Journal of Medicine, Engineering, Environmental & Physical Sciences

JOMEEPS

Academic research podium for scientists and technologists

Vol. 1, No. 1, June-July 2023 Issue

Journal of Medicine, Engineering, Environmental & Physical Sciences

JOMEEPS

Academic research podium for scientists and technologists

Volume 1, Number 1, June-July 2023

Published by

Klamidas Communications Ltd
No 42 Ajose Adeogun Street, Utako District, Abuja
Tel: (+234) 08033370200
Website: https://klamidas.com/JOMEEPS
Email: JOMEEPS@klamidas.com

in partnership with

The Division of General Studies
Chukwuemeka Odumegwu Ojukwu University,
Anambra State, Nigeria

Journal of Medicine, Engineering, Environmental & Physical Sciences
JOMEEPS
Academic research podium for scientists and technologists

JOMEEPS Editorial Board

About JOMEEPS Journal

Journal of Medicine, Engineering, Environmental and Physical Sciences (JOMEEPS) is an international, open-access journal published every two months (January, March, May, July, September, and November) by the Division of General Studies, Chukwuemeka Odumegwu Ojukwu University (COOU) and Klamidas.com, a notable academic publisher and webhost. It is published at the end of the month. The publishers' goal is to enhance and encourage cross-fertilization of ideas among scientists and technologists. Other benefits include: life-time archive of published papers on JOMEEPS web pages and on Google Scholar, free plagiarism check and paper amendment advisory services, free proof-reading/editing services, and availability of share buttons on every paper contributor's JOMEEPS journal page. Website: klamidas.com/jomeeps. Submit paper to jomeeps@ klamidas.com.

CITING ARTICLES IN THIS JOURNAL

AMA

Salvator NI, Finbarrs-Bello E, Ikemefuna OI, Ejuiwa MC, Ugwu V. Protective Roles of Quercetin, Vitamin C and Pyridoxine on Lead Neurotoxicity via Enhanced Haematopoietic and Antioxidants Components. *Journal of Medicine, Engineering, Environmental and Physical Sciences*, 2023;1(1): 7-22. Published July 2023. https://klamidas.com/jomeeps-v1n1-2023-01/

APA

Salvator, N.I., Finbarrs-Bello, E., Ikemefuna, O.I., Ejuiwa, M.C., & Ugwu, V. (2023). Protective Roles of Quercetin, Vitamin C and Pyridoxine on Lead Neurotoxicity via Enhanced Haematopoietic and Antioxidants Components. *Journal of Medicine, Engineering, Environmental and Physical Sciences*, 1(1), 7-22. https://klamidas.com/jomeeps-v1n1-2023-01/

Journal of Medicine, Engineering, Environmental & Physical Sciences

JOMEEPS

Academic research podium for scientists and technologists

Vol. 1, No. 1, June-July, 2023

Table of Contents

Protective Roles of Quercetin, Vitamin C and Pyridoxine on Lead Neurotoxicity via Enhanced Haematopoietic and Antioxidants Components

By

Nnachi Ifenna Salvator, Elizabeth Finbarrs-Bello, Ozor Ignatius Ikemefuna, Mba Christian Ejuiwa, & Vivian Ugwu

Abstract

Background: The harmful effects of lead exposure, especially its effect on the nervous system, raise serious concerns worldwide. This study is aimed at evaluating the effect of Quercetin, Vitamin C and Pyridoxine on Haematology, biochemical and histology of the cerebral cortex on lead induced neurotoxicity using adult Wistar rat models. **Materials and Methods:** Forty male Wistar albino rats were divided into five groups: control, lead only, lead + Quercetin, lead + Pyridoxine, lead and Vitamin C. 100mg/kg/bw of lead was used to induce-toxicity for 7 days and treated with the following: Quercetin, Pyridoxine and Vitamin C were administrated orally respectively for 14 days. Hematological and biochemical samples were collected in three phases. The cerebral cortex was examined under light microscopy after H&E staining. **Results**: lead decreased all hematological parameters (PCV, WBC, RBC, HB and Platelets) examined and in the biochemical parameters, decreased slightly SOD, increased MDA and reduced significantly (p values) GSH. Quercetin, Vitamin C and Pyridoxine had strong curative effects on both hematological and biochemical parameters. On the histology, lead revealed mild glial cell infiltration. All treatment groups showed normal neuronal cells. **Conclusion:** Quercetin, Vitamin C and Pyridoxine showed neuroprotective effects against lead-induced neurotoxicity; therefore, they can be used as routine supplements against lead toxicity in endemic communities.

Keywords: Quercetin, Pyridoxine, Lead, Ascorbic acid, neurotoxicity, lipid peroxidation

Introduction

Lead (Pb) is one of the most widely used heavy metals, especially in batteries, paint pigments, and plastics. This heavy use has produced local and global contamination of the air, soil, and water originating from lead-based pipes. The effect of exposure to Pb vary from mild to severe, depending on the degree of exposure, and is referred to as lead toxicity (Raymond, 2011). The nervous system (central and peripheral components) is the primary target of lead poisoning or toxicity (Brent, 2006; Bellinger, 2004). Pb toxicity is also known to induce a broad range of hematological, biochemical, and histomorphological dysfunctions in lab animals and humans (Hsu & Guo, 2002; Pande & Flora

2002). This is characterized by persistent vomiting, anemia, encephalopathy, lethargy, delirium, convulsions and coma, and death in extreme cases (Flora et al., 2006; Pearce, 2007). One of the possible mechanisms underlying Pb-induced toxicity or poisoning is its ability to induce oxidative stress in blood and other tissues, which contributes to the pathogenesis of poisoning by interfering with the delicate prooxidant/antioxidant balance that exists within the mammalian cells. Several investigators suggest a possible involvement of reactive oxygen species (ROS) in Pb-induced toxicity (Adonaylo & Oteiza, 1999; Pande & Flora, 2002; Hsu & Guo, 2002) where Pb increased lipid peroxidation indicator the malondialdehyde (MDA) and decreased the activities of antioxidants enzymes: glutathione peroxidase (GPx), and superoxide dismutase (SOD) in the rat brains (Kuhad & Chopra, 2007).

Antioxidants have been identified to protect the neurons against various experimental neurode generative conditions (Kuhad & Chopra, 2007). Vitamin C, vitamins E and B6, zinc, and selenium are antioxidants used to reverse Pb-mediated toxicity by ameliorating oxidative stress status (Hsu & Guo, 2002). Flavonoids have now become a topic of interest due to their beneficial effects on different diseases. Quercetin is a natural flavonoid, ubiquitously found in common fruits and vegetables such as onions, broccoli, and apples (Sriraksa et al., 2016). Studies have reported that quercetin exhibits substantial antioxidants property, has the ability to scavenge free radicals, and aids many biological processes involved in oxidative stress (Formica et al., 1995). This study, therefore, evaluates the hematological, biochemical, and histomorphological effects of Quercetin, Vitamin C and Pyridoxine on lead-induced neurotoxicity in adult Wistar rats.

Materials and Methods

Procurement of Compounds, Chemical and Drugs

5g of Quercetin was procured from Zigma, Aldrich USA. Lead (Pb) weight of 5.2g was procured from registered chemical store at Ogbete main market Enugu Metropolis, Nigeria. 5g of Vitamin C (ascorbic acid) and Pyridoxine (Vitamin B6) were procured from Omaryon group of companies Enugu Metropolis, Nigeria.

Animal Handling

Forty (40) Wistar rats weighing between 150 - 250g were purchased from the animal house of the University of Nigeria, Nsukka, Enugu State, Nigeria. The rats were housed at the animal facility of the College of Medicine, Enugu State University of Science and Technology Enugu Nigeria. The rats were housed for a period of 4 weeks to attain desired weights and to get them acclimatized in their new environment. The rats were fed pelleted rat chow (Vital, Nig. Ltd.)

and allowed water *ad libitum.* Thereafter, the rats were grouped into five (5) groups; each group had eight rats housed in two different cages 2 (n=4) per group. The rats were kept in ventilated cages at optimum temperature 28^{o}C with 12 hours light/dark cycle, and humidity of 60%. The study was reviewed and approved by the Faculty Ethics and Research Committee.

Induction of Lead Toxicity

The used dose for lead induction was adopted from Highab et al., (2018), 100 mg /kg/bw of lead was administered orally for 7days across groups. Thereafter, Quercetin was administered as modified using methods of Tian *et al.*, 2019, at 50mg /kg / bw). Vitamin C and Pyridoxine (Vitamin B6) were used as standard drug for the experiment, the doses were adopted from Razmkon *et al.*, (2011) at dosage 500 mg /kg /bw for Vitamin C and 100 mg/ kg/ bwt for Pyridoxine (Vitamin B6).all treatment were administered via oral gavage for 14 days.

Experimental Design

Group	Description of Treatments
GROUP A	Control group – 0.1mL Normal Saline
GROUP B	Treatment group: Lead 100 mg/kg + Pyridoxine 100 mg/k/ body weight
GROUP C	Treatment group: Lead 100 mg/kg + Quercetin 50 mg/k/ body weight
GROUP D	Treatment group: Lead 100 mg/kg + Vitamin C 500 mg/kg/body weight
GROUP E	Negative control: Lead 100 mg/kg/body weight

Hematological and Biochemical Evaluations

Blood samples were collected from all the rats thrice to form a baseline, after induction and after treatment as well as parameter for post induction. Materials used for collection of samples are; capillary tubes and plain EDTA bottles. The following were evaluated; PCV, WBC, RBC, HB, and Platelets for hematological studies using standard protocols. While serum Superoxide dismutase (SOD), Malondialdehyde (MDA) & Glutathione (GSH) antioxidant marker enzyme were determined using the respective kit in accordance with manufacturers recommended protocols (Fortress diagnostic limited UK). Measurement of Malondialdehyde (MDA), a prototype of the thiobarbituric reactive substances (TBARS) as a biomarker of lipid peroxidation and oxidative stress using modified thiobarbituric acid method (Todorova et al., 2005).The IBM SPSS package (IBM Corp., IBM SPSS Statistics for Windows, Version 25.0, Armonk, NY, USA),was used to analyze the data. Descriptive statistics was evaluated for hematological and antioxidative markers and presented as means and standard deviations. An analysis of variance test (One-way ANOVA) was used for comparison of the means for the hematological, and antioxidant enzymes. The P values for comparing means were considered significant at $p \geq 0.05$.

Termination of Study and Tissue Collection

On the 15th day (day one post treatment), the rats in all groups were sacrificed under light etherand the brains were harvested. The brains were fixed in 10% neutral formal saline for 48hrs. Thereafter the cerebrum were isolated for routine paraffin processing and stained with Haematoxylin and Eosin. Representative photomicrographs were captured after the interpretation.

Results

Hematological Analysis

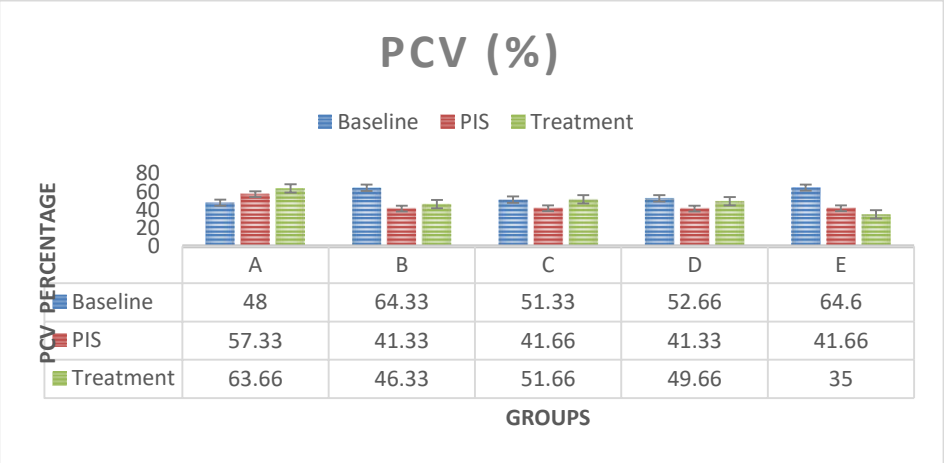


Figure 1: Shows PCV test results across groups. The PCV values for the baseline study, the post induction study (2nd study) and post treatment study (3rd study) were distinguished. In group E (Lead only), the PCV values regressed with continuous administration. Treatment groups B, C and D was observed to have increased PCV values after treatment which is similar when compared to observations in control group A. However, PCV values were not significant (P > 0.05) in paired sample correlations across groups in 2nd and 3rd study.

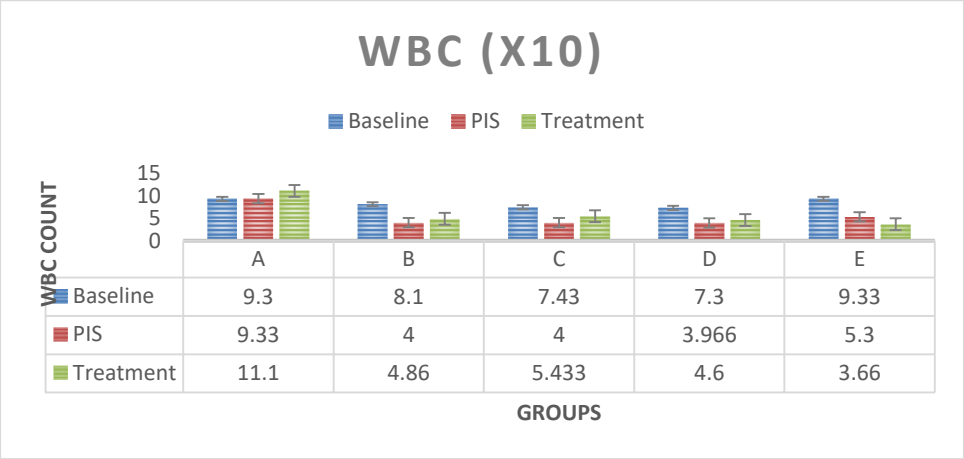
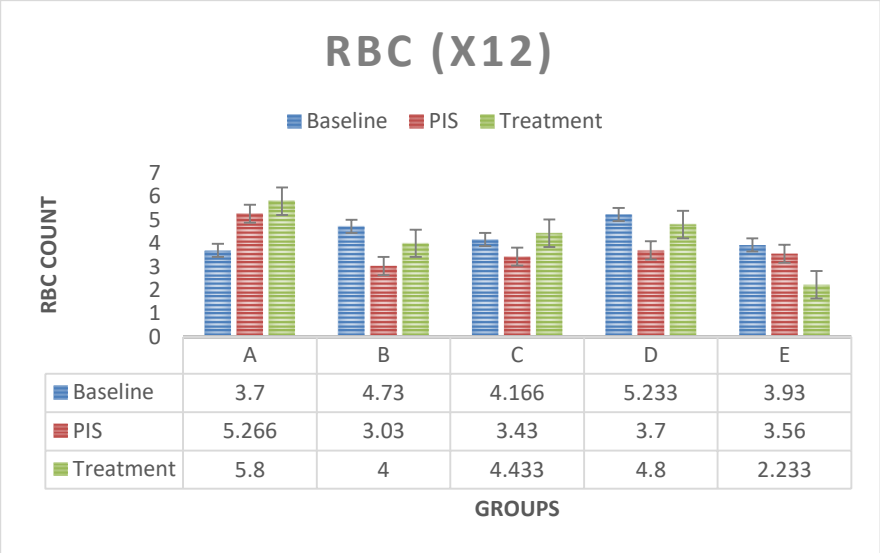
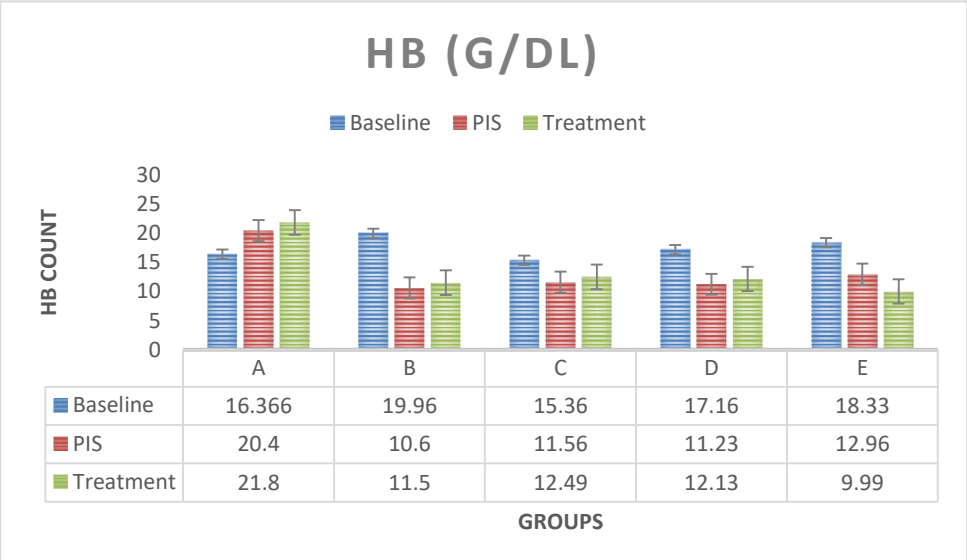


Figure 2: Shows WBC test results across groups. The WBC values for the baseline study, the post induction study (2nd study) and post treatment study (3rd study) were distinguished. In group E (Lead only), the WBC count was significantly lower ($P < 0.05$) compared to the control group A and treatment groups B, C and D. WBC values was observed to increase after treatment across treatment groups. WBC count was also significant ($P < 0.05$) in paired sample correlations across groups in 2nd and 3rd studies respectively.



	A	B	C	D	E
Baseline	3.7	4.73	4.166	5.233	3.93
PIS	5.266	3.03	3.43	3.7	3.56
Treatment	5.8	4	4.433	4.8	2.233

Figure 3: RBC test results across groups. The RBC values for the baseline study, the post induction study (2nd study) and post treatment study (3rd study) were distinguished. RBC values was reduced in the post induction study (2nd study) and increased at the treatment study across treatment groups (B, C & D) in comparison to lead only (E) group, which registered steady decline in RBC values. Paired sample correlates across groups in 2nd study and 3rd study groups also showed no significant difference ($P > 0.05$).



	A	B	C	D	E
Baseline	16.366	19.96	15.36	17.16	18.33
PIS	20.4	10.6	11.56	11.23	12.96
Treatment	21.8	11.5	12.49	12.13	9.99

Figure 4: The figure above shows HB test results across groups. The HB values for the baseline study, the post induction study (2nd study) and post treatment study (3rd study) were distinguished. Hemoglobin values was lower with continuous administration in group E (lead only group), in comparison to control group A and treatment group B, C and D. however, HB values was seen to reduce in the post induction study results and increase in the treatment study result across treatment groups. hemoglobin was significant ($P < 0.05$) in paired sample correlation across groups in post induction (2nd study) and post treatment (3rd study) groups.

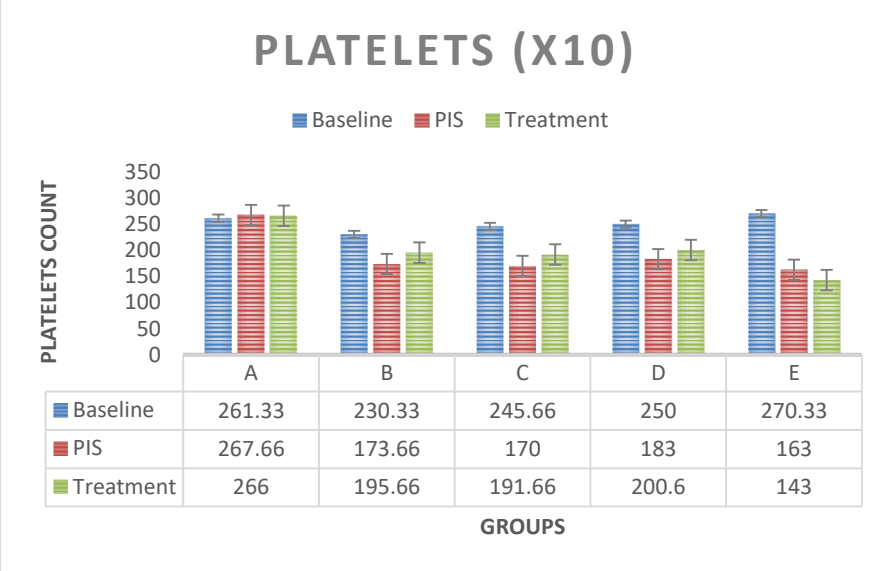


Figure 5: Platelets test results across groups. The platelets values for the baseline study, the post induction study (2nd study) and post treatment study (3rd study) were distinguished. Platelets values were continuously decreased in group E (Lead only) but there was no difference between treatment groups C, D and B. Platelet values were reduced in post induction study and increased in treatment group across treatment groups in comparison to control group A. However, paired sample correlations were significant ($P < 0.05$) across groups.

