperature of 105^0C for 24hrs to enable direct calculations of specific activity concentrations of radioisotopes. The samples were weighed and packed in 200ml plastic containers, tightly closed, and wrapped with aluminum foil to prevent the leakage of uranium, radon, and thorium. The samples were kept for four weeks to achieve secular equilibrium between ^{226}Ra and ^{232}Th [16].

II.3 GAMMA RAY CALIBRATION

Each sample was placed in a detector and monitored for a period 8 hours making it possible to run two samples per day. After background correction on the obtained spectra, for ^{40}K, the gamma peak with a centroid at 1460keV was used, ^{214}Bi (609 keV), 1765 keV for ^{238}U, ^{208}Ac and ^{208}Ti (583keV), 2615 keV for ^{232}Th while ^{214}Pb at 352keV and ^{212}Pb at 239keV photopeak's were used for activities of ^{238}U and ^{232}Th respectively.

II.4 SAMPLE ANALYSIS

II.4.1 Natural Activity Concentrations

The ready to measure rock samples were placed in the lead shielded NaITI gamma detector for an average of 8 hours to accumulate gamma counts and achieve well-formed photo-peaks. The activity of the NORMs was determined using the method of comparison given by equation 1 [17].

$$\frac{M_r A_r}{I_r} = \frac{M_s A_s}{I_s} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

Where; M, A, I, r and s represent mass, activity, intensity, reference and sample respectively.

II.4.2 Radium Equivalent (Ra_{eq})

The phrase radium equivalent refers to the proportionate total of ^{226}Ra, ^{232}Th, and ^{40}K activities based on the premise that $1BqKg^{-1}$ of ^{226}Ra, $0.7BqKg^{-1}$ of ^{232}Th, and $13BqKg^{-1}$ of 40K generate the same gamma dose rate as $1Bqkg^{-1}$ of ^{226}Ra [18].

Calculating the radium equivalent was based on the empirical relationship shown in Equation 2.

$$Ra_{eq} = AC_{Ra} + 1.423AC_{Th} + 0.077AC_K \dots\dots (2)$$

AC_{Ra}, AC_{Th}, and AC_K are the average activity concentrations in $Bqkg^{-1}$ of ^{226}Ra, ^{232}Th, and ^{40}K in $BqKg^{-1}$, respectively.

II.4.3 External Hazard Index (H_{ex})

Radiation from naturally occurring radionuclides found in construction rocks may cause external exposure to gamma radiation, measured using an external hazard index. If the external danger index of the radiation is less than one, the consequences are insignificant [19]. H_{ex} was determined by employing equation 3.

$$H_{ex} = \frac{AC_{Ra}}{370} + \frac{AC_{Th}}{259} + \frac{AC_K}{4810} \dots\dots\dots\dots\dots (3)$$

AC_{Th}, AC_{Ra}, and AC_K represent the average activity concentrations of ^{232}Th, ^{226}Ra, and ^{40}K.

II.4.4 Internal Hazard Index (H_{in})

Inhalation of terrestrial radionuclides due to presences of ^{40}K, ^{232}Th, and ^{238}U (^{226}Ra) in construction rocks causes internal harm [19]. H_{in} was calculated using equation 4 [18].

$$H_{in} = \frac{AC_{Ra}}{185} + \frac{AC_{Th}}{259} + \frac{AC_K}{4810} \dots\dots\dots\dots\dots (4)$$

AC_{Ra}, AC_{Th}, and AC_K are the mean activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in $BqKg^{-1}$ respectively. If the value is less than a unit, then the effects of the radiation are negligible to human organs [5].

III. RESULTS AND DISCUSSIONS

III.1. NATURAL ACTIVITY CONCENTRATIONS

Due to unequal distribution of primordial radionuclides and geological location, activity concentrations varied from one quarry to another. The average activity concentration of ^{232}Th, ^{283}U, and ^{40}K were 102 ± 5 Bq/kg, 56 ± 3 Bq/kg and 1845 ± 92 Bq/kg and ranged from 41 ± 2.09 to 138 ± 7 Bq/kg, 27 ± 1 to 116 ± 6 Bq/kg and 1042 ± 52 to 2690 ± 135 Bq/kg respectively. ^{238}U, ^{232}Th and ^{40}K average activity concentrations were above the world's average value of 50Bq/kg, 50Bq/kg and 500Bq/kg respectively. All the quarries showed a higher value for activity concentration of potassium-40 compared to world's average value. Seven quarries had a value of activity concentrations of ^{238}U being below the world average value. The average activity concentration of ^{40}K was higher compared to that of ^{232}Th and ^{238}U and is attributed to the minerals such as phosphate, quartzite, sandstone, and granite rich radioactive materials. Table 3.1 shows the activity concentration of the radionuclides from the collected samples.