Biochemical: Antioxidant Evaluation

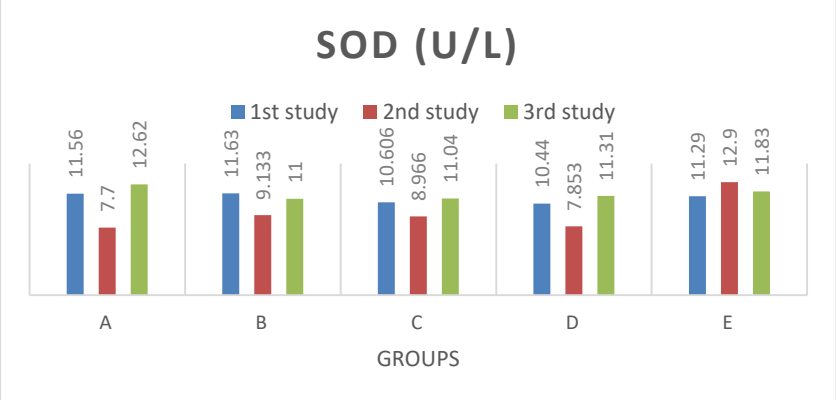


Figure 6; Shows SOD test results across groups. The SOD values for the baseline study, the post induction study (2nd study) and post treatment study (3rd study) were distinguished. There was no significant difference (*P*> 0.05) in SOD values across all groups. Also consistent with paired sample correlation of 2nd and 3rd study.

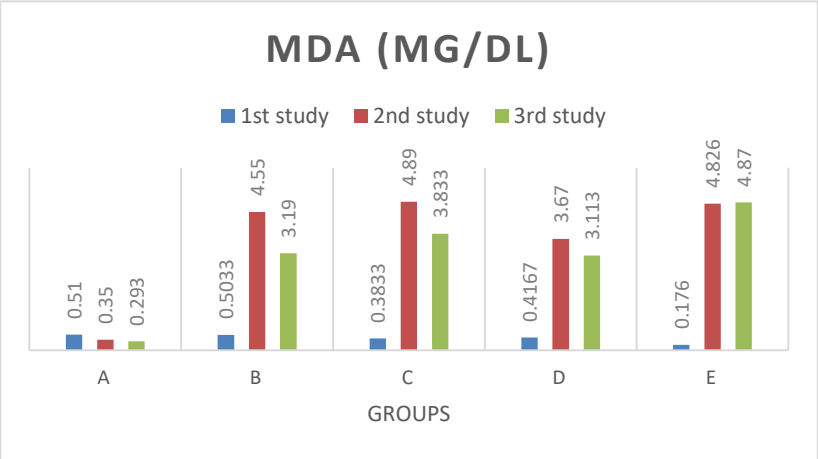


Figure 7; Shows MDA test results across groups. The MDA values for the baseline study, the post induction study (2nd study) and post treatment study (3rd study) were distinguished. In group E (lead only), MDA values increased at continuous induction of lead in comparison to control group A, treatment group B (lead and pyridoxine), C (lead and quercetin) and D (lead and ascorbic acid) where values were reduced after treatment. Values were significant at *P*< 0.05 across groups. Also consistent with findings from paired sample correlation.

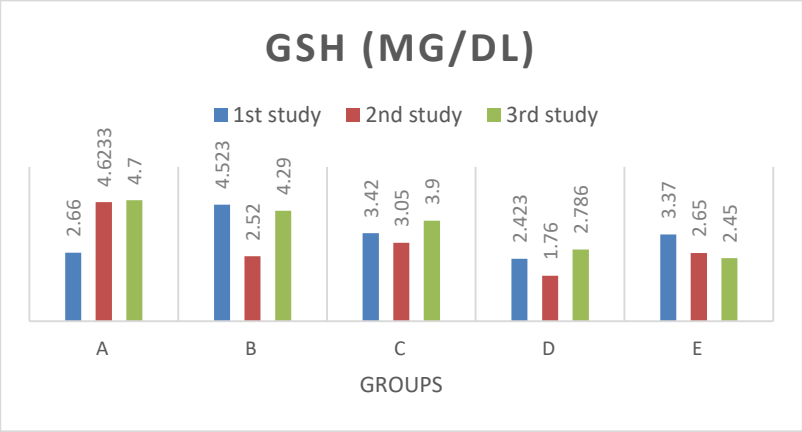


Figure 8: Shows GSH test results across groups. The GSH values for the baseline study, the post induction study (2nd study) and post treatment study (3rd study) were distinguished. GSH values continuously decreased in lead only group (group E), while there was notable increase in GSH values of treatment groups. There was significant difference (*P*> 0.05) in GSH post treatment values when compared with results of the baseline studies across group.

Histomorphological analysis

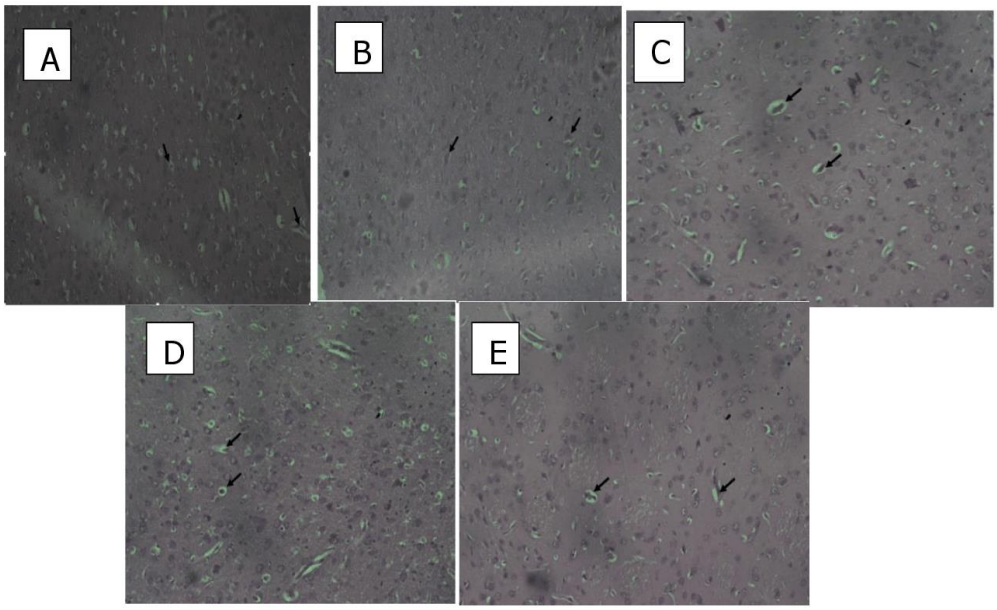


Figure 9; Sections of temporal cortices: (A) control rat (normal saline only)neuronal cells (arrow). cytoarchitecture appears normal. (B). Lead and Pyridoxine treated the cytoarchitecture appears normal with neuronal cells (arrow) (C) Lead and Vitamin C the cytoarchitecture appears normal with neuronal cells (arrow) (D) Lead and quercetin treated the cytoarchitecture appears normal with neuronal cells (arrow) (E) Lead only distortion of the cytoarchitecture (arrow) with mild glial cell infiltration. H&E. x200.

Discussion

Lead poisoning is known to cause iron deficiency which in turn is a strong contributing factor in the etiology of anemia (Staudinger & Roth, 1998). Anemia is classified as macrocytic, normocytic, or microcytic based on the size of red blood cells and the amount of hemoglobin (Sarma, 1990). A low level of hemoglobin reflects reduced PCV value, which is defined as the ratio of the RBC volume to the total blood volume (Beutler & Waalen, 2003). Additionally, anemia can be hypochromic when the MCHC value is low.In this study, lead toxicity was evident owing to the slightly decreased PCV and RBC values (Fig 1 & 3) across treatment groups. This is consistent with the findings of Mahdi *et al*., (2013) in a clinical study on lead-exposed workers. Also, WBC, HB, and Platelets count greatly decreased after induction of lead across all treatment groups (Fig 2, 4 & 5).This is consistent with the findings of previous studies (Omotayo *et al.*,2022; Mahdi *et al.*, 2013; Nabil *et al.*, 2012; Mugahi *et al.*,2003).

Vitamin C was also observed to show curative effects by increasing PCV, RBC, WBC, HB and Platelets count after observed reduction by lead

administration.This was attributed to its functional ability to donate reducing equivalents to prevent the formation of reactive oxygen that damage the RBC. This finding is in line with Ozor, (2020). In another study, ascorbic acid demonstrated a substantial rise in RBC, and WBC in ascorbic acid therapy (Masar *et al.,* 2021). Pyridoxine also exhibited a similar effect as vitamin C on the PCV, RBC, WBC, HB, and Platelets counts. This is in line with the findings of Boleslaw *et al.,* (2019). Quercetin enhanced all the blood parameters evaluated: PCV, RBC, WBC, HB, and platelets count. This is suggestive of haematopoietic enhancing property and affirms reports supporting quercetin supplementation enhanced RBC, WBC HB, PCV and Platelets count (Yahaya *et al.,* 2020; Kasmi *et al.,* 2018; Keskin *et al.,*2016; Selvakumar *et al.,* 2013; Mahmoud *et al.,* 2013).

Antioxidants play a vital role in mitigating the effect of oxidative stress on tissues and observations in this study showed SOD values after induction of lead were reduced but not significant across groups. Other studies have earlier reported similar outcomes (Jin *et al.,* 2006; Ahmed *et al.,* 2008). However, significant a increases in SOD activity has been reported in lead-exposed workers (Kasperczyk *et al.,* 2009; Rendon-Ramirez *et al.,* 2014). Lead toxicity level is evident as an increased level of MDA recorded in this study. Thus is consistent with several studies which found MDA levels to be significantly higher in lead-exposed groups(Tenchova *et al.,* 1997; Ye *et al.,* 1999, Yucebilgiç *et al*., 2003, Gurer-Orhan *et al*., 2004, Kasperczyk *et al*., 2013, Oktem *et al*. 2004, Patil *et al.,* 2006; Garçon *et al.,* 2007; Ergurhan-Ilhan *et al.,* 2008; Khan *et al.,* 2008, Mohammad *et al.,* 2008, Grover *et al.,* 2010, Permpongpaiboon *et al.,* 2011; Singh *et al,,* 2013). Further findings from this study also showed a significant decrease in GSH values on exposure to lead and several studies also identified a reduction in GSH levels in lead-exposed group (Mohammad *et al.,* 2008; Feksa *et al,* 2012; Kasperczyk *et al,* 2013). However, few studies identified increased GSH levels in lead exposed group (Gurer-Orhan *et al.,* 2004; Conterato *et al.,* 2013).

Evident from our findings quercetin considerably reduced MDA levels and increased SOD and GSH levels, thereby reaffirming its already described antioxidant properties (Yagmurca *et al.,*2015) and confirming the protective properties of Quercetin via the regulation of antioxidant and lip peroxidation entities (Polat et al., 2006; Ikizler *et al.,* (2017). Vitamin C reduced lead-induced oxidative stress by decreasing MDA levels while increasing SOD and GSH levels. Vitamin C has the tendency to ameliorate oxidative stress levels (Bailey *et al.,* 2011; Ozor, 2021). Vollaard *et al,* (2005) also posited that Vitamin C supplementation decreased serum MDA in exercise-induced oxidative stress. Pyridoxine also improved antioxidant markers. Pyridoxine supplementation exerted antioxidant and lipid profiles oflead-induced neurotoxicity (Tas *et al.,* 2017).

Histological observations revealed normal cytoarchitecture of the temporal cortices of the treated groups but not lead which revealed mild glial infiltrations. This was attributed to the lead effect on the cortex.Lead acetate caused mild histomorphological alterations in the brain (Jarrar *et al.*, 2012) and dose- dependant cellular degenerative changes (Highab *et al.*, 2018). Thus, lead exhibited a neurotoxic effect while the treatment quercetin, vitamin C, and pyridoxine exerted neuroprotective potential. This result was consistent with previous studies which reported the protective and antioxidant roles of quercetin, vitamin C, and pyridoxine (Vollard *et al*, 2005; Ikizler et al, 2017; Amanda *et al*, 2019; Ozor, 2021). Quercetin, particularly, enhances the survival of neuronal cells in the cerebral cortex (Khan *et al*, 2018).

Conclusion

Lead-induced oxidative stress consequently altered hematological parameters and temporal cerebral microstructure. The treatments with quercetin, ascorbic acid, and pyridoxine mitigated the adverse effect of lead via hematopoietic, antioxidant, and neuroprotective mechanisms.

Conflict of Interest

The authors declared that the research was conducted in the absence of any commercial or financial relationship that could be construed as a potential conflict of interest.

Acknowledgement

We thank the staff of the histology laboratory for providing the technical assistance.

Author Contributions

FBE: conception and design and supervised the research; MEC: wrote the draft; assembled and analyzed the histology; NIS and VU: performed the study, contributed to the discussion, reviewed; OII: review literature and edited the draft. All authors read and approved the manuscript.

References

Adonaylo, A., and P. Oteiza (1999). Lead intoxication: Antioxidant and oxidative damage in rat brain. Toxicology. 135: 77.

Al-kurdy, M. (2021). Effect of ascorbic acid supplement on hematological parameters and some enzyme activities of Male Rabbits. Annals of the Romanian society for cell biology. 25.2758-2764.

Amanda, D., Giustina, F, P. (2019). Vitamin B6 reduces oxidative stress in lungs and liver in experimental sepsis. Biological Sciences. An. Acad. Bras. Ciênc. 91 (04); https://doi.org/10.1590/0001-3765201920190434

Bailey, C D. M., Williams, J. A., Betts, D., Thompson, T. L. (2011). Oxidative stress, inflammation and recovery of muscle function after damaging exercise: effect of 6-week mixed antioxidant supplementation. European Journal of Applied Physiology, vol. 111, no. 6, pp. 925–936,

Bellinger, D.C. (2004). Lead. Pediatrics.113:1016–1022.

Beutler, E., Waalen, J. (2006). The definition of anemia: what is the lower limit of normal of the blood hemoglobin concentration? Blood.;107(5):1747–50.

Brent, J.A. (2006). Review ofMedical Toxicology. Clin Toxicol.;44:355–355.

Conterato, G.M., Bulcao, R.P., Sobieski, R., Moro, A.M., Charao, M.F., de Freitas, F.A.,et al. (2013). Blood thioredoxin reductase activity, oxidative stress and hematological parameters in painters and battery workers: relationship with lead and cadmium levels in blood. J Appl Toxicol 33(2):142–150. doi:10.1002/jat.1731

Ergurhan-Ilhan, I., Cadir, B., Koyuncu-Arslan, M., Arslan, C., Gultepe, F.M., Ozkan, G. (2008) Level of oxidative stress and damage in erythrocytes in apprentices indirectly exposed to lead. Pediatr Int 50:45-50

Feksa, L.R., Oliveira, E., Trombini, T., Luchese, M., Bisi, S., Linden, R.,et al. (2012). Pyruvate kinase activity and delta-aminolevulinic acid dehydratase activity as biomarkers of toxicity in workers exposed to lead. Arch Environ Contam Toxicol 63(3):453–460. doi:10.1007/ s00244-012-9786-z

Flora, S.J., Flora, G, Saxena, G. Mishra,, M. (2007). Arsenic and lead induced free radical generation and their reversibility following chelation. Cell Mol Biol (Noisy-le-grand);53:26–47.

Flora, S.J.S. (2002). Nutritional components modify metal absorption, toxic response and chelation therapy. J Nut Environ Med.;12:53–67.

Formica, J.V., Regelson, W. (1995). Review of biology of Quercetin and Related Bioflavonoids. Food and Chemical Toxicology, 33, 1061-1080. http://dx.doi.org/10.1016/0278-6915(95)00077-1

Garçon, G., Leleu, B., Marez, T., Zerimech, F., Haguenoer, J.M., Furon, D., Shirali, P. (2007). Biomonitoring of the adverse effects induced by the chronic exposure to lead and cadmium on kidney function: Usefulness of alpha-glutathione S -transferase. Sci Total Environ 377:165–172

Ghanwat, G., Patil, A.J., Patil, J., Kshirsagar, M., Sontakke, A., Ayachit, R.K.. (2016). Effect of Vitamin C Supplementation on Blood Lead Level, Oxidative Stress and Antioxidant Status of Battery Manufacturing Workers of Western Maharashtra, India. J Clin Diagn Res. Apr;10(4):BC08-11. doi: 10.7860/JCDR/2016/15968.7528.

Grover, P., Rekhadevi, P.V., Danadevi, K., Vuyyuri, S.B., Mahboob, M., Rahman, M.F. (2010). Genotoxicity evaluation in workers occupationally exposed to lead. Int J Hyg Environ Health 213:99–106

Gurer-Orhan, H., Sabir, H.U., Ozgunes, H. (2004). Correlation between clinical biomarkers of lead poisoning and oxidative stress parameters in controls and lead-exposed workers. Toxicology 195:147–154

Highab, S.M., Magaji, R.A., Muhammad, B.Y. (2018). Effects of lead poisoning and antidepressant drugs on the cerebral cortex of Wistar rats. Acta Scientific Pharmaceutical Sciences 2.5.16-21.

Hsu, P., Guo Y (2002). Antioxidant nutrients and lead toxicity. Toxicology 180: 33–44

Ikizler, M., Erkasap, N., Dernek, S., Kural, T., Kaygisiz, Z. (2007). Dietary polyphenol quercetin protects rat hearts during reperfusion: enhanced antioxidant capacity with chronic treatment. Anadolu Kardiyol Derg; 7 (4): 404–410.

Jarrar, B.M., Taib, N.T. (2012). Histological and histochemical alterations in the liver induced by lead chronic toxicity. Saudi J Biol Sci. Apr;19(2):203-10. doi: 10.1016/j.sjbs.2011.12.005.

Jin, Y., Liaob, Y., Lua, C., Lia, G., Yue, F., Zhic, X., Xud, J., Liud, M., Yang, J., (2006). Health effects in children aged 3-6 years induced by environmental lead exposure. Ecotoxicol Environ Saf 63:313-317.

Kalicki, B., Aneta, L., Krystyna, J., Monika, L., Justyna, M.J., Slawomir, L. (2019). Vitamin B6 improves blood parameters in rats fed a protein deficient diet and subjected to moderate, long term exercise. Cent Eur J Immunol. 44(1):23-32.

Kasmi, S., Bkhairia, I., Harrabi, B., Mnif, H., Marrakchi, R., Ghozzi, H., et al.(2018). Modulatory effects of quercetin on liver histopathological, biochemical, hematological, oxidative stress and DNA alterations in rats exposed to graded doses of score 250. Toxicol Mech Methods ;28:12-22

Kasperczyk, S., Kasperczyk, J., Ostalowska, A., Zalejska-Fiolka, J., Wielkoszynski, T., Swietochowska, E., Birkner, E. (2009). The role of the

antioxidant enzymes in erythrocytes in the development of arterial hypertension among humans exposed to lead. Biol Trace Elem Res 130:95–106

Kasperczyk, S., Slowinska-Lozynska, L., Kasperczyk, A., Wielkoszynski, T., Birkner, E. (2013). The effect of occupational lead exposure on lipid peroxidation, protein carbonylation, and plasma viscosity. Toxicol Ind Health. doi:10.1177/0748233713491804

Keskin, E., Dönmez, N., Kılıçarslan, G., Kandır, S. (2016). Beneficial effect of quercetin on some haematological parameters in streptozotocin-induced diabetic rats. Bull Environ Pharmacol Life Sci 2016;5:65-8.

Khan, D.A., Qayyum, S., Saleem, S., Khan, F.A. (2008). Lead-induced oxidative stress adversely affects health of the occupational workers. Toxicol Ind Health 24:611–618

Kuhad, A., and Chopra, K. (2007). Curcumin attenuates diabetic encephalopathy in rat: Behavioral and biochemical evidence. European Journal of Pain 576: 34.

Mahmoud, A.M. (2013). Hematological alterations in diabetic rats - Role of adipocytokines and effect of citrus flavonoids. EXCLI J;12:647-57.

Mohammad, I.K., Mahdi, A.A., Raviraja, A., Najmul, I., Iqbal, A., Thuppil, V. (2008) Oxidative stress in.painters exposed to low lead levels. Arh Hig Rada Toksikol 59:161–169

Monteiro, H.P., Abdalla, D.S.P., Arcuri, A.S., Bechara, E.J.H. (1985) Oxygen toxicity related to exposure to lead. Clin Chen 31(10):1673–1676

Mugahi, M.N., Heidari, Z., Sagheb, H.M., Barbarestani, M. (2003). Effects of chronic lead acetate intoxication on blood indicies of male adult rat. DARU Journal of Pharmaceutical Sciences 11(4):147-151.

Nabil, M.I., Esam, A.E., Hossam S.E., Yasmin, E.A.M. (2012). Effect of lead acetate toxicity on experimental male albino rat. Asian Pac J Trop Biomed Jan;2(1):41-46.

Oktem, F., Arslan, M.K., Dündar, B., Delibas, N., Gültepe, M., Ergürhan-Ilhan, I. (2004). Renal effects and erythrocyte oxidative stress in long-term low-level lead-exposed adolescent workers in auto repair workshops. Arch Toxicol 78:681–687

Omotayo, B.1., Esther, F.A., Temitope, T.O., Bruno, C. (2022). Lead exposure – induced changes in hematology and biomarkers of hepatic injury: protective role of Trevo supplement. Environ Anal Health Toxicol; 37(2):e2022007.

Ozor, I.I. (2021). Biomarker patterns and neuroprotective effects of ascorbic acid, progesterone and statin in induced traumatic brain injury using a rat model. Apr,

Patil, A.J., Bhagwat, V.R., Patil, J.A., Dongree, N.N., Ambekar, J.G., Das, K.K. (2006). Biochemical aspects of lead exposure in silver jewelry workers in Western Maharashtra (India). J Basic Clin Physiol Pharmacol 17(4):213–229.

Permpongpaiboon, T., Nagila, A., Pidetcha, P., Tuangmungsakulchai, K., Tantrarongroj, S., Porntadavity, S. (2011). Decreased paraoxonase I activity and increased oxidative stress in low lead - exposed workers. Hum Exp Toxicol 30(9):1196–1203.

Polat, C., Tokyol, C., Kahraman, A., Sabuncuoglu, B., Yilmaz, S. (2006). The effects of desferrioxamine and quercetin on hepatic ischemia-reperfusion induced renal disturbance. Prostaglandins Leukot Essent Fatty Acids; 74 (6): 379–383.

Raymond, F. (2011). Lead presentation on biology 464 aquatic toxicology

Razmkon,, A., Sadidi, A., Sherafat-Kazemzadeh, E., Mehrafshan, A., Jamali, M., Malekpour, B., Saghafinia, M. (2011) Administration of vitamin C and E in sever head injury: a randomized double-blind controlled trial. Clin Neurosurg; 58:133-7. Doi: 10.1227/nue.0bo13e3182279a8f.PMID:21916138.

Rendon-Ramirez, A.L., Maldonado-Vega, M., Quintanar-Escorza, M.A., Hernandez, G., Arevalo-Rivas, B.I., Zentella-Dehesa, A., Calderon-Salinas, J.V.M. (2014). Effect of vitamin E and C supplementation on oxidative damage and total antioxidant capacity in lead-exposed workers. Environ Toxicol Pharmacol 37(1):45–54. doi:10.1016/j.etap.2013.10.016

Roels, H.A., Buchet, J.P., Lauwerys, R.R., Sonnet, J. (1975). Comparison of in vivo effect of inorganic lead and cadmium on glutathione reductase system and δ-aminolevulinate dehydratase in human erythrocytes. Br J Ind Med 32:181–192

Sarma ,P.R. (1990). Red cell indices. Clinical methods: The history, physical, and laboratory examinations. 3rd ed. Butterworths;.

Selvakumar, K., Bavithra, S., Suganya, S., Ahmad, B.F, Krishnamoorthy, G., Arunakaran, J. (2013). Effect of quercetin on haematobiochemical and histological changes in the liver of polychlorined biphenyls-induced adult male Wistar rats. J Biomark:960125.

Sina, K., Mahdi, B.M., Seyed, R.M., Mohammad, T.S., Bita, D., Valiollah, M., Mahmoud, S. (2013). Clinical, Toxicological, biochemical and hematologic

parameters in lead exposed workers of a car battery industry. Iran J Med Sci. Mar;38(1):30-37.

Singh, Z., Chadha, P., Sharma, S. (2013). Evaluation of oxidative stress and genotoxicity in battery manufacturing workers occupationally exposed to lead. Toxicol Int 20(1):95–100. doi:10.4103/0971-6580.111550

Sriraksa, N., Wattanathorn, J., Muchimapura, S., Tiamkao, S., Brown, K., Chaisiwamongkol, K. (2012). Cognitive-enhancing effect of quercetin in a rat model of Parkinson's disease induced by 6-hydroxydopamine. Evid Based Complement Alternt. Med.:823206

Staudinger, K.C., Roth, V.S. (1998). Occupational lead poisoning. American family physician, 57, 719-726.

Syeda, M., Zehra, B., Saiqa, T., Laraib, L., Sadia, S., Sidrah, S., Fizza, N., Sadia, S., Sarwat, Y., Amber, N., Saara, A., Irfan, S., Asia, A., Saida, H. (2021). Quercetin exhibits potent antioxidant activity, restores motor and non-motor deficits induced by rotenone toxicity; https://doi.org/10.1371/journal.pone.0258928

Taş, S., Sarandöl, E., Dirican, M. (2014). Vitamin B6 supplementation improves oxidative stress and enhances serum paraoxonase/arylesterase activities in streptozotocin-induced diabetic rats. Scientific World Journal.;2014:351598. doi: 10.1155/2014/351598.

Tenchova, V., Petkova, V., Pavlova, S., Simeonov, I. (1997). Lipid peroxidation in chronic lead exposure. Probl Khig. 22:54–61

Todorova, I., Simeonova, G., Kyuchukova, D. (2005). Reference values of oxidative stress parameters (MDA, SOD, CAT) in dogs and cats. Comp Clin Path13, 190-194.

Vollaard, N. B. J., Shearman, J. P., Cooper, C. E. (2005). "Exercise-induced oxidative stress: myths, realities and physiological relevance," Sports Medicine, vol. 35, no. 12, pp. 1045–1062,

Yagmurca, M., Yassar, Z., Bas, O. (2015). Effects of quercetin on kidney injury induced by doxorubicin. Bratisl med.j, 116(8). Doi: 10.4149/BLL-092.

Yahya, P., Farhad, O., Mahin, N.Z., Mehrnaz, A., Azizollah, P., Mahboobe, H. (2020). Effects of Quercetin Supplementation on Hematological Parameters in Non-Alcoholic Fatty Liver Disease: a Randomized, Double-Blind, Placebo-Controlled Pilot Study. Clin Nutr Res.Jan;9(1):11-19

Ye, X., Fu, H., Zhu, J., Ni, W., Lu, Y., Kuang, X., Yang, S., Shu, B. (1999). A study on oxidative stress in lead-exposed workers. J Toxicol Environ Health A

56:161–172

Yucebilgiç, G., Bilgin, R., Tamer, L., Tukel, S. (2003). Effects of lead on Na + -K + ATPase and Ca +2 ATPase activities and lipid peroxidation in blood of workers. Int J Toxicol 22:95–97

Authors' Brief Data

Nnachi Ifenna Salvator is of the Department of Anatomy, Faculty of Basic Medical Sciences, Enugu State University of Science and Technology, Parklane, Enugu State, Nigeria. *Email* (correspondence author): nnachiifenna@gmail.com

Dr (Mrs) Elizabeth Finbarrs-Bello is a lecturer at the Department of Anatomy, Faculty of Basic Medical Sciences, Enugu State University of Science and Technology, Parklane, Enugu State, Nigeria. *Email*: elizabeth.finbarrs-bello@esut.edu.ng

Ozor Ignatius Ikemefuna is of the Department of Anatomy, Faculty of Basic Medical Sciences, Enugu State University of Science and Technology, Parklane, Enugu State, Nigeria.

Mba Christian Ejuiwa is affiliated to the Department of Anatomy, Faculty of Basic Medical Sciences, Enugu State University of Science and Technology, Parklane, Enugu State, Nigeria.

Vivian Ugwu is affiliated to the Department of Anatomy, Faculty of Basic Medical Sciences, Enugu State University of Science and Technology, Parklane, Enugu State, Nigeria.

Acid Hydrolysis of Cassava Peel Waste for Ethanol Production

Ifeoma E. Madukasi

Abstract

Alternative substrates for ethanol production other than food crops will definitely lead to enhancement of farmer's income and lead to food security. Cassava peel waste (CPW) rich in starch content was utilized in ethanol production. The cassava peel was collected from cassava tuber processors, milled (0.027mm) hydrolysed with 20% H_2SO_4 prior to fermentation with 5% baker's yeast for 3 – 5 days. The fermented broth was distilled using distillation apparatus. Chemical properties of the distillate identified hydroxyl ion as its functional group while physical characterization of the distillate showed ethanol yield to be 33.74g/cm^3. The odour compares favourably with absolute and industrial ethanol respectively.

*Keywords***:** cassava peel waste, ethanol production, acid hydrolysis, solid waste management

1. Introduction

Globally, ethanol production has been mainly from food crops such as corn, sugarcane, potatoes and cassava tubers [1]. These are essential crops in Africa and Nigeria in particular as they are staple and economic food crops. However, the demand for ethanol production is on the increase in recent times due to its wide use in chemical and transportation industries and also because of its role in green house gas emission reduction [2]. Although Nigeria is one of the highest cassava producers and processors in the world, the abundant waste that accrues from cassava processing is yet to be adequately tapped. In Nigeria, cassava wastes are mainly left to rot away or burnt off to create space for the accumulation of new generation of waste heaps, emitting carbon dioxide and producing a strong offensive smell [3], [4].

Cassava peel waste (CPW) is high in cyanogenic glucosides and the pomace also high in biodegradable organic matters and may cause surface water pollution especially if they are stored under heavy rain or simply disposed of in surface waters [5]. This is typical scenario in Nigeria. The price of cassava has recently increased due to high demand of the tubers as it is now mandatory in Nigeria to include 10% to 20% high quality cassava flour (HQCF) into bread and confectionaries. This has seriously affected the availability of cassava tubers as numerous cassava food derivatives abound. It is also expected that the policy on 10% to 20% inclusion of HQCF into bread and confectionaries will spur more cassava growers consequently leading to more waste from cassava

processing. Unattended wastes invariably will breed unhealthy environment which can hinder the sustainability of the production and processing process.

Cassava processing produces large amounts of waste and is generally considered to contribute significantly to environmental pollution [6]. Thus, an attribute of global warming induced climate change. Generally, the long-term and broad-based impact of cassava processing on the environment can be corrected by proper cassava waste management [7], [6] which includes the use of cassava by-products as feedstuffs or as an alternative substrate for biotechnological processes which includes alcohol production thereby alleviating environmental issues [5].

Development of proper waste management for cassava waste is very important as it will solve many environmental challenges as well as alleviate poverty, and enhance the incomes of both urban and rural farmers. It will also enable the nation to meet the Millennium Development Goals (MDG) on environmental sustainability [8], [9]. Utilization of cassava peel waste for ethanol production is a carbon neutral process which will not affect the teeming populace that depends on cassava as food sources; rather, it will close the loop in cassava processing in Nigeria.

Cassava flour has potentials for alcohol production due to its high content of fermentable sugar and stable shelf-life [10], [11] and also because of its complete and easier hydrolysis compared to other flours [9]. However, for its use in ethanol production, acids or cellulose enzymes catalyze the breakdown of cellulose into glucose, which are fermented to ethanol [12]. Enzyme hydrolysis for the production of ethanol from starchy materials is an expensive process [13]. Chemical hydrolysis gives advantages for short residence time than enzyme hydrolysis [14].

Basically, two different processes can be used to produce ethanol from starchy crops: dry milling and wet milling processes. In dry milling, the feed material is ground mechanically and cooked in water to gelatinize the starch. The enzymes or acids are then added to break down the starch to form glucose, which yeast ferments to ethanol. The separate hydrolysis and fermentation process uses distinct process steps for starch hydrolysis and glucose fermentation. The primary advantage of this process is that hydrolysis and sugar fermentation can be treated separately, thus minimizing the interaction between these steps [12].

Utilization of cassava flour in ethanol production will add to food insecurity, hence the proposed utilization of agro-waste rich in starch and cellulosic matter. The aim of this work is to produce bio-ethanol from cassava peel waste and other agro-waste materials that are high in starch and cellulosic matters through acid hydrolysis and fermentation processes.

2. MATERIALS AND METHODS

2.1. Materials: The CPW was collected from FIIRO pilot garri processing plant, dried, milled with hammer milling machine (0.027mm).

Fig 1: FIIRO CASSAVA PROCESSING LINE

2.2. Pretreatment: Dry milling process was used before acid activation, this step enhanced visibility of the pores of the CPW for easier acid hydrolysis. In this method, the sieved CPW was boiled in water with constant stirring to a temperature of 70^{O}C until the CPW gelatinized.

2.3. Acid Hydrolysis To the gelatinized sample, the prepared solution of the sulfuric acid was added with constant stirring until a homogenous mixture was formed. The solution was heated with constant stirring on a magnetic stirring hotplate until temperature of 65^{o}C was reached. At this point, the texture and color of the solution changed. This was allowed to cool, filtered through No.1 whatman filter paper and the pH was adjusted to 4.5 with 0.1M Na0H.

2.4. Fermentation The CPW hydrolysate was fermented in an aspirator bottle (previously sterilized to exclude other microorganisms) with the baker's yeast. The bottle was topped with straw to allow carbon dioxide to escape. Fermentation was done for 3 days and 5 days at room temperature. At the end of the fermentation period, the alcohol was separated from the extract using simple distillation.

2.5. Distillation process The distillation apparatus consisted of conical flask, condenser, splash head (to avoid the entrance of water vapors into the receiver) and the receiver. The fermented CPW hydrolysate was added into the conical flask and the set up was heated with a heating mantle at temperature between 75-80^{O}C. The distillate collected was allowed to cool and the density was obtained.

2.6. Determination of Percentage Ethanol Concentration A slight modification of method according to [15] was used. Series of percentage (V/V) ethanol water solution were prepared and were weighed. The density of each of the prepared ethanol solution was calculated and a standard curve of density against percentage ethanol was plotted. The distillate was weighed and its density calculated. The percentage ethanol concentration of ethanol produced was obtained by comparing its density with the standard ethanol density curve.

2.7. Methodology: The sample was dried, milled with hammer milling machine (0.027mm), cooked in a pressure pot for 30 minutes prior to addition of 20% (18molar) sulphuric acid. The mixture was stood for 48hr and 5% baker's yeast added into the content after pH adjustment to optimum condition of pH5.5. The mixture was agitated and 72hr to 96hr was allowed for complete fermentation. The liquor was filtered and the filtrate distilled using distillation apparatus. The process flow chart is as shown in Fig. 2.

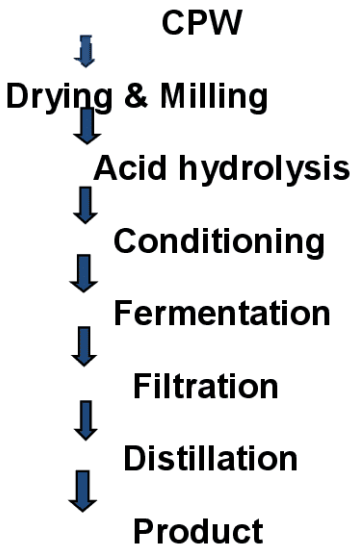


Fig. 2: Process flowchart of ethanol production from cassava peel waste

3. Results and Discussion:

Table 1: Evaluation of Product Recovered From Preliminary Investigation

Investigations	Volume Recovered (ml/100g)	Quantity Produced	pH Values
Sample A	42ml	33.74g/cm^3	5.74
Sample B	41ml	32.94g/cm^3	4.55
Sample C	76ml	61.05g/cm^3	4.01
Sample D	15ml	12.05g/cm^3	7.54
Sample E	69ml	55.43g/cm^3	7.97

N/B: Density and pH of absolute ethanol= 0.8033g/cm3 and 7.00

Table 2: Determination of Physical & Chemical Properties of Ethanol Produced from CPW

Sample	pH	Density	Refractive Index	Solubility	Functional Group (OH^-)
Absolute Ethanol	7.00	0.78	-	Positive	Positive
CPW A	5.74	0.9743	1.3405	Positive	Positive
CPW B	4.55	0.9757	1.3407	Positive	Positive
CPW C	4.01	0.9769	1.3313	Positive	Positive
CPW D	7.54	0.9309	1.334	Positive	Positive
CPW E	7.94	0.9943	1.3309	Positive	Positive

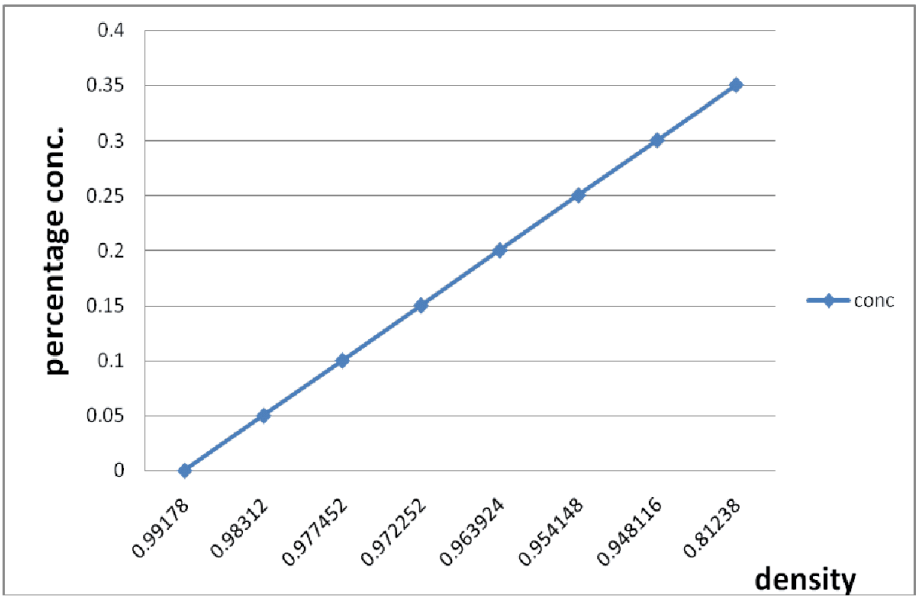


Fig 3: Determination of Ethanol Concentration

The distillate collected was measured with a measuring cylinder and expressed as quantity of ethanol produced in g/l by multiplying the volume yield of the distillate by ethanol density. From the trial investigations as shown in Table 1 above, CPW ethanol yield is comparable with literature value of 40% and above as recorded by [13]. The CPW yield was in the range of 33 – 60g/cm^3 for the sterilized hydrolysate and 15-28g/cm^3 for the non-sterilized hydrolysate. This is an indication that the baker's yeast would have competed with other micro-organisms that hindered its activity otherwise depleted the available sugar in the case of non-sterilized hydrolysate. Table 2 shows the physical and chemical properties of ethanol as to ascertain the strength level and its degree of purity as compared to standard (absolute ethanol).

In addition, CPW granules were extracted by crushing and pressure cooking to gelatinize the starchy content which was then treated with acid at 50 – 60 degree Celsius for 30 minutes to convert the starchy content into sugar (maltose). Addition of yeast in adequate proportion at room temperature converted the maltose to glucose with the aid of maltase while zymase also found in yeast decomposed glucose to ethanol with evolution of carbon dioxide. In summary, acid hydrolysis of carbohydrate to sugar is favoured in that it is faster with shorter residence time than enzyme hydrolysis.

4. CONCLUSION

In summary, acid hydrolysis of carbohydrate to sugar is favoured in that it is faster with shorter residence time in ethanol production. The use of cassava peel waste in ethanol production has shown that cassava has a holistic value and if properly harnessed will improve the economic values of the cassava growers in Nigeria. In addition, the work indicates that proper waste management is a tool to wealth creation and resource recovery.

References:

[1] Yan S; Yao J; Yao L; Zhi Z; Chen X and Wu J (2013). Fed batch enzymatic saccharification of food waste improves the sugar concentration in the hydrolysates and eventually the ethanol fermentation by Saccharomyces cerevisiae HO58. Braz. Arch. Boil. Technol. Vol. 55 No. 2 curitiba

[2] Nuwamanya E; Chiwona-Karltun L; Robert S; Baguma KY (2012). Bio-Ethanol Production from Non-Food Parts of Cassava (Manihot esculenta Crantz). Ambio. 41: 262-170.

[3] Aro S.O; Aletor V.A (2010). Proximate composition and amino acid profile of different fermented cassva tuber wastes collected from a cassava starch producing factory in Nigeria. http://www.lrrd.org/lrrd24/3/aro24040.htm

[4] Adebayo, A. O (2008). Using cassava waste to raise goats. Project 2008-4345. World Bank Development Marketplace. http://wbi.worldbank.org/ development market place/idea/using-cassava-waste-raise-g…

[5] Pandey A; Soccol C.R; Nigam P, Brand D, Mohan R, Roussoss S (2000c). Biotechnology potential of agro-industrial residues, Part II. Cassava bagasse. Biores. Technol. 74: 81-87.

[6] FAO (2011). Food Waste Repository programme of the Food and Agricultural Organisation of the United Nations

[7] Ademiluyi F.T and Mepba H.D (2013). Yield and Properties of Ethanol Biofuel Production from Different Whole Cassava Flours. Hindawi Publishing Corporation. ISRN Biotechnology. 2013: ArticleID918481,6pages (http://dx.doi.org/10.5402/2013/916481).