Table 1: Activity Concentration of the Collected Samples.

Average Activity Concentration of the Radionuclides (Bq/kg)			
	^{232}Th	^{226}Ra	^{40}K
MIN	41±2	26±1	512±26
MAX	138±7	116±6	1919±96
AVERAGE	101±5	56±3	1100±55

Source: Authors, (2022).

Though the reported findings on activity concentrations being higher than the world's recommended values, they are far much below the exemption limits of 1000Bq/kg, 1000 Bq/kg and 100000 Bq/kg for ^{232}Th, ^{238}U and ^{40}K respectively, thus making the rocks excavated in Kericho county quarries safe for use.

III.2. RADIUM EQUIVALENT

The radium equivalent was determined using equation 2 and the results were graphically illustrated in Figure 2. The mean radium equivalent for the samples was 344 ± 17 Bq/kg which does not exceed the proposed radioactivity criterion levels hence below the recommended maximum value of 370 $Bqkg^{-1}$ [9]. Radium equivalent for all the individual samples was graphically represented in Figure 2.

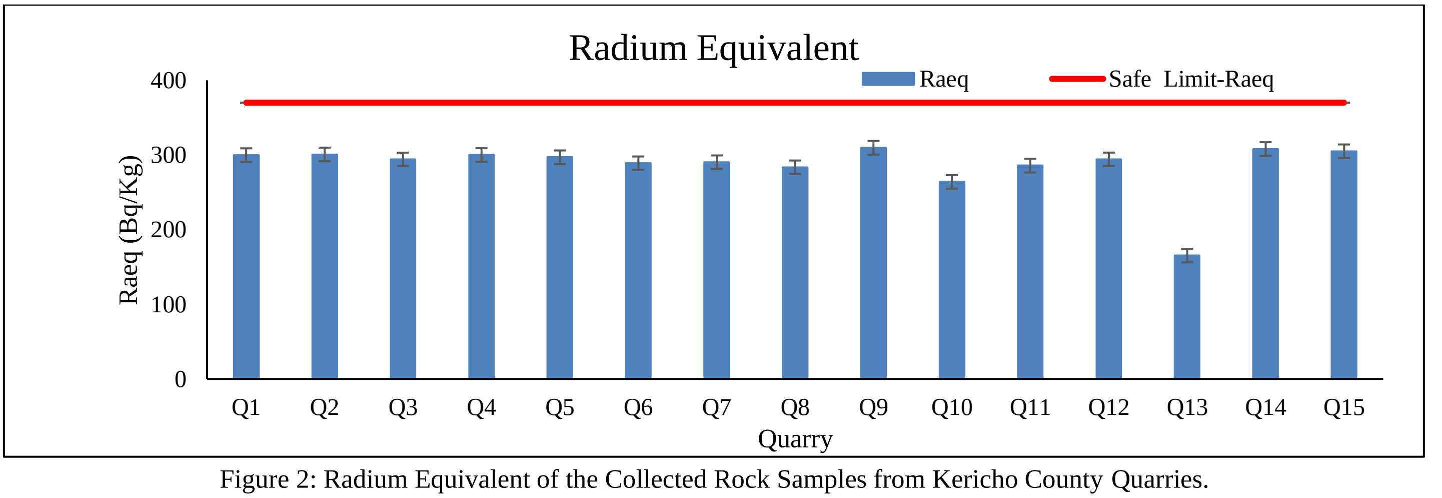

Figure 2: Radium Equivalent of the Collected Rock Samples from Kericho County Quarries.
Source: Authors, (2022).

All the collected samples recorded a radium equivalent which was less than the world's recommended maximum value of 370 Bq/kg as shown in Figure 2. The radium equivalent values shown in Figure 3.1 ranged between 165 ± 8 Bq/kg and 309 ± 15 Bq/kg. Therefore, the construction rocks pose minimal radiological risk since all the radium equivalent values at the study area were less than the world's permissible maximum value of 370 Bq/kg [20].

III.3. HAZARD INDICES

External exposure due to gamma radiations was determined using equation 3. The values obtained averaged at 0.8 mSv/y, which was less than the worlds recommended value of 1 mSv/y [21]. Determination of internal exposure due to inhalation and ingestion of primordial radionuclides was done by employing equation 4. H_{in} averaged at 0.9 mSv/y, which was less than the worlds recommended value of 1 mSv/y. Figure 3 shows the hazard indices values obtained from the analysis of the collected samples.