[8] Rabah A.B, Oyeleke S.B, Manga S.B, Hassan L.G (2011). Microbial Pretreatment of Rice husk and groundnut shell for bioethanol Production. International Research Journal of Microbiolgy. 2:253-258

[9] Kim S; Dele E (2005). Global potential Bio-ethanol production from wasted crop and crop residue. Biomass Bioenergy, 26: 361-347.

[10] Holt J.G; N.R. Kneg, P.H. Sneath, T.J. Stanley and S.T. Williams (1994). Bergy's manual of determinative bacteriology, pp: 983-987.

[11] Humprey C.N; U.C. Okafoagu (2007). Optimization of ethanol production from *Garcinia kola* (bitter kola) pulp Agro Waste. African Journal of Biotechnology, 6(17):2033-2037.

[12] Agulejika E.O; Olabode F.I; Babatunde K.A (2005). Ethanol production from waste fruits. International Journal of Food and Agricultural Research. Vol. 2 No 2: 190-194.

[13] Muratianto BW; Chandra BA (2008). Production of bio-ethanol from cassava peel waste (CPW) using sweet corn enzyme powder. Semesta Bilingual Boarding School Semarang Indonesia

[14] Echegi USC; Ejikeme PCN; Ejikeme EM (2013). Effects of process factors on the synthesis of bioethanol from cassava tubers using H2SO4 as catalyst. International Journal of Engineering and Science (IJES) Vol. 2, Issue 5, 1-9.

[15] Oyeleke, S.B; Jibrin N.M (2009). Production of bioethanol from guinea cornhusk and millet husk. African Journal of Microbiology Research Vol. 3(4) pp. 147-152

Author's Brief Data

Dr Ifeoma E. Madukasi is a lecturer in the Department of Environmental Management, Chukwuemeka Odumegwu Ojukwu University, Uli Campus, Anambra State, Nigeria. *E-mail*: madify2002@gmail.com

\

Null Controllability of Semi-Linear Differential Systems of NonLocal Initial Conditions with Distributed Delays in the Control in Banach Spaces

Paul Anaetodike Oraekie

Paul Anaetodike Oraekie, PhD, is of the Department of Mathematics,
Chukwuemeka Odumegwu Ojukwu University, Uli Campus,
Anambra State, Nigeria
Email: drsirpauloraekie@gmail.com

ABSTRACT

In this work, a Semi linear Differential System of Non Local Initial Conditions with Distributed Delays in the Control in Banach spaces of the form

$$x^1(t) = Ax(t) + f\big(t, x(t)\big) + \int_{-h}^{0} [d_\theta H(t,\theta)]\, u(t+\theta)$$

$$x(0) + g(x) = x_0$$

is presented for controllability analysis. Necessary and Sufficient Conditions for the System to be null controllable are established . *Use is made of the Unsymmetric Fubini theorem and Schauders' fixed point theorem to etablish results . Conditions are also placed on the perturbation f which guaratee that if the linear control base system is proper and if the uncotrolled linear system is uniformly asymptotically stable, then the Semilinear Differential System is nullcontrollable with constraints .*

Keywords: null-controllability, semi-linear, distributed delays, nonlocal initial conditions, Banach spaces

1. INTRODUCTION

Controllability and Null Controllability of nonlinear systems represented by differential and Integrodifferential equations in Banach Spaces have been investigated extensively by many authors; **Balachandran, K. Anandhi (2004), Y.K.Chang, J.J. Nieto(2009), Oraekie,P.A(2017)**.A method is to transform the controllability problem into a fixed point problem for an appropriate operator in a function space. However, **Balachandran and Kim(2003)** pointed out that controllability results are only true for ordinary differential Systems in finite-dimensional spaces if the corresponding operator semi groups are

compact.**Xue,X(2008)** studied the existence of integral solutions for a nonlinear differential equations with nonlocal initial conditions through Huasdorff measure of no compactness in the separable and uniformly smooth Banach spaces. In his work, **Xue, X (2008)** dropped the compactness of semi group. The semi group in his work is a contraction semi group satisfying equicontinuity, which is a special case of a strongly continuous semigroup.With respect to controllability, it is known from the of **Hermes and J.P. La Salle (1969)** that if the linear ordinary control system

$$\dot{x}(t) = A(t)x(t) + B(t)u(t) \qquad (1)$$

Is proper and if the free system

$$\dot{x}(t) = A(t)x(t) \qquad (2)$$

Is uniformly asymptotically stable, then system (1) is null controllable with constraints. A similar result was obtained by **Chukwu(1980)** for the delay system of the form

$$\dot{x}(t) = L(t\,, x_t) + B(t)u(t) \; + f\big(t, x_t, u(t)\big) \qquad (3)$$

$$where\,, L(t, \phi) = \sum_{k=0}^{\infty} A_k(t)\phi(-t_k) + \int_{-r}^{0} A(t\,, s)\phi(s)ds.$$

Shinba (1985) studied the nonlinear infinite delay system of the form

$$\dot{x}(t) = L(t\,, x_t) + B(t)u(t) \; + \int_{-\infty}^{0} A(\theta)x(\theta)d\theta + f\big(t, x_t, u(t)\big) \qquad (4)$$

And showed that system (4) is Euclidean null controllable if the linear base system

$$\dot{x}(t) = L(t\,, x_t) + B(t)u(t) \qquad (5)$$

Is proper and the free system

$$\dot{x}(t) = L(t\,, x_t) + B(t)u(t) \; + \int_{-\infty}^{0} A(\theta)x(\theta)d\theta \qquad (6)$$

is uniformly asymptotically stable, provided that f satisfies some growth conditions.

Onwuatu(1993), studied the neutral systems with infinite delay of the form

$$\frac{d}{dt}D(t\,, x_t) = L(t\,, x_t) + B(t)u(t) \; + \int_{-\infty}^{0} A(\theta)x(t+\theta)d\theta + f\big(t, x_t, u(t)\big) \qquad (7)$$

$$x(t) = \phi(t);\; t \in (-\infty, 0]$$

$$where\,, L(t, \phi) = \sum_{k=0}^{\infty} A_k(t)\phi(-t_k) + \int_{-r}^{0} A(t\,, s)\phi(s)ds.$$

He developed sufficient computable criteria for the null controllability of system (7).

While ***Oraekie*** **(2018)***studied the nonlinear infinite neutral systems with Multiple Delays in the Control of the form*:

$$\frac{\mathrm{d}}{\mathrm{dt}}\mathrm{D}(\mathrm{t}, \mathrm{x_t}) = \mathrm{L}(\mathrm{t}, \mathrm{x_t}) + \sum_{\mathrm{j}=1}^{\mathrm{m}} \mathrm{B_j}\,\mathrm{u}\big(\mathrm{t} - \mathrm{h_j}\big) + \int_{-\infty}^{0} \mathrm{A}(\theta)\mathrm{x}(\mathrm{t}+\theta)\,\mathrm{d}\theta + \mathrm{f}\big(\mathrm{t}, \mathrm{x_t}, \mathrm{u}(\mathrm{t})\big) \ldots\ldots\ldots (8)$$

He developed sufficient computable criteria for the null controllability of the system (8).

His results extend those of ***Hermes and Salle*** **(1969)**, ***Chukwu*** **(1980)**, ***Sinba*** **(1985)*and*** ***Onwuatu*** **(1993)** *to nonlinear infinite neutral systems with multiple delays in the control.*

In this paper, therefore, we consider the null controllability of the Semilinear Differential Systems of Nonlocal Initial Conditions with Distributed Delays in the Control in Banach Spaces of the form:

$$x^1(t) = Ax(t) + \int_{-h}^{0} [d_\theta H(t, \theta)]\, u(t+\theta) + f\big(t, x(t)\big) \qquad (9)$$

$$x(0) + g(x) = x_0$$

$with\ the\ main\ objective\ of\ investigating\ the\ null\ controllability\ of\ the\ system(8).$

$Here, the\ state\ x(.)\ takes\ value\ in\ a\ Banach\ Space\ X = R^n\ with\ the\ norm\ |.|;$

$the\ operator\ A\ generates\ a\ strong\ continuous\ not\ necessarily\ compact, semigroup\ T(t)\ in\ X.$

$And\ the\ control\ function\ u(.) is\ given\ Lebsgue\ square\ integrable\ functions\ L_2(J,U);$

$there\ is\ a\ Banach\ Space\ of\ admissible\ control\ functions\ with\ U\ a\ Banach\ Space.\ H(t,\theta)\ is\ an$

$nxn\ matrix\ function\ continuous\ at\ t\ and\ of\ bounded\ variation\ in\ \theta\ on\ [-h\ ,0]\ , h > 0$

$for\ each\ t\ [t_0, t_1]\ ; t_1 > t_0.$

$The\ functions\ f: JxX \to X\ , g: C(J,X) \to X\ are\ continuous.\ Here, x_0 = x(0)\ is\ a\ given$

$element\ in\ X\ , C(J,X)\ denotes\ the\ Banach\ \ space\ of\ continuous\ functions\ x(.) : J \to X$

$with\ the\ norm\ \|x\| = sup\{|x(t)|\ , t \in J\}.$

$The\ nonlocal\ initial\ condition\ is\ a\ generizeation\ of\ tthe\ classical\ initial\ condition, which$

$was\ motivated\ by\ physical\ phenomena.\ The\ pioneering\ work\ on\ nonlocal\ conditions\ is\ due\ to$

$\boldsymbol{Byszewski}\ (\mathbf{1991})\ followed\ by\ \boldsymbol{Fu.X.Ezzinbi}(\mathbf{2003}).$

2. Preliminaries and Notations

Consider the following dynamical system(9) given as

$$x^1(t) = Ax(t) + \int_{-h}^{0} [d_\theta H(t,\theta)]\, u(t+\theta) + f\big(t, x(t)\big) \qquad (11)$$

$$x(0) + g(x) = x_0$$

$If\ T(t,t_0): B \to B\ , t > t_0\ is\ defined\ by\ T(t,t_0)\phi = x_t(t_0,\phi)\ and\ the\ solution\ x(t)\ of$

$system(11) with\ the\ initial\ complete\ state\ \boldsymbol{y_{t_0}} = \{\boldsymbol{x_0}\ , \boldsymbol{u_0}\}\ is\ of\ the\ following\ form$

$(\boldsymbol{see\ Klamka}(\mathbf{1978})\boldsymbol{as\ contained\ in\ Klamka}(\mathbf{1980})$:

$$x(t) = T(t)[x_0 - g(x)] + \int_{t_0}^{t} T(t-s) f(s\ , x(s)) ds$$

$$+ \int_{t_0}^{t} T(t-s) \int_{-h}^{0} [d_\theta H(t\ , \theta)]\, u(t+\theta) ds \qquad (12)$$

$Where\ T(t-s)\ is\ the\ state\ transition\ of\ the\ following\ linear\ homogeneous\ system$

$$x^1(t) = Ax(t) \qquad (13)$$

The third term in the right – hand side of system(12)*contains the values of the control* $u(t)$ $for\ t < t_0$ *, as well as for* $t > t_0$*. The values of the control* $u(t)$ $for\ t \in [t_0 - h\ , t_0]$ *enter into the definition of initial complete state* $\boldsymbol{y_{t_0}}$ *. To separate them , the third term of system*(12) *must be transformed by changing the order of integration*..Using the Unsymmetric Fubini theorem, we have the following equalities:

$$x(t) = T(t)[x_0 - g(x)] + \int_{t_0}^{t} T(t-s) f(s\ , x(s)) ds + \int_{-h}^{0} d_{H_\theta} \left(\int_{t_0}^{t} T(t-s)\, H(l\ , \theta) u(l+\theta) dl \right) \qquad (14)$$

$$\Rightarrow x(t) = T(t)[x_0 - g(x)] + \int_{t_0}^{t} T(t-s) f\big(s\ , x(s)\big) ds + \int_{-h}^{0} d_{H_\theta} \left(\int_{t_0+\theta}^{t+\theta} T(t-s)\, H(l-\theta\ , \theta) u(l-\theta+\theta) dl \right) \qquad (15)$$

$$= T(t)[x_0 - g(x)] + \int_{t_0}^{t} T(t-s) f\big(s\ , x(s)\big) ds + \int_{-h}^{0} d_{H_\theta} \left(\int_{t_0+\theta}^{t+\theta} T(t-s)\, H(l-\theta\ , \theta) u(l) dl \right) \qquad (16)$$

$$\Rightarrow\ x(t) = T(t)[x_0 - g(x)] + \int_{t_0}^{t} T(t-s) f\big(s\ , x(s)\big) ds + \int_{-h}^{0} d_{H_\theta} \left(\int_{t_0+\theta}^{t_0} T(t-s)\, H(l-\theta\ , \theta) u_{t_0}(l) dl \right) + \int_{-h}^{0} d_{H_\theta} \left(\int_{t_0}^{t+\theta} T(t-s)\, H(l-\theta\ , \theta) u(l) dl \right) \qquad (17)$$

Where the symbol d_{H_θ}*denotes that the integration is in the* $Lebesque - Sieltjes$ *senes with respect to the variable* θ *in the function*$H(l\ , \theta)$.

Let us introduce the following notation

$$H_t(l, \theta) = \begin{cases} H(l\ , \theta),\ l < t, \theta \in R \\ 0,\ l > t\ , \theta \in R \end{cases} \qquad (18)$$

Thus, $x(t)$*can be expressed in the following form*:

$$\Rightarrow\ x(t) = T(t)[x_0 - g(x)] + \int_{t_0}^{t} T(t-s) f\big(s\ , x(s)\big) ds$$

$$+\int_{-h}^{0} d_{H_\theta}\left(\int_{t_0+\theta}^{t_0} T(t-s)\,H(l-\theta\,,\theta)u_{t_0}(l)dl\right)$$
$$+\int_{-h}^{0} d_{H_\theta}\left(\int_{t_0}^{t} T(t-s)\,H_t(l-\theta\,,\theta)u(l)dl\right) \qquad (19)$$

Using again the Unsymmetric Fubini theorem, the equality (19) *can be rewritten in a more convenient form as follows*:

$$x(t) = T(t)[x_0 - g(x)] + \int_{t_0}^{t} T(t-s)f\big(s\,,x(s)\big)ds$$
$$+\int_{-h}^{0} d_{H_\theta}\left(\int_{t_0+\theta}^{t_0} T(t-s)\,H(l-\theta\,,\theta)u_{t_0}(l)dl\right)$$
$$+\int_{t_0}^{t}\left(\int_{-h}^{0} T(t-s)\,d_\theta H_t(l-\theta\,,\theta)\right)u(l)dl \qquad (20)$$

Now let us consider the system (20) *– the exact mild solution of the system*(8) *for* $t = t_1$

$$x(t_1) = T(t_1)[x_0 - g(x)] + \int_{t_0}^{t_1} T(t_1-s)f\big(s\,,x(s)\big)ds$$
$$+\int_{-h}^{0} d_{H_\theta}\left(\int_{t_0+\theta}^{t_0} T(t_1-s)\,H(l-\theta\,,\theta)u_{t_0}(l)dl\right)$$
$$+\int_{t_0}^{t_1}\left(\int_{-h}^{0} T(t_1-s)\,d_\theta H_{t_1}(l-\theta\,,\theta)\right)u(l)dl \qquad (21)$$

2.1 BASIC SET FUNCTION AND PROPERTIES.

Definition 2.1.1 (Reachable Set)

The reachable set of the system(9) *denoted by* $R(t_1\,,t_0)$ *is given as*:

$$\boldsymbol{R(t_1\,,t_0)} = \left\{\int_{t_0}^{t_1}\left(\int_{-h}^{0} T(t_1-s)\,d_\theta H_{t_1}(l-\theta\,,\theta)\right)u(l)dl \;\; : u\in U; \left|u_j\right| \le 1\,; j = 1,2,\dots,m\right\}$$

where $U = \{u \in L_2([t_0\,,t_1]\,,R^m)\}$.

Definition 2.1.2 (Target Set)

The target set for the system(9) *denoted by* $G(t_1\,,t_0)$ *is given as*:

$G(t_1\,,t_0) = \{x(t_1\,,x_0\,,u)\,:\; t_1 \ge \tau > t_0\,, for\ some\ fixed\ \ \tau \in [t_0\,,t_1]\ \ and\ u \in U\}$.

Definition 2.1.3 (Attainable Set)

The attainable set for the system(9) *denoted by* $A(t_1, t_0)$ *is given as*:

$A(t_1, t_0) = \{x(t_1, x_0, u) : u \in U \; ; |u_j| \leq 1 \; ; j = 1,2, \dots, m \}; \; U = \{u \in L_2([t_0, t_1], R^m)\}.$

Definition2.1.4 (Controllability Grammian or Map)

The controllability grammian or map of the system(9)*denoted by* $W(t_1, t_0)$ *is given as*

$$W(t_1, t_0) = \int_{t_0}^{t_1} \left(\int_{-h}^{0} T(t_1 - s)\, d_\theta H_{t_1}(l - \theta, \theta) \right) \left(\int_{-h}^{0} T(t_1 - s)\, d_\theta H_{t_1}(l - \theta, \theta) \right)^T$$

Where T denotes matrix transpose.

$$\boldsymbol{If \quad Y(t_1) = \int_{-h}^{0} T(t_1 - s)\, d_\theta H_{t_1}(l - \theta, \theta)} \qquad (22)$$

$$\boldsymbol{Then, \quad W(t_1, t_0) = \int_{t_0}^{t_1} Y(t_1)\, Y^T(t_1) \; and \qquad W^{-1}(t_1, t_0) = \frac{1}{\int_{t_0}^{t_1} Y(t_1)\, Y^T(t_1)}} \qquad (23)$$

Definition2.1.5 (Properness)

The system (9)*is said to be proper on an interval* $[t_0, t_1]$ *if*

$$C^T \int_{-h}^{0} T(t_1 - s)\, d_\theta H_{t_1}(l - \theta, \theta) = 0 \; ae, l \in [t_0, t_1] \Rightarrow C = 0; C \in R^n.$$

If the system(9)*is proper on each interval* $[t_0, t_1]; t_1 > t_0$, *we say that system*(9) *is proper in* R^n.

Definition2.1.6 (Positive Definite)

The controllability grammian or map of the system(9)*denoted by* $W(t_1, t_0)$ *is said to be positive definite if* $W(t_1, t_0)$ *varnishes only at the origin and* $W(x) > 0$, *for all* $x \neq 0; x \in D$, *where* $D = \{x \in R^n : \|x\| \leq r; r > 0\} \subset R^n$.

Definition2.1.7 (Complete Controllability)

The system(9) *is said to be completely controllable on the interval* $[t_0, t_1]$ *if for every function* ϕ *and every state* $x_1 \in R^n$, *there exists an admissible control energy function* $u \in U$ *such that* $x(t_1) = x_1$.

Definition2.1.8 (Complete State)

$$We\ denote\ the\ complete\ state\ of\ system(9)\ by\quad \boldsymbol{z(t)} = \{\boldsymbol{x(t)}, \boldsymbol{u_t}\}$$

$Then, the\ initial\ complete\ state\ of\ system(9)\ at\ time\ t_0\ is\ \boldsymbol{z(t_0)} = \{\boldsymbol{x(t_0)}, \boldsymbol{u_{t_0}}\}$

Definition2.1.9 (Null Controllability)

$The\ system(9)\ is\ said\ to\ be\ null\ controllable\ on\ the\ interval\ [t_0, t_1]\ if\ for\ every$

$function\ \phi \in B([t_0, t_1], R^n), there\ exists\ a\ time\ t_1 \geq t_0, u \in L_2([t_0, t_1], P), P\ a\ compact$

$convex\ subset\ of\ R^m\ such\ that\ the\ solution\ x(t, t_0, \phi, f)\ of\ system(9)\ satisfies$

$$x_{t_0}(t_0, \phi, f) = \phi\ and\ x(t_1, t_0, \phi, f) = 0$$

Definition2.1.10 (Relative Controllability)

$$The\ system(9)\ is\ said\ to\ berelatively\ controllable\ on\ the\ interval\ [t_0, t_1]\ if$$

$$A(t_1, t_0) \cap G(t_1, t_0) \neq \phi, \qquad t_1 > t_0 \in [t_0, t_1].$$

3. MAIN WORK

The following theorems on controllability of system(9) are similar to the corresponding results for linear control systems of various types including some with delays and some without delays**(see Oraekie(2017),Onwuatu(1993),Hermes and La Salle(1963)).**

Theorem 3.1

The following statements are equivalent:

(i) $The\ controllability\ grammian\ W(t_1, t_0)\ of\ sysem(9) is\ non-singular$

$(ii).\ System(9)\ is\ completely\ controllable\ on\ the\ interval\ [t_0, t_1].\ t_1 > t_0$

$(iii).\ System(9)\ is\ proper\ on\ the\ interval\ [t_0, t_1].\ t_1 > t_0$

Proof

$The\ controllability\ grammian\ W(t_1, t_0)\ of\ sysem(9) is\ nonsingular\ is\ equivalent\ to\ saying$

$that\ it\ is\ positive\ definite, which\ in\ turn\ is\ equivalent\ to\ saying\ that\ the\ C^T of\ the\ controllability$

$index\ of\ system(9) is\ equal\ to\ zero\ almost\ everywhere, implies\ that\ C = 0.$

$$i.e\ .\ C^T\int_{-h}^{0} T(t_1-s)\,d_\theta H_{t_1}(l-\theta\,,\theta)=0\ a\ e\ ,l\in[t_0\,,t_1]\Rightarrow C=0;C\in R^n.Thus,showing\ that(i)and(iii)are\ \ equivalent..$$

$Now\ consider$

$$C^T\int_{t_0}^{t_1}\left(\int_{-h}^{0} T(t_1-s)\,d_\theta H_{t_1}(l-\theta\,,\theta)\right)u(l)dl=0\ ae\ ,l\in[t_0\,,t_1].$$

$$\boldsymbol{For\ each\ l,then}$$

$$\int_{t_0}^{t_1} C^T\left(\int_{-h}^{0} T(t_1-s)\,d_\theta H_{t_1}(l-\theta\,,\theta)\right)u(l)dl=\ C^T\left[\int_{t_0}^{t_1}\left(\int_{-h}^{0} T(t_1-s)\,d_\theta H_{t_1}(l-\theta\,,\theta)\right)u(l)dl\right]=\mathbf{0}$$

$$It\ follows\ from\ this\ \ that\ C\ is\ orthogonal\ to\ the\ reachable\ set\ \boldsymbol{R(t_1\,,t_0)}.$$

$If\ we\ assume\ the\ relative\ controllability\ of system(9)\ now,then$

$\boldsymbol{R(t_1\,,t_0)}=R^n\,,sothat\ C=0\ \ .Showing\ that\ \ (ii)\ implies\ (iii).$

$Conversely,assume\ that\ system(9)is\ not\ controllable\ so\ that$

$$\boldsymbol{R(t_1\,,t_0)}=R^n,t_1\ >t_0\ .$$

$Then\ there\ exists\ \ C\neq 0,C\in R^n\ \ such\ that$

$$C^T\boldsymbol{R(t_1\,,t_0)}=0$$

$It\ follows\ now\ that\ for\ all\ admissible\ controls\ u\in U\subset L_2([t_0\,,t_1],R^n)$

$$0=\ C^T\left[\int_{t_0}^{t_1}\left(\int_{-h}^{0} T(t_1-s)\,d_\theta H_{t_1}(l-\theta\,,\theta)\right)u(l)dl\right]$$

$$Hence,C^T\boldsymbol{R(t_1\,,t_0)}=0\ \ \ a\ e\ ,l\in[t_0\,,t_1],C\neq 0.$$

$This\ situation,impliesthat\ system(9)\ is\ not\ proper\ by\ the\ definition\ of\ properness\ since$

$C\neq 0.Hence,the\ system(9)is\ relatively\ controllable\ on\ [t_0\,,t_1]\ and\ hence\ completely\ controllable.$

Theorem 3.2

$Assume\ for\ system\ (9)\ that:$

$(i).the\ constraint\ set\ U\ is\ an\ arbitrary\ compact\ subset\ of\ R^n.$

$(ii).\ the\ system(6)\ satisfies\ \ exponential\ estimate.$

$$i.e.\|x(t\ ,t_0,\phi\ ,0\ )\| \le Me^{-\delta(t-t_0)}\|\phi\|\ ,\qquad for\ some\ \delta>0, M>0.$$

$(iii).\ the\ linear\ control\ system-\big(system(5)\big), is\ proper\ in\ R^n.$

$(iv).\ the\ continuous\ function\ f\ satisfies$

$|f(t\ ,x(.),u(.))| \le exp(-Nt)\pi\big(x(.),u(.)\big), for\ all\ \big(t\ ,x(.),u(.)\big) \in [t_0\ ,\infty)xExL_2\ ,$
$where\ \int_{t_0}^{\infty}\pi\big(x(s),u(s)\big)ds \le \lambda<\infty\ and\ N-\delta\ge 0\ , then\ system(9) is\ null\ controllable.$

Proof

$By\ (iii)-the\ linear\ base\ control\ system\ \big(system(5)\big), there\ exists\ an\ inverse\ of$
$the\ controllability\ grammian\ say\ W^{-1}(\boldsymbol{t_1}\ ,\boldsymbol{t_0})\ for\ each\ time\ t_1>t_0.\ Suppose\ that\ the$
$pair\ of\ functions\ x\ and\ u\ form\ a\ solution\ pair\ to\ the\ set\ of\ integral\ equations:$

$$u(t) = -\left[\int_{-h}^{0} T(t_1-s)\,d_\theta H_{t_1}(l-\theta\ ,\theta)\right]^T W^{-1}(\boldsymbol{t_1}\ ,\boldsymbol{t_0})\left[T(t_1)\big(x_0-g(x)\big)+\int_{t_0}^{t_1}T(t_1-s)f\big(s\ ,x(s)\big)ds + \int_{-h}^{0} d_{H_\theta}\left(\int_{t_0+\theta}^{t_0} T(t_1-s)\,H(l-\theta\ ,\theta)u_{t_0}(l)dl\right)\right]$$

Substituting equation (22) and (23) into the above, we have

$$u(t) = \frac{-\boldsymbol{Y^T(t_1)}}{\int_{\boldsymbol{t_0}}^{\boldsymbol{t_1}}\boldsymbol{Y(t_1)\,Y^T(t_1)}}\left[T(t_1)\big(x_0-g(x)\big)+\int_{t_0}^{t_1}T(t_1-s)f\big(s\ ,x(s)\big)ds + \int_{-h}^{0} d_{H_\theta}\left(\int_{t_0+\theta}^{t_0} T(t_1-s)\,H(l-\theta\ ,\theta)u_{t_0}(l)dl\right)\right] \qquad (24)$$

$$x(t) = T(t)[x_0-g(x)] + \int_{t_0}^{t} T(t-s)f\big(s\ ,x(s)\big)ds + \int_{-h}^{0} d_{H_\theta}\left(\int_{t_0+\theta}^{t_0} T(t-s)\,H(l-\theta\ ,\theta)u_{t_0}(l)dl\right) + \int_{t_0}^{t}\left(\int_{-h}^{0} T(t-s)\,d_\theta H_t(l-\theta\ ,\theta)\right)u(l)dl \qquad (25)$$

$x(t) = \phi(t), t \in [t_0 - \lambda\,, t_0]$.

Then u is square integrable on $[t_0\,, t_1]$ *and x is a solution of system*(9)*corresponding to u with the initial state* $x(t_0) = \phi$.

Also, using u as expressed in equation (24), *we have*

$$x(t_1) = T(t_1)[x_0 - g(x)] + \int_{t_0}^{t_1} T(t_1 - s) f\big(s\,, x(s)\big) ds + \int_{-h}^{0} d_{H_\theta}\left(\int_{t_0+\theta}^{t_0} T(t_1 - s)\, H(l - \theta\,, \theta) u_{t_0}(l) dl\right) + \int_{t_0}^{t_1}\left(\int_{-h}^{0} T(t_1 - s)\, d_\theta H_{t_1}(l - \theta\,, \theta)\right) \frac{-\boldsymbol{Y^T(t_1)}}{\int_{\boldsymbol{t_0}}^{\boldsymbol{t_1}} \boldsymbol{Y(t_1)\, Y^T(t_1)}} \left[T(t_1)\big(x_0 - g(x)\big) + \int_{t_0}^{t_1} T(t_1 - s) f\big(s\,, x(s)\big) ds + \int_{-h}^{0} d_{H_\theta}\left(\int_{t_0+\theta}^{t_0} T(t_1 - s)\, H(l - \theta\,, \theta) u_{t_0}(l) dl\right)\right] \quad (26)$$

$$\boldsymbol{But\ Y(t_1) = \int_{-h}^{0} T(t_1 - s)\, d_\theta H_{t_1}(l - \theta\,, \theta), therefore, we\ have}$$

$$x(t_1) = T(t_1)[x_0 - g(x)] + \int_{t_0}^{t_1} T(t_1 - s) f\big(s\,, x(s)\big) ds + \int_{-h}^{0} d_{H_\theta}\left(\int_{t_0+\theta}^{t_0} T(t_1 - s)\, H(l - \theta\,, \theta) u_{t_0}(l) dl\right) + \int_{t_0}^{t_1} \big(\boldsymbol{Y(t_1)}\big)\left(\frac{-\boldsymbol{Y^T(t_1)}}{\int_{\boldsymbol{t_0}}^{\boldsymbol{t_1}} \boldsymbol{Y(t_1)\, Y^T(t_1)}}\right)\left[T(t_1)\big(x_0 - g(x)\big) + \int_{t_0}^{t_1} T(t_1 - s) f\big(s\,, x(s)\big) ds + \int_{-h}^{0} d_{H_\theta}\left(\int_{t_0+\theta}^{t_0} T(t_1 - s)\, H(l - \theta\,, \theta) u_{t_0}(l) dl\right)\right] \quad (27)$$

$$\Rightarrow\ x(t_1) = T(t_1)[x_0 - g(x)] + \int_{t_0}^{t_1} T(t_1 - s) f\big(s\,, x(s)\big) ds + \int_{-h}^{0} d_{H_\theta}\left(\int_{t_0+\theta}^{t_0} T(t_1 - s)\, H(l - \theta\,, \theta) u_{t_0}(l) dl\right) - \left(\frac{\int_{\boldsymbol{t_0}}^{\boldsymbol{t_1}} \boldsymbol{Y(t_1) Y^T(t_1)}}{\int_{\boldsymbol{t_0}}^{\boldsymbol{t_1}} \boldsymbol{Y(t_1)\, Y^T(t_1)}}\right)\left[T(t_1)\big(x_0 - g(x)\big) + \int_{t_0}^{t_1} T(t_1 - s) f\big(s\,, x(s)\big) ds + \int_{-h}^{0} d_{H_\theta}\left(\int_{t_0+\theta}^{t_0} T(t_1 - s)\, H(l - \theta\,, \theta) u_{t_0}(l) dl\right)\right] \quad (28)$$

$$\Rightarrow\ x(t_1) = T(t_1)[x_0 - g(x)] + \int_{t_0}^{t_1} T(t_1 - s) f\big(s\,, x(s)\big) ds$$

$$+\int_{-h}^{0} d_{H_\theta}\left(\int_{t_0+\theta}^{t_0} T(t_1-s)\,H(l-\theta\,,\theta)u_{t_0}(l)dl\right)$$
$$-\mathbf{1}\left[T(t_1)\big(x_0-g(x)\big)+\int_{t_0}^{t_1} T(t_1-s)f\big(s\,,x(s)\big)ds\right.$$
$$\left.+\int_{-h}^{0} d_{H_\theta}\left(\int_{t_0+\theta}^{t_0} T(t_1-s)\,H(l-\theta\,,\theta)u_{t_0}(l)dl\right)\right] \qquad (29)$$

$$\Rightarrow\ x(t_1)=T(t_1)[x_0-g(x)]+\int_{t_0}^{t_1} T(t_1-s)f\big(s\,,x(s)\big)ds$$
$$+\int_{-h}^{0} d_{H_\theta}\left(\int_{t_0+\theta}^{t_0} T(t_1-s)\,H(l-\theta\,,\theta)u_{t_0}(l)dl\right)$$
$$-\big[T(t_1)\big(x_0-g(x)\big)\big]-\int_{t_0}^{t_1} T(t_1-s)f\big(s\,,x(s)\big)ds$$
$$-\int_{-h}^{0} d_{H_\theta}\left(\int_{t_0+\theta}^{t_0} T(t_1-s)\,H(l-\theta\,,\theta)u_{t_0}(l)dl\right)=0\ .$$

It remains to show that the function $u:[t_0\,,t_1]\to U$ is an admissible control. That is, we need to show that $u:[t_0\,,t_1]\to U$ is in the arbitrary compact constraint subset of R^m. That is $|u|\le\delta_1$, for some constant $\delta_1>0$.
By (ii) of theorem 3.2, we have

$$\left|\left[\int_{-h}^{0} T(t_1-s)\,d_\theta H_{t_1}(l-\theta\,,\theta)\right]^T W^{-1}(\boldsymbol{t_1}\,,\boldsymbol{t_0})\right|<\lambda_1$$

$$i.e\quad;\ \left|\frac{\boldsymbol{Y^T(t_1)}}{\int_{\boldsymbol{t_0}}^{\boldsymbol{t_1}}\boldsymbol{Y(t_1)}\,\boldsymbol{Y^T(t_1)}}\right|<\lambda_1\ ,\qquad \text{for some } \lambda_1>0\ and$$

$$|\,T(t_1)[x_0-g(x)]|\le\lambda_2\exp\big(-\delta(t_1-t_0)\big)\quad,\text{for some constant } \lambda_2>0$$

Hence,

$$|u(t)|\le\lambda_1\big[\lambda_2 exp\big(-\delta(t_1-t_0)\big)\big]\int_{t_0}^{t_1}\lambda_3 exp\big[-\delta(t_1-s)exp(-Ns)\pi\big(x(.),u(.)\big)ds\big]$$

Thus,

$$|u(t)|\le\lambda_1\big[\lambda_2 exp\big(-\delta(t_1-t_0)\big)\big]+\lambda\lambda_3 exp(-\delta t_1) \qquad (30)$$

since $N-\delta\ge 0$ and $s\ge t_0\ge 0$.

Hence, by taking t sufficiently large, we have

$|u(t)|\le\delta_1\quad, t\in[t_0\,,t_1]$, showing that u is an admissible control.

Finally, we now prove the existence of a solution pair of the integral equations(24)*and*(25).

Let E be the Banach space of all functions (x,u): $[t_0-h\,,t_1]x[t_0-h\,,t_1]\to R^n xR^m$,

where $x\in \boldsymbol{E}([\boldsymbol{t_0}-\boldsymbol{h}\,,\boldsymbol{t_1}]\,,\boldsymbol{R^n})\,; u\in \boldsymbol{L_2}([\boldsymbol{t_0}-\boldsymbol{h}\,,\boldsymbol{t_1}]\,,\boldsymbol{R^m})$ *with the norm defined by*

$$\|(x\,,u)\| = \|x\|_2 + \|u\|_2$$

$$where\,, \|x\|_2 = \sqrt{\int_{t_0-h}^{t_1} |x(s)|^2\,ds}\;\;,\; \|u\|_2 = \sqrt{\int_{t_0-h}^{t_1} |u(s)|^2\,ds}$$

We define the operator T by $T: E\to E$ *by* $T(x\,,u)=(y\,,v)$ *,where*

$$v(t_1) = \frac{-\boldsymbol{Y^T(t_1)}}{\int_{\boldsymbol{t_0}}^{\boldsymbol{t_1}} \boldsymbol{Y(t_1)\,Y^T(t_1)}}\Bigg[T(t_1)\big(x_0-g(x)\big) + \int_{t_0}^{t_1} T(t_1-s) f\big(s\,,x(s)\big)ds + \int_{-h}^{0} d_{H_\theta}\left(\int_{t_0+\theta}^{t_0} T(t_1-s)\,H(l-\theta\,,\theta)u_{t_0}(l)dl\right)\Bigg] \qquad (24)$$

And $v(t)=\omega(t)$ *,for some* $t\in[t_0-\lambda\,,t_0]$

$$y(t_1) = T(t_1)[x_0-g(x)] + \int_{t_0}^{t_1} T(t_1-s) f\big(s\,,x(s)\big)ds + \int_{-h}^{0} d_{H_\theta}\left(\int_{t_0+\theta}^{t_0} T(t_1-s)\,H(l-\theta\,,\theta)u_{t_0}(l)dl\right) + \int_{t_0}^{t_1}\left(\int_{-h}^{0} T(t_1-s)\,d_\theta H_{t_1}(l-\theta\,,\theta)\right)u(l)dl \qquad (25)$$

$y(t)=\phi(t), t\in[t_0-\lambda\,,t_0]$.

We have already shown that $|u(t)|\le\delta_1$ *,*$t\in J=[t_0\,,t_1]$ *and also for the function*

$$v:\ [t_0-h\,,t_0]\to U\,,$$

we have $|v(t)|\le\delta_1$ *.Hence,* $\|x\|_2\le\delta_1(t_0+h-t_0)^{\frac{1}{2}}=N_0$.

Again, $|y(t)|\le\lambda_2 exp[-\delta(t_1-t_0)]+\lambda_4\int_{t_0}^{t_1}|v(s)|\,ds+\lambda\lambda_3 exp(-\delta t_1), where$

$$\lambda_4 = sup\left|\int_{-h}^{0} T(t_1-s)\,d_\theta H_{t_1}(l-\theta\,,\theta)\right|.$$

Since $\delta>0\,, t_1\ge t_0\ge 0$ *,we deduce that*

$$|y(t)|\le\lambda_2+\lambda_4\delta(t_1-t_0)+\lambda\lambda_3=N_1\;\;,t\in[t_0\,,t_1].$$

$$and \ , |y(t)| \leq \sup|\phi| = \beta \, , \mathrm{t} \in [t_0 - r \, , t_0].$$

Hence, if $\mathrm{M} = \max[N_1, \beta]$, then , $\|y\|_2 \leq M(t_0 + h - t_0)^{\frac{1}{2}} = N_2 < \infty.$

Let $\rho = \max[N_0 \, , N_2]$.

Then , if $\mathrm{G}(\rho) = \{(x \, , u) \in E : \ \|x\|_2 \leq \rho \, , \|u\|_2 \leq \rho \ \}$, we have thus shown that the operator T maps G into its self. i. e, $\mathrm{T} : \mathrm{G}(\rho) \rightarrow \mathrm{G}(\rho)$.

Since $G(\rho)$is closed, bounded and convex, by ***Riesz theorem*** *as contained in* **Kantorovica , L. V and G. P. Akilov (1982),** ***p297****, and* ***Oraekie*****(2017) .** ***Onwuatu*** **(1993)** *it is relatively compact under the transformation of T . Hence, the Schauders$'$fixed point theorem implies that T has a fixed point. Thus, the system*(9) *is null controllable.*

4 . *CONCLUTION*

The Set Functions upon which our studies hinged are also extracted from the mild solution which we cultivated. Necessary and Sufficient Conditions for the null controllability of the Semi linear differential systems with distributed delays in the control have been derived.

These conditions are given with respect to the controllability of the linear controlled base system of system(9) and the uniformly asymptotic stability of the uncontrolled linear system of the system(9),assuming that the perturbation f satisfies some smoothness and growth conditions. These results extended known results in the literature.

5. REFERENCES

1 Balachandran,K ,Anandhi E.R (2004),Controllability of neutral functional Integrodifferential infinite delay systems in Banach spaces,Taiwan Journal of athematics, 8 pp689-702

2 Chang Y.K, Nieto J.J and W.S.Li (2009); Controllability of Semilinear differential systems with nonlocal initial conditions in Banach spaces , Journal of Optimization Theory and Application ,42,pp267-273.

3 Oraekie, P.A (2017); Null Controllability of Nonlinear Infinite space of Neutral Differential Systems with Distributed Delays in the Control, Journal of Nigerian Association of Mathematical Physics, vol.41, pp11-20.

4 Balachandran K. and KIM, J.H (2003) ; Remark on the paper,' Controllability of Second Order Differential Inclusion in Banach spaces''Journal of Mathematical Analysis and Applications , 285,pp537-550.

5 Xue,X (2008);Nonlocal Nonlinear Differential Equations with Measure of Noncompactness in Banach spaces,Nonlinear Analysis-doi:10.1016lj-na.2008.03.046

6 H.Hermes and J.P La Salle (1969);Functional Analysis and Time Optimal Control, Academic Press, NewYork.

7 Chukwu,E.N (1980);On the Null Controllability of Nonlinear Systems with Retarded Control, Journal of Mathematics and Applications,76,pp283-396.

8 Sinba, A.S.C (1985); Null Controllability of Nonlinear Infinite Delay systems with Restrained Control,International Journal of Control, 42,pp735-741.

9 Onwuatu, J.U (1993); Null Controllability of Nonlinear Infinite Neutral Systems,KYBERNETIKA,Vol.29,N04,pp325-336.

10 Oraekie, P.A (2018); Euclidean Null Controllability of NonlinearNeutral Systems with Multiple Delays in Control, Journal of the Nigerian Association of Mathematical Physics, Vol.44, pp--------xx-------

11 Byszewski, L .(1991);Uniqueness Criterion for Solution to abstract nonlocal Cauchy problem,Journal of Application of Mathematics,Stoch.Anal.162,49-54.

12 Fu.X.Ezzinbi (2003);Existence of Solutions for Neutral Functional Differential Evolution Equations with Nonlocal Conditions, Nonlinear Analysis,54,pp215-227.