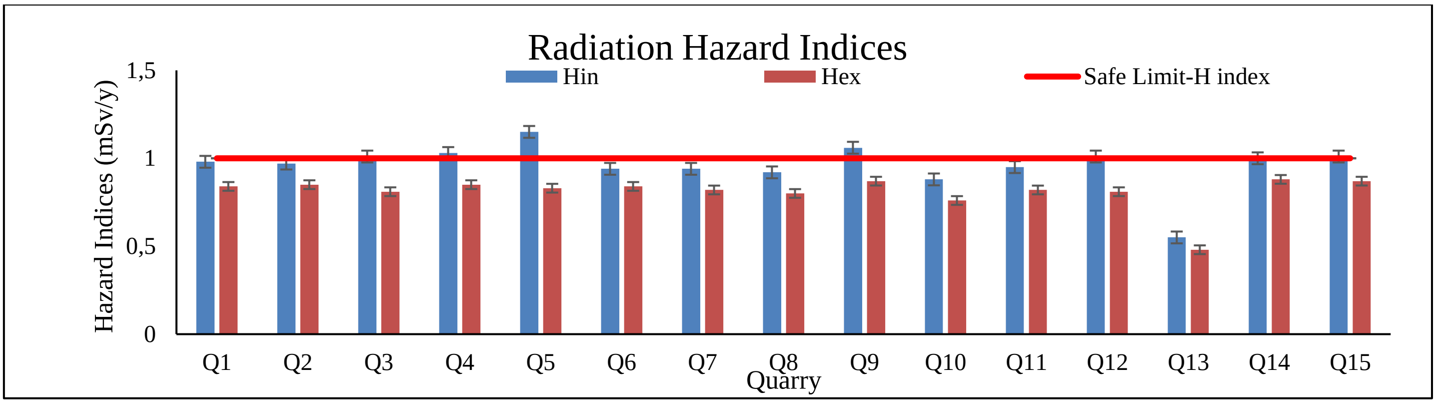

Figure 3: Hazard Indices of the Collected Rock Samples from Kericho County Quarries.
Source: Authors, (2022).

From Figure 3, the minimum and maximum external hazard index were 0.4 ± 0.02 and 0.8 respectively. H_{in} obtained ranged from 0.5 mSv/y to 1.1 mSv/y. Most samples posted hazard indices below a unit while the rest of the samples were within the recommended criterion limit of 100 mSv/y. This was because of varying activity concentration of ^{238}U, ^{232}Th and ^{40}K. This made some samples hazard indices to be higher than a unit but still below the recommended exceptional value of 100 mSv/y hence posing minimal significant potential health threat to the general population.

IV. CONCLUSIONS

Determination of the natural radioactivity levels in rocks used for construction in Kericho County from selected quarries has been done using NaI(TI) gamma ray spectrometer. The average activity concentration of ^{232}Th, ^{238}U, and ^{40}K were 101 ± 5 Bq/kg, 56 ± 3 Bq/kg and 1100 ± 55 Bq/kg respectively. The radium equivalent ranged from 165 ± 8 Bq/kg to 309 ± 15 Bq/kg with an average value of 285 ± 14 Bq/kg which is below the permissible limit of 370Bq/kg. The average external hazard index was 0.8 mSv/y while the average internal hazard index was 0.9 mSv/y. They were less than acceptable limit of 1mSv/y. Though the activity concentrations were above the worlds recommended values, they were below the exemption limits, thus, rocks excavated from Kericho county are safe for use. Since this research work did not take into consideration Radon concentration in the underground water sources around the quarries where rocks are excavated, there is need for determination of Radon – 222 concentration levels in underground water sources around the studied quarries.

V. AUTHOR'S CONTRIBUTION

Conceptualization: Chepngetich Betty, Fred Wekesa Masinde, Enoch Kipnoo Rotich and Conrad Khisa Wanyama.
Methodology: Chepngetich Betty, Fred Wekesa Masinde, Enoch Kipnoo Rotich and Conrad Khisa Wanyama.
Investigation: Chepngetich Betty, Fred Wekesa Masinde, Enoch Kipnoo Rotich and Conrad Khisa Wanyama.
Discussion of results: Chepngetich Betty, Fred Wekesa Masinde, Enoch Kipnoo Rotich and Conrad Khisa Wanyama.
Writing – Original Draft: Chepngetich Betty, Fred Wekesa Masinde, Enoch Kipnoo Rotich and Conrad Khisa Wanyama.
Writing – Review and Editing: Chepngetich Betty, Fred Wekesa Masinde, Enoch Kipnoo Rotich and Conrad Khisa Wanyama.
Resources: Chepngetich Betty, Fred Wekesa Masinde, Enoch Kipnoo Rotich and Conrad Khisa Wanyama.
Supervision: Chepngetich Betty, Fred Wekesa Masinde, Enoch Kipnoo Rotich and Conrad Khisa Wanyama.
Approval of the final text: Chepngetich Betty, Fred Wekesa Masinde, Enoch Kipnoo Rotich and Conrad Khisa Wanyama.

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VII. CONFLICT OF INTEREST

The author declares no conflict of interest regarding publication of this paper.

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