13 Klamka (1980); Controllability of Nonlinear Systems with Distributed Delays in Control, International Journal of Control,Vo31,N0.5,pp811-819.

14 Kantorovica,L.V and G.P.Akilov (1982);Functional Analysis .Pergaman Press,Oxford.

Author's Brief Data

Prof. Paul Anaetodike Oraekie is of the Department of Mathematics, Chukwuemeka Odumegwu Ojukwu University, Uli Campus, Anambra State, Nigeria.
Email: drsirpauloraekie@gmail.com

Applications of Information Cryptography in Its Various Stages of Evolution, from Antiquity to the Modern Era

Nnaemeka Uchenna Ezeonyi, Obikwelu Raphael Okonkwo & Obinna Arthur Enweka

Abstract

Communication is a daily activity. Information needs to be move from a sender to a receiver, for a communication to hold. However, there are information or messages that should be kept secret and does not require knowledge of a third party. Such messages are encrypted or coded into a cipher text, so as to make no meaning to a third party who may eventually intercept it. This coding of information is called Encryption, while Decryption is the reverse of encryption. Thus, Cryptography is the process of encryption of plain texts and decryption of cipher texts. Cryptography began in early civilizations of Hebrew, Egypt, and Rome with the Atbash, Hieroglyph and Ceaser's Ciphers respectively. This period is regarded as the "Antiquity". Cryptography later evolved into Classic Cryptography, in the Middle Ages, where the "Key Model" and "Cryptanalysis" or code-breaking were introduced. Furthermore, Cryptography evolved to "Field Ciphers" and "Tele-Printer Ciphers" during the World War I. Moreover, the World War II saw the evolution of cryptography into various "Cipher Machines". In modern times, cryptography evolved into sophisticated mathematical equations called "Algorithms", for encrypting and decrypting messages. At these various evolution stages, cryptography is seen to be applied in civil communications, wars, cryptanalysis and e-commerce.

Keywords: cryptography, cryptanalysis, ciphers, encryption, decryption, data.

1.0 Introduction

Cryptography is a method of protecting information and communications through the use of codes, so that only those for whom the information is intended can read and process it (Richards, 2021).Cryptography is one of the techniques used to ensure secure transmission of information via a channel between a pair of communicators. This prevents third parties from being acquainted with the data in transit (Peralta et al, 2014).Cryptography is a Greek word that means 'secret writing'. Cryptography is the science of both encryption and decryption.

Encryption is the process of encoding a message in such a way as to hide its contents. A plain or normal text sent over the network is converted into cipher text so that the information can only be used by the sender and the receiver (Krishna and Manikandan, 2020). The reverse process of encryption is called Decryption. It is the process of converting Cipher Text into Plain Text. Cryptographers use the decryption algorithms at the receiver side to obtain the original message from non-readable message i.e. Cipher Text (Naser, 2021). However, from ancient times till this modern times, several cryptographic techniques have been invented. This study presents cryptography in different era and are treated in the following order:

- Cryptography in the Antiquity
- Cryptography in the Middle Ages (*Classical Cryptography*)
- Cryptography in the World War I
- Cryptography in the World War II
- Modern Cryptography

2.0 Main Body

2.1 Cryptography in Antiquity

Antiquity is any period before the European Middle Ages (5th to 15th centuries) but still within the history of Western civilization ("Antiquity", 2023). According to Naser (2021), from the beginning of civilization when people started to live in different tribes or groups, each of them got the idea to be more powerful than others and to rule other tribes. So they feel for a secure and secret communication and thus how the process of primary cryptography was introduced. Hebrew scholars made use of simple mono-alphabetic substitution ciphers (such as the Atbash cipher) beginning perhaps around 600 to 500 BC ("Antiquity", 2023). Early civilizations in Egypt, Greece, and Rome adopted encryption for communication. Nearly 1900 B.C. (2000 B.C.), in ancient Egypt, a non-standard encryption was utilized on hidden “hieroglyphics” engraved on stone—the earliest known instance of cryptography—to conceal the meanings from those who did not know them, and for the amusement (Naser, 2021).By later periods of antiquity, cryptography was widely used to protect important military information, a purpose that it still serves to this day. A prominent example of Roman cryptography, known as the Caesar cipher, involved shifting the letters of an encrypted message by a certain number of places down the Latin alphabet.

Knowing this system and the number of places to shift the letters, a recipient could successfully decode the otherwise illegible message.

Figure 1: Hieroglyph (First techniques of Cryptography) (Hashmi and Choubey, 2018).

Below is a summary of the cryptographic techniques in Antiquity.

Period	Cryptographic Techniques		
Antiquity (5th to 15th Century)	(1). Atbash Cipher • 600 – 500 BC • By Ancient Hebrew • Used in Civil Communications • Mono-Alphabetic Substitution Technique	(2). Hieroglyph • 300 BC • By Ancient Egypt • Used in Wars and in Civil Communications • Pictorial Writing Technique	(3). Caesar Cipher • 100 BC • By Julius Caesar and Roman Armies • Used in War • Mono-Alphabetic Shift Technique

2.2 Cryptography in the Middle Ages (Classic Cryptography)

According to Hashmi and Choubey (2018), around 500 – 600 BC, Cryptography became popular, so encryption followed these methods:

- Substitution
- Transposition
- Codes
- Additionally, Cryptanalysis began in the Medieval ("History of

Cryptography", 2023)

2.2.1 Substitution cryptographic method

This was the first cipher method which makes use of key model. Therefore, it can be called a 'Substitution Cipher'. Key means replacing alphabet to other alphabet for some secret rule. This rule becomes called a key (Abbasi and Singh, 2021).

There are Two (2) applications of substitution method.

i. Mono-Alphabetic Cipher

According to Aung et al. (2019), in Mono-Alphabetic substitution, a character (or a symbol) in the plain text is always changed to the same character (or a symbol) in the cipher text regardless of its position in the text (Aung et al., 2019).Examples are: Additive cipher, Shift cipher, Caesar cipher, Multiplicative cipher, Affine cipher, etc.

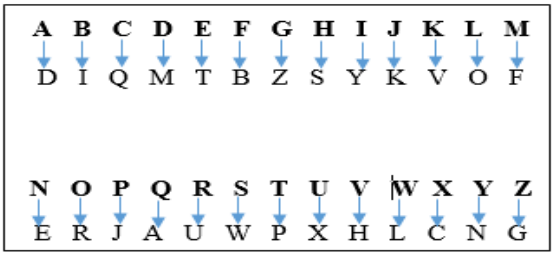


Figure 2: A Mono-Alphabetic Substitution Cipher (Hashmi and Choubey, 2018)

ii. Poly-Alphabetic Cipher

In Poly-Alphabetic substitution, each occurrence of a character may have a different substitute. (Aung et al., 2019). Examples of Poly-Alphabetic ciphers are: Vigenère cipher, Autokey cipher, Playfair cipher, Beaufort cipher, Running key cipher, Porta cipher, Hill cipher, One-Time pad, Rotor cipher, etc.

2.2.2 Transposition cryptographic method

According to Twum et al (2019), transposition ciphers shuffles characters around, instead of substituting them with other characters, as in the Substitution Method treated earlier. A transposition cipher is one which rearranges the order of the letters in the cipher text (encoded text), according to some predetermined method, without making any substitutions (Nrich, 2018).

E	N	E	M	Y	T	A
N	K	S	A	P	P	R
O	A	C	H	I	N	G
H	I	L	L	E	I	G
H	T	S	I	X	T	H
R	E	E	S	T	O	P

Plain Text: ENEMY TANKS APPROACHING HILL EIGHT SIX THREE STOP

Cipher Text: ENOHH RNKAI TEESC LSEMA HLISY PIEXT TPNIT OARGG HPXXX

Figure 3: A Simple Columnar Transposition Cipher (UMich, 2018).

2.2.3 Codebook cryptographic method

Codebook makes use of codes to replace a word or a phrase. Using Code, it was a good way to obfuscate meaning if the message is small and the codebooks are safe (Hashmi and Choubey, 2018).

plaintext	attack	to	taj	on	five	dec	eighteen
symbol	&	%	@	!	<	#	?

Figure 4: A Codebook Cipher Method (Hashmi and Choubey, 2018)

2.2.4 Cryptanalysis

Frequency Analysis technique was designed by Al-Kindi, an Arab mathematician, for breaking mono-alphabetic substitution ciphers. This was around AD 800, in the medieval ("History of Cryptography", 2023). Cryptanalysis means trying to break any security system (or cipher) by using unauthorized ways to access the information in that system. Thus, cryptanalysis works against cryptography. The cryptanalyst tries to find any weakness in the cryptographic system to get either the source of information (plaintext) or the key used in the encryption algorithm (Al-Janabi, Al-Khateeb and Abd, 2017). The objective of cryptanalyst is to be able to decrypt cipher text (Tiwari, Nandi and Mishra, 2013). In the modern era, among several instances, Brute-force key-space search has broken some real-world ciphers and applications, including single-DES, 40-bit "export-strength" cryptography, and the DVD Content Scrambling System. In 2008, researchers conducted a proof-of-concept break of SSL using weaknesses in the MD5 hash function and certificate

issuer practices that made it possible to exploit collision attacks on hash functions ("Cryptanalysis", 2023). In World War II, the Allies benefitted enormously from their joint success cryptanalysis of the German ciphers – including the Enigma machine and the Lorenz cipher – and Japanese ciphers, particularly 'Purple' and JN-25. In World War II, the Enigma cipher system was broken by Polish and British cryptographers. ("Cryptanalysis", 2023). Below is a summary of cryptographies used in the medieval period.

Period	**Cryptographic Techniques**			
Medieval (500 – 1500 CE)	(1). Substitution • Makes use of Ciphers • Substitutes alphabets with another • Used in Civil Communications	(2). Transposition • Makes use of Ciphers • shuffles characters around • Used in Civil Communications	(3). Codebook • Makes use of Codes to replace words or phrases • Used in Civil Communications where the message is small and codebooks are safe • Used in Wars	(4). Cryptanalysis • The cryptanalyst tries to find any weakness in the cryptographic system in order to break the code. Thus, cryptanalysis works against cryptography.

2.3 Cryptography in the World War 1

According to Cthaeh (2021), Radio was invented at the very end of the 18th century and World War I and became the first big war in which it was used. Naturally, making communications more effective also increased communication traffic by several orders of magnitude.World War I has a timeline from 28th July, 1914 to 11th November, 1918 (Ray, 2018). According to Cthaeh (2021), World War I is the second largest military conflict in history, surpassed only by World War II. The war was fought between two camps — the Central Powers and the Allied Powers — and lasted until late 1918. The main participants on the side of the Central Powers were Germany, Austria-Hungary, the Ottoman Empire, and Bulgaria. On the side of the Allied Powers were France, Britain, Russia, and Italy. Many other countries joined the conflict at different stages (including the United States on the side of the Allied Powers). The invention of the electric telegraph increased the traffic of messages dramatically. Messages could now travel through electric wires close to the speed of light.

2.3.1 Standard codes used in World War I

Cthaeh (2021) stated that the most common use of codes was for naval, diplomatic, and strategic communication. In general, using codes is more cumbersome compared to ciphers, since the encoding/decoding process is significantly slower and the secure distribution of codebooks is always a challenging task, especially when the communicating parties are constantly on the move. On the other hand, these codes were considered far more secure than ciphers. That's why they were preferred for communication that required absolute secrecy.

Trench Codes: These were less sophisticated codes with a much smaller vocabulary of up to only a few thousand words, used by armies inside trenches. They were less secure but easier to distribute. The lower security wasn't necessarily a serious issue. Even if the enemy managed to break the code for a particular message, it wouldn't matter too much unless they break it fast enough. The situation on the battlefield is changing quickly and old information becomes useless very fast (Cthaeh, 2021).

2.3.2 Field ciphers used in World War I

i. Playfair (British): The Playfair cipher system was widely used by American army and English Army during the World War I (Shang & Lu, 2012).The British used it for tactical communication. Later on, the Americans picked it up too when they joined the war (Cthaeh, 2021).

ii. Interrupted Columnar Transposition (French): The French used the interrupted columnar transposition cipher for very similar purposes to the British's use of the Playfair cipher (tactical communication on the battlefield) (Cthaeh, 2021).

iii. Turning Grilles Cipher (German): This is a pure transposition cipher that uses a square made up of smaller squares. Crucially, there were holes at the positions of a quarter of the smaller squares. The Germans used squares of different sizes, depending on the length of the message they wanted to send (like 7×7 or 10×10), always removing a quarter of the small squares (Cthaeh, 2021).

iv. ADFGX and ADFGVX cipher (German): The cipher's name initially was **ADFGX** and shortly after it became **ADFGVX**, after a small modification. However, the ADFGVX modification doesn't change the nature of the cipher. Germany introduced it in early 1918 and used it for communications between divisions, corps, and army headquarters during the Spring Offensive I told you about earlier (Cthaeh, 2021).

v. Vigenere Cipher (Russia): Ernst Fetterlein was in the Tsarist Russian Ministry of Foreign Affairs from 1896 and solved (among others) German, Austrian and British codes. He became chief cryptographer with the rank of admiral. The Russians used an overcomplicated version of the Vigenère Cipher. It was broken within three days by Austro-Hungarian cryptanalyst Hermann Pokorny (Cthaeh, 2021).

2.3.3 Tele-printer ciphers used in World War I

In 1917, Gilbert Vernam proposed a tele-printer cipher in which a previously prepared key, kept on paper tape, is combined character by character with the plaintext message to produce the cypher text. This led to the development of electromechanical devices as cipher machines, and to the only unbreakable cipher, the One-Time pad (Rijmenants, 2022).

One-Time Pad

To perform one-time pad encryption, we need a key, called one-time pad. A one-time pad can be a single sheet, a booklet or a strip or roll of paper tape that contains series of truly random digits. A one-time pad set consists of two identical one-time pads, one pad called OUT and one called IN. To establish one-way communications, you only need one OUT pad for the sender and an identical copy called IN pad for the receiver. To communicate in both ways, you need two different one-time pad sets: person A has an OUT pad of which person B has the IN copy, and person B has another OUT pad of which person A has the IN copy (Rijmenants, 2022). Below is a summary of cryptography used in the World War 1

Periods	**Cryptographic Techniques**		
World War 1 (1914 - 1918)	(1). Codebooks • Makes use of Codes to replace words or phrases • Used in Civil Communications where the message is small and codebooks are safe • Used in World War 1 (Codebook with super-encryption). • Example: **Trench Codes.**	(2). Field Ciphers i. PlayFair Cipher (British) ii. Interrupted Columnar Transposition (French) iii. Turning Grilles Cipher (Germany) iv. ADFGX and ADFGVX cipher (Germany) v. Vigenere Cipher (Russia)	(3). Tele-Printer Ciphers • This is a technique, in which a previously prepared key, kept on paper tape, is combined character by character with the plaintext message to produce the cypher text. • Example: One Time Pad Cipher

2.4 Cryptography in the World War II

By World War II, mechanical and electromechanical cipher machines were in wide use ("History of cryptography", 2023). The World War II has a timeline from 1939 to 1945. The principal belligerents were the Axis powers—Germany, Italy, and Japan —and the Allies—France, Great Britain, the United States, the Soviet Union, and, to a lesser extent, China (Hughes and Royde-Smith, 2023).

In the 1920s, various mechanical encryption deviceswere invented to automate the process of encryption. Most were based on the concept of a rotor, a mechanical wheel wired to perform a general substitution (Sokouti, Sokouti and Pashazadeh, 2009).

2.4.1 Cipher machines used in World War II

Enigma (Germany): As complicated as the Enigma was, it was broken during World War II. First, a team of Polish cryptographers broke the German Enigma and explained their attack to the British. The Germans modified their Enigma as the war progressed, and the British continued to cryptanalyze the new versions (Sokouti, Sokouti and Pashazadeh, 2009).

Fig 5: The German Enigma ("History of cryptography", 2023)

Purple (Japan): In the early 1930s, the Japanese government purchased the commercial version of the Enigma machine from the German government in order to build an enhanced version of it. This cryptographic machine was named ''Red" by the US government. Soon after the ''Red" cipher was broken by the U.S.A, the Japanese government created a more evolved and secure cipher known as ''97-shiki O-bun In-ji-ki" or ''97 Alphabetical Typewriter", named for its creation on the Japanese year 2597 in 1937. The US later named it as Purple. Unlike the Enigma machine, which used the blinking lights to represent the message, Purple used an electric typewriter, which could

write the message on paper. This was easy to use than the Enigma machine. However, it was heavy and tedious to carry in combat areas. It was a complex machine used to encrypt data not only in the 1930s, but even today. It falls under the category of homophonic substitution ciphers, where a single plaintext letter can be replaced by any of the different cipher text letters. (Shikhare, 2015).

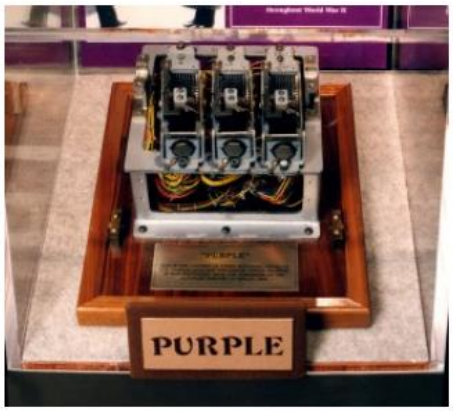


Fig 6: The Japanese 'Purple'(Shikhare, 2015)

Typex (Britain): After the World War I, the British government in 1926, established the Inter-Departmental Cipher Committee to explore possible cipher machines to replace their current book cipher systems. In 1935, the Committee decided upon "Enigma type cipher machines improved through the use of 'Type X' attachments" or Typex. The Typex machine, developed by Wing Commander O.G.W. Lywood, was such a close relative of the Enigma machine that the British use Typex machines in place of Enigma when trying to decipher Enigma messages. When German soldiers recovered a Typex machine sans rotors, they successfully converted it into an Enigma machine. This similarity discouraged German cryptanalysts from attempting to cryptanalyze Typex enciphered messages because they believed Enigma to be unbreakable (Chang, 2012).

Fig 7: The British 'Typex' (Chang, 2012).

Sigaba (USA): SIGABA is a cipher machine used during World War II until the 1950s. It takes a shot at the electromechanical arrangement of rotors (Pal, Datta and Karmakar, 2020). In the 1930s, the U.S. Army cryptologist William Friedman and his assistant Frank Rowlett drew on this simple precept to conceive a cipher machine that was easy to use, simple to rekey, and ostensibly impossible to break. To the Army it was known as SIGABA, to the Navy, ECM (Electric Cipher Machine) II. Not only was SIGABA the most secure cipher machine of World War II, but it went on to provide yeoman service for decades thereafter (Mucklow, 2015)

Fig 8: The USA 'SIGABA' (Mucklow, 2015)

Below is a summary of cryptography used in the World War II.

Period	**Cryptographic Techniques**	
World War II (In the 1920's)	(1). Codebooks • Used in World War 2 (Eg. The Japanese JN-25 Code)	(1). Cipher Machines Mechanical encryption devices that were invented to automate the process of encryption. Most were based on the concept of a rotor, a mechanical wheel wired to perform a general substitution. Examples: i. Enigma (Germany) ii. Purple (Japan) iii. Typex (Britain) iv. Sigaba (USA)

2.5 Modern Cryptography

Around 1990, the use of the Internet for commercial purposes, the introduction of online commercial transactions and as wireless networks became more common among households, the need for encryption grew, as a level of security was needed in these everyday situations ("History of Cryptography", 2023). Adomey (2020) explained three (3) types of Cryptography:

i. Secret (Symmetric) Key Cryptography

ii. Public (Asymmetric) Key Cryptography

iii. Hash Functions

iv. Hybrid Cryptography (additional)

2.5.1 Secret (Symmetric) key cryptography

The Symmetric Key Cryptography is also known as Secret Key Cryptography or Conventional Cryptography. The Symmetric Key Cryptography is an encryption system in which the sender and receiver of a message share a single, common key used to encrypt and decrypt the message. It uses an algorithm called Secret Key Algorithm or Symmetric Algorithm (Adomey, 2020).

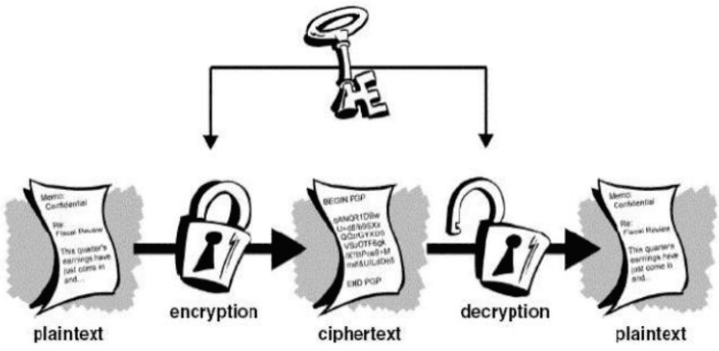


Figure 9: Symmetric Key Cryptography (Adomey, 2020)

Some examples of popular Symmetric Key Cryptography are: DES – Data Encryption Standard, Triple-DES, AES – Advanced Encryption System, Rivest Cipher 4 (RC4).

2.5.2 Public (asymmetric) key cryptography

According to Adomey (2020), Asymmetric cryptography, also known as Public-key cryptography, refers to a cryptographic algorithm which

requires two separate keys, one of which is private and one of which is public. The public key encrypts the message while the private key decrypts the encrypted message. Public Key Cryptography is a very advanced form of cryptography. Officially, Whitfield Diffie and Martin Hellman invented it in 1975. The British Clifford Cocks of Communications-Electronics Security Group (CESG) of (Government Communications Headquarters - GCHQ) first discovered the basic technique of public key cryptography in 1973 but this was a secret until 1997. The figure below depicts a public key cryptography.

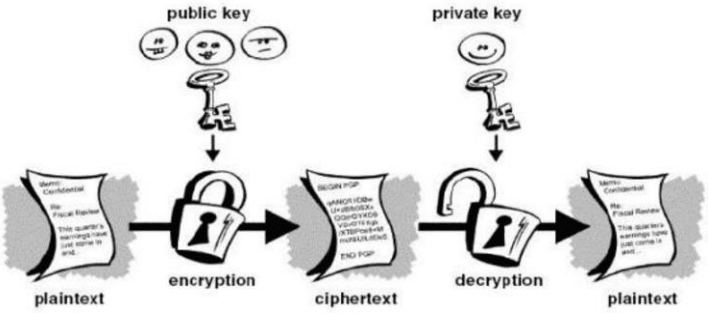


Figure 10: Public (Asymmetric) Key Cryptography (Adomey, 2020)

Some examples of asymmetric cryptography are: Rivest-Shamir-Adleman (RSA) Algorithm, Digital Signature Standard, EIGamal, etc.

2.5.3 Hash functions

According to Kundu and Dutta (2020), hash functions refer to a function that compresses a string of arbitrary input to a string of fixed length. In other words, we get a fixed-length message digest out of a variable-length message. Compared to the message the digest is normally much smaller. The main purpose of hashing is related with message security like protecting message integrity, authenticity, etc. Wahome (2021) further explained that using hash functions for cryptography refers to cryptographic hash function. He continued that all cryptographic hash functions are hash functions, but not all hash functions are cryptographic hash functions. Mathematically, Wahome classified cryptographic hash functions into two classes:

- Unkeyed hash functions also known Manipulation Detection Code (MDC) or Message Authentication Code (MAC) with a single parameter, an input message.
- Keyed hash functions with two distinct input, an input message and a secret key.

Wahome (2021) also listed the examples of cryptographic hash functions

as follows:

- The Secured Hash Algorithm (SHA) family - They are six hash functions: SHA -0, SHA – 1, SHA – 224, SHA – 256, SHA – 384 and SHA – 512. The first four operate on 512-bit message blocks divided into 32-bit words and the last two on 1024-bit blocks divided into 64-bit words. Bitcoin, the original and largest cryptocurrency (at the time of writing), uses the SHA-256 hash function.

- **The MD (Message Digest)** family — comprises of MD2, MD4, MD5 and MD6 authored by Ronald Rivest for RSA security and was adopted as the Internet Standard RFC 1321.

- **RIPEMD (RACE Integrity Primitives Evaluation Message Digest)** — a family of cryptographic hash functions based upon the design principles used in MD4 developed by Hans Dobbertin, Antoon Bosselaers, and Bart Preneel at the COSIC research group at the Katholieke Universiteit Leuven. RIPEMD-160 produces a hash digest of 160 bits (20 bytes).

- **Whirlpool** — designed by Vincent Rijmen and Paulo S. L. M. Barreto, this hash function based on a substantially modified version of the Advanced Encryption Standard (AES). Whirlpool produces a hash digest of 512 bits (64 bytes).

- **BLAKE** — a hash function submitted to the NIST hash function competition by Jean-Philippe Aumasson, Luca Henzen, Willi Meier, and Raphael C.-W. Phan. It is based on Dan Bernstein's ChaCha stream cipher, but a permuted copy of the input block, XORed with round constants, is added before each ChaCha round.

- **Curl-P** — a hash function formerly used in IOTA Signature Scheme (ISS). IOTA is a cryptocurrency designed for use with the Internet of Things (IoT) and automotive ecosystems. ISS is based on Winternitz One-Time Signatures but unlike traditional Winternitz, in IOTA users sign the hash of a message. Thus, the security of ISS relies on its cryptographic hash function, which was Curl-P-27.

2.5.4 Hybrid cryptographic systems

Hybrid cryptography means combining two or more cryptosystems. There are benefits and limitations in both symmetric and asymmetric

ciphers. Symmetric ciphers are fast but suffer key exchanging. Asymmetric ciphers solve the key exchange problem, in other words secure, but slow. Practically, hybrid cryptography, which is an integration of symmetric and asymmetric ciphers, makes use of the efficiency of symmetric ciphers and the simplicity and security of asymmetric ciphers (Murad and Rahouma, 2021b).

2.5.4.1 Approaches to hybrid cryptography

In this study, three (3) approaches to hybrid cryptography were studied:

Double Encryption (of Symmetric or Asymmetric)

The first approach, according Murad and Rahouma (2021a), involves performing two layers of symmetric or asymmetric encryption. Here, data is double encrypted by applying two consecutive, either symmetric or asymmetric ciphers in a row. See figure below.

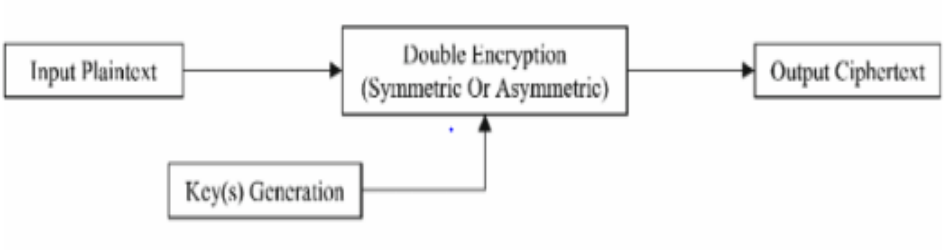


Figure 11: Hybrid scheme uses double encryption of either symmetric ciphers or asymmetric ciphers for data encryption (Murad and Rahouma, 2021a)

Symmetric / Asymmetric Hybrid Cryptography

As shown in the next figure below, this approach utilizes a symmetric algorithm to encrypt the data and applies an asymmetric algorithm to encrypt the secret key. See figure below.

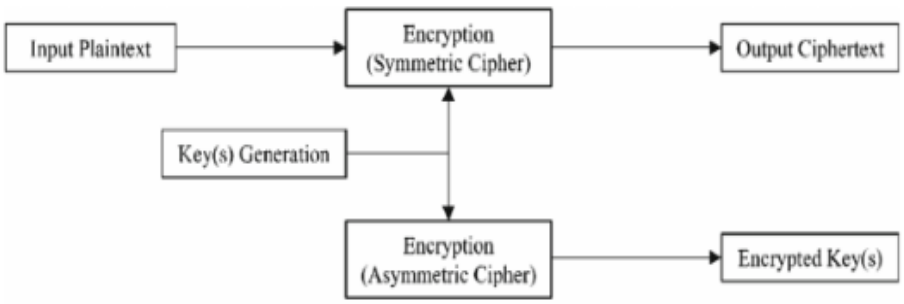


Figure 12: Hybrid scheme uses symmetric ciphers for data encryption and asymmetric ciphers for key encryption (Murad and Rahouma, 2021a)

Cryptography with other Supportive Methods (i.e. with other technologies)

To further strengthen cryptography, researchers have presented schemes where supportive methods were used to improve cryptography security level. Examples of such supportive methods are:

- Hybrid cryptography and steganography method to embed encrypted text message within image (Jassim, et al., 2019)
- A hybrid scheme of cryptography and watermarking (Kaur and Kaur, 2016)
- A hybrid cryptographic technique using RSA algorithm and scheduling concepts (Shankar and Akshaya, 2014)

These supportive methods are applied to increase the strength of a symmetric / asymmetric hybrid algorithm.

Below is a summary of cryptography used in the modern era.

Period	**Cryptographic Techniques**			
Modern Era	(1). Symmetric (Secret key) Cryptography Sender and receiver of a message share a single, common key, used to encrypt and decrypt the message. **Examples**: i). Data Encryption Standard (DES) ii). Triple-DES iii). Advanced Encryption System (AES) iv). Rivest Cipher 4 (RC4) Etc.	(2). Asymmetric (Public key) Cryptography This requires two separate keys, one of which is private and one of which is public. The public key encrypts the message while the private key decrypts the encrypted message. **Examples**: i). Rivest-Shamir-AdlemanAlgorithm(RSA) ii). Digital Signature Standard iii). EIGamal Etc.	(3). Hash Functions Here, we get a fixed-length message digest out of a variable-length message. **Examples**: i). Secured Hash Algorithm (SHA) family ii). MD (Message Digest) family iii). RIPEMD family iv). Whirlpool v). Blake vi). Curl-P	(4). Hybrid Cryptography Hybrid cryptography means combining two or more cryptosystems. **Approaches**: 1). Double Encryption (AES + AES) 2). Symmetric + Asymmetric (AES + RSA) 3). Cryptography + Supportive Methods. Eg: - (RSA + Scheduling Concepts)

3.0 Conclusion

Based on the above reviews, cryptography has evolved in so many ways and is still evolving. It has been found to be applied in the following ways:

i. Civil Communication

Cryptography is applied in encrypting messages in civil communications or messages between two regular individuals or organizations. Starting from antiquity, through the medieval, and through the world wars, and in the modern era, messages can be encrypted to ensure confidentiality. Emails are usually encrypted in order to keep them confidential. As messages travel through communication links, both wired and wireless, they are often encrypted.

ii. Cryptanalysis

Cryptanalysis is as an application of cryptography, though as a reverse process. Cryptanalysis began in the Medieval period. This is because classical cryptography began in this era, with the introduction of keys-based cryptography or ciphers. The medieval period cryptographic methods and those used in the world wars were at a point in time broken. In this modern era, cryptographic systems are not easily broken, because, they cannot be solved by hand. However, the One-Time-Pad is a Tele-Printer Cipher which has never been broken.

iii. Wars

In antiquity, Hieroglyphs were used to encrypt messages between soldiers. Cryptography in wars was mostly applied in the World War I and in the World War II. Cryptography is very essential during wars since each army group needs to frequently send messages to their colleagues in case of a need of unfavorable circumstances like need for back-up, need for a retreat, need for change of plans or change of direction, need for supply of more ammunitions. The message must be confidential, otherwise the enemy camp will know their plans and move ahead of them.

iv. E-Commerce

Cryptography is very important and is carefully applied for commercial purposes. Encryption keeps your data secure when you're shopping or banking online. It scrambles data like your credit card details and home address to ensure hackers can't misuse this information. Cryptography in e-commerce ensures data privacy.

References

Abbasi, F. and Singh, P. (2021). Cryptography: Security and integrity of data management. *Journal of Management and Service Science,*1(2), 1 – 9.

Adomey, M.K.G. (2020). *Introduction to Cryptography* [PowerPoint Slides]. Retrieved from https://www.itu.int/en/ITU-D/Cybersecurity/ Documents/01-Introduction%20to%20Cryptography.pdf, on 30 August 2021.

Al-Janabi, S.T., Al-Khateeb, B. and Abd, A.J. (2017). Intelligent techniques in cryptanalysis: Review and future directions. *UHD Journal of Science and Technology*, 1(1), 1 – 10.

Antiquity. (2023, April 6). In *Wikipedia*. https://en.wikipedia.org/wiki/ Antiquity

Aung, T. M., Naing, H. H. and Hla, N. N. (2019). A complex transformation of mono-alphabetic cipher to poly-alphabetic cipher: (Vigenère-Affine Cipher). *International Journal of Machine Language and Computing*, 9 (3), 296 – 303.

Chang, K. (2012). *Cryptanalysis of Typex* [Master's thesis, San Jose State University]. https://www.cryptomuseum.com/crypto/uk/typex/files/kelly.pdf

Cthaeh (2021, May 10). *Cryptography During World War I*. Retrieved May 24, 2023, from https://www.probabilisticworld.com/ cryptography-during-world-war-i/

Hashmi, A. and Choubey, R. (2018). Cryptographic Techniques in Information Security. *International Journal of Scientific Research in Computer Science, Engineering and Information Technology*, 3(1), 854 – 859.

History of cryptography. (2023, May 22). In *Wikipedia*. https://en. wikipedia.org/wiki/ History_of_cryptography

Hughes, T. A. and Royde-Smith, J. G. (2023, May 23). World War II. Encyclopedia Britannica. https://www.britannica.com/event/World-War-II

Jassim, K.N., Nsaif, A.K., Nseaf, A.K., Hazidar, A.H., Priambodo, B., Naf'an, E., Masril, M., Handriani, I. and Putra, Z.P. (2019). *Hybrid cryptography and steganography method to embed encrypted text message within image. In 2019 Journal of Physics: Conference Series, Volume 1339, International Conference Computer Science and Engineering*, 26 – 27th April 2019, Padang Indonesia: IOP Publishing, 1 – 9.

Kaur A. and Kaur R. (2016). A hybrid scheme for cryptography and watermarking. *International Journal of Advanced Research in Computer and Communication Engineering*, 5(7), 183 – 188.

Krishna, A and Manikadan, L.C. (2020). A study on cryptographic techniques. *International Journal of Scientific Research in Computer Science, Engineering and Information Technology*, 6(4), 321 – 327.

Kundu, R. and Dutta, A. (2020). Cryptographic hash functions and attacks – A detailed study. *International Journal of Advanced Research in Computer Science, 11(2)*, 37-44.

Mucklow, T. (2015). *The SIGABA / ECM II Cipher Machine: "A Beautiful Idea"*. USA: Center for Cryptologic History.

Murad, S.H., and Rahouma, K.H. (2021a). Hybrid Cryptographic Approach to Safeguard Cloud Computing Services: A Survey. In: Hassanien, AE., Chang, KC., Mincong, T. (Eds) *Advanced Machine Learning Technologies and Applications. AMLTA 2021.* (pp. 785 – 793). Springer.

Murad, S.H., and Rahouma, K.H. (2021b). Implementation and Performance Analysis of Hybrid Cryptographic Schemes applied in Cloud Computing Environment. *Procedia Computer Science*, 194(2021), 165 – 172.

Naser, S. M. (2021). Cryptography: From the ancient history to now, it's applications and a new complete numerical model. *International Journal of Mathematics and Statistics Studies*, *9*(3), 11-30.

Nrich (2018), *Transposition Cipher* [PowerPoint Slides]. Retrieved from https://nrich.maths.org/7940, on 25 August 2021.

Pal, S.K., Datta, B. and Karmakar, A. (2020). Cryptography and network security: a historical transformation. *SCHOLEDGE International Journal of Multidisciplinary and Allied Study*, 7(2), 30 – 44.

Peralta, D., Triguero, I., Sanchez-Reillo, R., Herrera, F. (2014). Fast fingerprint identification for large databases. *ACM Digital Library*, 47(2), 588 – 602.

Richards, K. (2021, September 1). *Cryptography*. Techtarget. Retrieved June 10, 2023, from https://www.techtarget.com/searchsecurity/definition/cryptography

Rijmenants, D. (2022). The complete guide to secure communications with the one-time pad cipher. *Cipher Machines and Cryptology*, 1 – 27.

Shang, Y., & Lu, L. (2012, July 18). *An extended algorithm based on playFair cipher* [Conference presentation]. Atlantis Press. https://www.atlantis-press.com/article/2979.pdf

Shankar M. and Akshaya P. (2014). Hybrid cryptographic technique using RSA algorithm and scheduling concepts. *International Journal of Network Security & Its Applications*, 6(6), 39-48.

Shikhare, A. (2015). *Cryptanalysis of the Purple Cipher using Random Restarts* (Publication No. 428) [Master's thesis, San Jose State University]. https://scholarworks.sjsu.edu/ etd_projects/428

Sokouti, M., Sokouti, B. and Pashazadeh, S. (2009). An approach in improving transposition cipher system. *Indian Journal of Science and Technology*, 2(8), 9 – 15.

Tiwari, G., Nandi, D. and Mishra, M. (2013). Cryptography and cryptanalysis: A Review. *International Journal of Engineering Research and Technology*, 2(10), 1898 – 1902.

Twum, F., Acquah, J.B. and William, M. (2019). A proposed enhanced transposition cipher algorithm based on Rubik's Cube transformations. *International Journal of Computer Applications*, 182 (35), 18 – 26.

Umich (2018). *Transposition Systems* [PowerPoint Slides]. Retrieved from http://websites.umich.edu/~umich/fm-34-40-2/ch11.pdf, on 25 August 2021.

Wahome M. (2021). Cryptographic Hash Functions. 1-9. Retrieved from https://www.researchgate.net/publication/351837904_Cryptographic_Hash_Functions, on 07 October, 2021.

Authors' Brief Data

Nnaemeka Uchenna Ezeonyi is System Analyst, University Library, Chukwuemeka Odumegwu Ojukwu Universty, Igbariam, Anambra State, Nigeria. *Email*: nu.ezeonyi@gmail.com.

Obikwelu Raphael Okonkwo is of the Department of Computer Science, Nnamdi Azikiwe University, Awka, Anambra State. *Email*: ro.okonkwo@unizik.edu.ng.

Obinna Arthur Enweka is affiliated to Department of Computer Science, Federal Cooperate College, Oji River, Enugu State, Nigeria. *Email*: enweka.arthur@gmail.com.

Use of Fenton's Reagent for Pollutants Removal in Pharmaceutical Effluent

E.I. Madukasi and O.B.Tojuola

Abstract

Effluent from a pharmaceutical factory producing a single chemical product was treated on a bench scale with advance oxidation process (H_2O_2 & Fe^{2+}). The effluent was as a result of the factory treatment of the pharmaceutical wastewater by UASB (up flow anaerobic sludge bed) and a SBR (sequencing batch reactor) process. The chromatechemical oxygen demand (CODcr) range of the discharged effluent was between 8000-10,000mg/L with some residual recalcitrant compounds. The residual recalcitrant compounds which were measured by gas chromatography mass spectrometry (GC-MS) mainly consisted of alcohols, phenols and nitrogenous and sulfur compounds. The experimental variables studied include dosages of Fe^{2+}, H_2O_2 and mixing speed. The result showed that the oxidation by Fenton's reagent was best when concentration of iron (II) sulfate and hydrogen peroxide were [Fe^{2+}]=1.093mmol/L; [H_2O_2] = 2.5mmol/L at pH = 3.0 for 30min at 80rpm; followed by conditioning with lime (1%) to pH = 8.0 where coagulation by iron hydroxide took place over 20min. Under these optimal operating conditions, the maximum removal efficiency for CODcr, Color and the aromatic compounds were 56%, 95% and 90% respectively.

Keywords: Fenton reagent; pharmaceutical effluent; hydrogen peroxide; ferrous salt; effluent treatment; chemical treatment

Introduction

The process of toxicity reduction in pharmaceutical wastewater is of paramount importance due to known fact that substances synthesized in pharmaceutical industry are either toxic inhibitory compound or structurally complex organic chemicals that are resistant to biological degradation and consequent accumulation in the environment as well as possible carcinogenic and mutagenic effect (Jia *et al***,** 2015; Ronak & Shweta, 2015***;*** Balcioglu & Otker, 2003). This makes conventional treatment methods inadequate for the treatment of pharmaceutical wastewater. One of the possible methods for their degradation and removal is chemical oxidation, especially advanced oxidation

processes (AOPs) using for example O_3/H_2O_2 (peroxone); $O_3/H_2O_2/UV$; O_3/UV; H_2O_2/UV; Tio_2/UV and Fenton reactions. These processes involve the in-situ formation of highly reactive hydroxyl radicals (•OH), which react quickly and non-selectively with almost all organic pollutants (Vrushali & Gawande, 2015**;** Tijani *et al.*, 2016; Sanchis *et al.*, 2013). One of the most important advance oxidation processes used to generate hydroxyl radicals employs the Fe^{2+}/H_2O_2 system where the catalyst (ferrous ions) is dissolved in water, thus being known as Fenton process (Yuan *et al.*, 2013). Fenton's reaction is one of the most effective methods of oxidation of organic pollutants that are oxidatively degraded by hydroxyl radicals generated from H_2O_2 in the presence of Fe^{3+} as a catalyst (Hartmann *et al.*, 2010; Maezono *et al.*, 2011). $Fe^{2+} + H_2O_2$ ----------> $fe^{3+} + OH + OH•$ equation1.

When ferrous salts are used, the hydroxyl radical is produced immediately by the rapid reaction between ferrous ion and H_2O_2 (equqtion1). Fe^{3+} can also be used to decompose H_2O_2 and to produce oxidative radicals in the Fenton-like process. With Ferric salts, the hydroxyl radical is produced in a two-stage process with the slow reaction between ferric ion and H_2O_2 (equation2) followed by the rapid reaction between the produced ferrous ion and additional hydrogen peroxide [Kiwi *et al.*,1993]. $Fe^{3+} + H_2O_2$----------> $fe^{2+} + HO_2^{\bullet} + H^+$ equation 2.

In most applications, it does not matter whether fe^{2+} or fe^{3+} ions are used to catalyze the reaction, although some authors (Pera-Titus *et al.*, 2004; Walling & Amarnath, 1982) suggested that if low doses of Fenton's reagent are used ferrous ions may be preferable. The efficiency of Fenton's process depends on H_2O_2 and fe^{2+} concentrations and the pH of the reaction. According to some previous researcher's report, pH value should range from 3 to 5 (Mohammadine *et al.*, 2014; Navalon *et al.*, 2010 and Maezono *et al.*, 2011).

Fenton reagent was found to be very effective in treating various industrial wastewater components, including aromatic & aliphatic compounds (Barbusinski & Filipek, 2001), a wide variety of dyes (Hsueh et al., 2005) as well as many other substances, including pesticides (Barbusïñki & Filpek., 2001). In this work, we present the oxidative treatment of pharmaceutical effluent that contained some recalcitrant compounds by Fenton reaction, using COD as determinand for the parameter only. This is because the pharmaceutical effluent will be subjected to critical biological treatment but effort was geared towards understanding the behavior of the effluent in a chemical treatment method hence the use of a single and most suitable parameter for efficiency determination.

Material & Methods

Wastewater:

The pharmaceutical effluent is from a medium scale drug manufacturing plant situated in Ota near Lagos State Nigeria. The presence of toxic compounds in wastewater was both due to the factory product as well as chemicals used in sterilizing the manufacturing equipment. The intermittent cleaning and disinfecting of the tanks used in the production as well as domestic utilization of the tap water make up the wastewater coming out of the plant. The plant manufacturing line is operated as batch reactor. All the characteristics of the wastewater (Table1) were measured according to procedures described in standard methods (AWWA, 1995)

Table1: **Pharmaceutical Effluent Chemical Characterization**

PARAMETERS	MEAN VALUE
pH	4,3 ± 0,3
BOD5 (mg L-1)	1370 ± 260
COD (mg L-1)	8030 ± 800
Suspended solids (mg L-1)	65 ± 10
Total solids (mg L-1)	1400 ± 400
Fats and Oils (mg L-1)	45 ± 25
Detergents (mg L-1)	100 ± 50
Odour	Noticeable, peculiar, savoury

Experimental procedure:

The following parameters of Fenton's reaction were examined and optimized; hydrogen peroxide and ferrous concentration, [fe^{2+}]: [H_2O_2] ratio, and initial pH of the reaction. A liter of wastewater was added into one liter Erlenmeyer flask which served as the reactor, acidified with H_2SO_4 (Fenton reaction is effective at acidic pH range). Since the initial pH of the wastewater is above 5.0, the sample was acidified to the desired value in the pH range of 2.5 –4.0. After which various doses of 30% H_2O_2 and solid $FeSO_4.7H_2O$ were added, the mixture was vigorously stirred for 1hour at 80rpm (oxidation process), then pH was adjusted to 8.0 with 1% lime and coagulated at 30rpm for 20min. it was allowed to sediment and chemical oxygen demand (COD) and residual H_2O_2 were determined in the clear solution. COD tests were made after total removal of residual H_2O_2. The residual H_2O_2 can increase the COD value since it acts as a reductant, especially in the chromate based analysis of COD determination. Talinli and Anderson (1992) investigated the reducing effect of H_2O_2 on $K_2Cr_2O_7$ and they showed linear relationship between concentration of H_2O_2 and COD.

Residual H_2O_2 removal

This was achieved by raising the pH of the solution (pH=10.5) at high temperature (45) in the presence of fe^{3+} with stirring at 65rpm and was sit overnight (Walling & Amarnath, 1982; Krzysztof Barbusinski, 2009).

Analytical methods

Aromatic and aliphatic compounds were analyzed by Infrared spectrometer (FTIR spectrometer) and confirmed with gas chromatography – mass spectrometry (GC– MS) as shown in fig1. The trace element analyses were carried out with inductive coupled plasma (optimal emission spectrometer, optima 5300DV). COD (closed reflux, trimetric method). Concentration of residual H_2O_2 was analyzed by the $KMnO_4$ method.

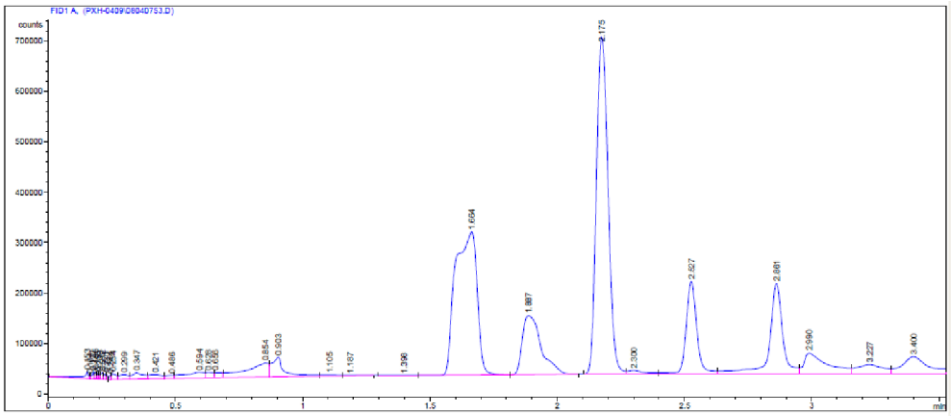


Fig.1: **GC Chromatogram of the pharmaceutical Effluent**

Statistical Analysis

Data are presented as mean ± SD of triplicate determinations and descriptive statistics was conducted using Microsoft Excel (2016).

Result and Discussion

Effect of Fe^{2+} concentration.

It was shown that as the concentration of Fe^{2+} increased, the COD removal increased until a point where further addition of iron becomes inefficient. The feature of an optimal dose range for the iron catalyst is characteristics of Fenton reagent although the range varies for different wastewater. Typical ranges are $[Fe^{2+}]:[H_2O_2\ ]$ = 5– 25 (Pere-Titus *et al.*, 2004). Figure2 shows the effect of iron dosage on COD removal using different initial H_2O_2

concentrations. The result showed that the efficiency of Fenton reaction depends on the concentration of fe^{2+} as occurs in the classical Fenton reagent process. (Rajesh & Raman, 2013) have demonstrated that the COD removal is nearly the same using either fe^{2+} or fe^{3+} in the degradation of a textile wastewater by the Fenton process. The maximum COD removal achieved in this study was between 40 – 56% depending on the hydrogen peroxide dosage.

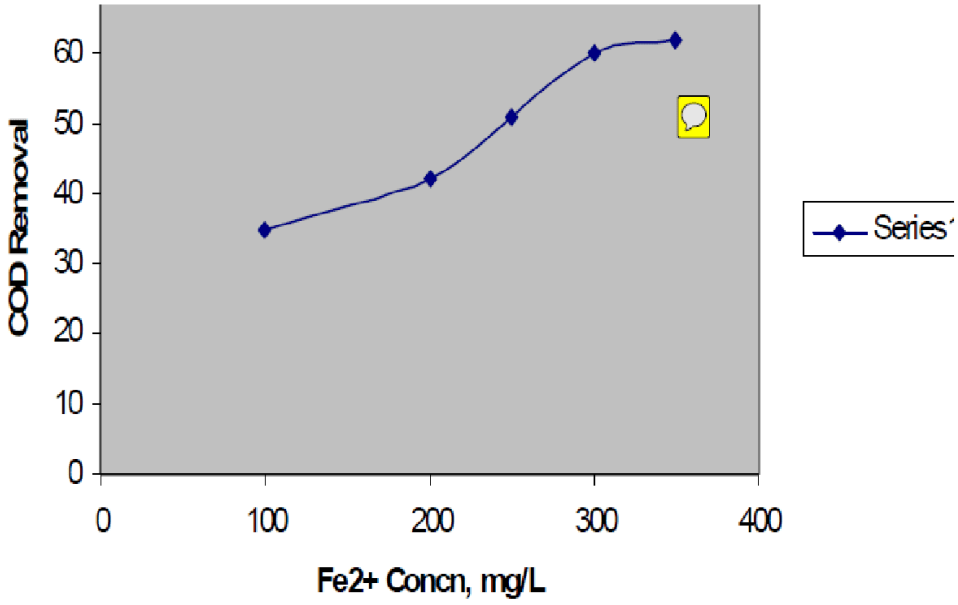


FIG. 2:: **Effect of Fe^{2+} Concentration variation**
H_2O_2 @ 1.6M; pH = 2.5; Mixing speed = 100rpm @ 30min

Effect of temperature and pH

An initial experiment was carried out at room temperature and at 50°C, to show the effect of temperature on COD removal efficiency but no significant differences were observed in the treatment efficiency for the tested temperatures (data not shown). Thus all further work was carried out at room temperature. Research findings indicate that the temperature of the wastewater almost does not affect the efficiency of COD removal in Fenton's oxidation (Peral *et al.,* 2002; Casero *et al.,* 1997), although the redox reaction can be accelerated by rising the temperature as expected. The time required for the oxidation to be completed at room temperature was about 15–20 times longer than at 50°C which required several minutes (data not shown). When tested with initial pH range of 2.5 – 4.5, no significant differences in the treatment efficiency were observed although pH 3.5 showed slightly better results. This finding is in adherence with the recent research reports that suggest that the optimum pH for Fenton oxidation is between 3–5 and that it is independent of the nature of the wastewater. (Tambosi *et al.,* 2006; Hsueh *et al.,* 2005) all observed that pH affects significantly the degradation of organics by Fenton reaction and acidic condition is required to produce sufficient hydroxyl radicals

by the decomposition of hydrogen peroxide catalyzed by ferrous ions. In a recent study, (Zhang *et al.,* 2005) reported the optimum pH as 2.5 for the treatment of landfill leachate by Fenton's oxidation.

Effect of H_2O_2 concentration

The degradation rate of organics in wastewater increases as the concentration of H_2O_2 increases until a critical H_2O_2 concentration is achieved (Huseh, *et al.,* 2005). Above this critical concentration, the degradation rate of organic compounds decreases as a result of the scavenging effect, according to equation3 $H_2O_2 + OH\bullet$ ----------> $HO_2^{\bullet} + H_2O$ (3) Fig.3 clearly shows that as the concentration of H_2O_2 increases, there was an increase in the COD removal efficiency up to the optimum concentration of 15ml/L. Above this amount of H_2O_2, there was decrease in the efficiency removal.

Conclusion

The Fenton process could be applied to pharmaceutical effluent. The COD removal efficiency using oxidation was greatly affected by the initial pH of the solution. The most efficient reaction was observed at a pH of 3.0 and the optimum coagulation pH range to maximize the COD removal efficiency was between 6.0 – 8.0. For a pharmaceutical wastewater with a COD range of 8000 – 10000mg/L, average COD removal efficiency was highest when the ratio of H_2O_2/Fe^{2+} was about 150–250. At 0.3M H_2O_2 and 0.012M the optimum COD removal efficiency of 65% was achieved. Fenton reagent could be used to treat pharmaceutical wastewater that contains some constituents that are extremely toxic to biological processes hence viewed as biocides. Fenton's reaction proves to be an efficient treatment technology when biological treatment is not feasible.

Acknowledgements

The authors wish to acknowledge the technical support given by FIIRO and COOU respectively.

REFERENCES

Alpha Standard Methods for the Examination of Water and Wastewater, 18th edn. American Public Health Association Washington, DC, 1992.

Balcioglu, A. and Otker,M.(2003). Treatment of pharmaceutical wastewater containing antibiotics by O3 and O3/H2O2 processes, *Chemosphere* 50: 85–95.

Barbusïñki, K. and Filpek, K. (2001). Use of Fenton's Reagent for Removal of pesticides from Industrial Wastewater. *Polish Journal of Environmental Studies*. 10(4): 207 – 212.

Barbusinski, K. (2009). Fenton Reaction-Controversy concerning the chemistry, *Journal of society of ecological chemistry and engineering*, 16(3):348-358.

Casero, D., Sicilia, S. R, and Perez, D. B. (1997). Chemical degradation of aromatic amines by Fenton's reagent, *Water Res*.31: 1985 - 1995.

Hsueh,C. L; Huang, Y.H., Wang, C.C. and Chen, C.Y. (2005). Degradation of azo dyes using low iron concentration of Fenton and Fenton-like system, *Chemosphere*, 58: 1409-1414.

Huicen, Z., Weimin, G., Zhemin, S., Qingli,T., Wenchao, J. and Lijuan, J. (2015). QSAR models for degradation of organic pollutants in ozonation process under acidic condition. *Chemosphere* 119:.65-71.

Jimoh. O., Tijani, O., Fatoba, O., Omotola, O., Babajide, L. and Petrik, F.(2016). Pharmaceuticals, endocrine disruptors, personal care products, nanomaterials and perfluorinated pollutants. A review. *Environmental chemistry letters*. 14(1):27-49.

Kiwi, J., Dulgarin, C., Peringer, P. and Gratzel, M. (1993). Beneficial effects of homogenous photofenton pretreatment up on the biodegradation of anthraquinone sulfonate in wastewater treatment. *Appl. Catal. B. Environmental*. .3: 85-88.

Maezono, T., Tokumura, M., Sekine M., and Kawase, Y. (2011). Hydroxyl radical concentration profile in photo-Fenton oxidation process: Generation and consumption of hydroxyl radicals during the discoloration of azo-dye Orange II. *Chemosphere* 82(10):1422-1430.

Marin, S., Ramos, A. J., Cano-Sancho, G., and Sanchis, V. (2013). Mycotoxins: Occurrence, toicology and exposure assessment (Review). *Food and Chemical Toxicology* 60: 218–237.

Mohammadine, E. H., Abdelmajid, Regti., Rachid, Laamari., Rachid, Mamouni. and Nabil, Saffaj. (2014). Use of Fenton reagent as advance oxidative process for removing textile dyes from aqueous solutions. *Journal of Material and Environmental Science* 5(3): 667-674.

Navalon, S., Alvaro, M. and Garcia, H. (2010). Heterogeneous Fenton catalysts based on clays, silicas and zeolites. *Applied Catalysis B: Environmental*. 99(1-2):1-26.

Pere-Titus, M., Garcia-Molina, V., Banos, M. A., GimeneZ, J., Esplugas, S. (2004). Degradation of chlorophenols by means of advanced oxidation process: a general review, *Applied Catalysis B: Environmental*, 47: 219-256.

Pérez, M., Torrades, F., Doménech, X. and Peral, J. (2002). Fenton and photo-Fenton oxidation of textile effluents, *Water Res*. 36: 2703–2710.

Rajesh, N., and Raman, S. (2013). Treatment of Pharmaceutical Sludge by Fenton Oxidation Process. *International Journal of Chemical Engineering and Applications*. 4(6): 359-364.

Ronak, S., Shweta, V. (2015). Fenton's Reagent for the Treatment of Pharmaceutical Industry Wastewater. *International Journal of Science and Research*. 4(7): 3093-3095.

Talinli, I. Anderson, G. K. (1992). Interference of hydrogen peroxide on the standard COD test. *Wat. Res*. 26: 107- 110.

Tambosi, J.L., Domenico, M., Schirmer, W.N., Jose, H.J., Moreira-Reaina, F.P.M (2006). Pre-oxidation and coagulation on pper & pulp wastewater by fenton-like process. *J. Chem. Tech and Biotech*. 81(8): 1426-1432.

Vrushali, P. and Sagar, G. (2015). .An overview of the Fenton Process for Industrial Wastewater. *Journal of Mechanical and Civil Engineering*. 21:127-136.

Walling, C., Amarnath, K. (1982). Oxidation of mandelic acid by Fenton's reagent. *J. Am. Chem. Soc.* 104: 1185-1189.

Zhang, H., Choi, H. J. and Huang, C. P. (2005) Optimization of Fenton process for the treatment of landfill leachate, *J. Hazard. Mater*. 125: 66-174.

Authors' Brief Data

Dr Edith Ifeoma Madukasi is a lecturer in the Department of Environmental Management, Faculty of Environmental Sciences, Chukwuemeka Odumegwu Ojukwu University, Uli, Anambra State, Nigeria. *Email*: madify2002@gmail.com

O.B.Tojuola works at the Federal Institute of Industrial Research, Oshodi, Lagos, Nigeria.

Uniqueness of Optimal Control for the Relative Controllability of Neutral Integro-differential Systems in Banach Spaces with Distributed Delays in the Control

Paul Anaetodike Oraekie

ABSTRACT

A new method of approach is derived for the proof of the existence of an optimal control for Neutral Integrodifferential Systems in Banach Spaces with Distributed Delays in the Control, using the properties of optimal control energy function. The set functions upon which our studies hinged were extracted from the mild solution of the system. Use was also made of the unsymmetric Fubini theorem to establish the mild solution. Necessary and sufficient conditions for an admissible control to be an optimal control are established.

Keywords: Optimal control, uniqueness, controllability, controllability grammian, set functions.

INTRODUCTION:

The pioneering work of Vito Volterra on the integration of the differential equations of dynamics and partial differential dynamical systems published in 1884 gave vent to the conception of integral equations of the volterra type **(Oconnor and et al (2005);Oraekie(2014))**. It is equally observed in **Balachandran and Dauer (1989)**; **Oraekie (2017**) that the mixed initial boundary hyperbolic partial differential equation which arises in the study of Lossless transmission lines can be replaced by an associated neutral differential equation. This equivalence has been the basis of a number of investigations of the stability properties of distributed networks. **(see Balachandran and Dauer (1997) and Oraekie(2015)).**

The problem of controllability of linear and nonlinear systems represented by ordinary differential equation in finite dimensional space has been extensively studied. Many authors have extended the controllability concept to infinite dimensional systems in Banach spaces with bounded operators **(see Naito (1989))**. Naito has studied the controllability of semi linear systems. **Yamamoto and Park (1990)** discussed the same problem for parabolic equation with uniformly bounded nonlinear term. While **Chukwu and Lenhart (1991)** studied the controllability of nonlinear systems in abstract spaces. **Quinn and Carmichael (1984)** showed that

the controllability problem in Banach space can be converted into a fixed pointed theorem problem for a single-valued mapping**. Balachandran (1996, 1998);Oraekie(2017)** had studied the controllability and local null controllability of Sobolve type integrodifferential systems and functional differential systems in Banach spaces by using Schauders fixed point theorem.

The purpose of this paper is to investigate the uniqueness of the optimal controllability of the abstract neutral functional integrodifferential systems with distributed delays in the control of the form.

$$\frac{d}{dt}[x(t) - g(t, x_t)] + A(t)x(t) = \int_0^t f(s, x_s)ds + \int_{-h}^{0} (d_s\, D(s,r)u(s+r) \qquad (1.1)$$

$$x(to) = x_0 = \emptyset \in B, \qquad t \in [0, a] = T$$

where B is the phase space, the state variable $x(.)$ takes values in Banach space X and the control function $u(.)$ is given in $L_2(J, U)$ $(where\ |u_j| \leq 1, \quad j = 1, 2, \ldots\ldots.)$, the Banach space of admissible control functions with u a Banach space. D is a bounded linear operator from U into X, the unbounded linear operators $-A$ generates an analytic semi group and $f, g \in JxB \to X$ are appropriate functions.

2.0 *Preliminaries and Definitions*

Throughout this work X will be a Banach space with norm $\|.\|, -A: D(A) \to X$ will be the infinitesimal generator of a compact analytic semigroup of uniformly bounded linear operator $T(t)$. Let $0 \epsilon \rho(A)$, then it is possible to define the fractional power A^{α}, for $0 < \alpha \leq 1$, as a closed linear operator on its domain $D(A^{\alpha})$.

To study the system (1.1), we assume that the histories

$$x_t: (-\infty, 0) \to X, \qquad x_t(\theta) = x(t + \theta)$$

belong to some abstract phase space B, which is defined axiomatically.

Thus, B will be a linear space of functions mapping $(-\infty, 0]$ into X, endowed with a norm $\|.\|_B$.

Let us assume that B satisfies the following axioms:

(1). *If $x: [\alpha, \alpha + a] \to X, \quad a > 0$, is continuous on $[\alpha, \alpha + a]$ and $x_{\alpha} \in B, \quad$ then for every time $\tau \in [\alpha, \alpha + a]$ the following conditions hold:*

(a) *x_t is in B;*

(b) $\|x(t)\| \leq k\, \|x_{\tau}\|_B$;

(c) $\|x_\tau\|_B \leq H(\tau-\alpha)sup\{\|x(s)\|: \alpha \leq s \leq \tau\} + M(\tau-\alpha)\|x_\alpha\|_B$.

$Here\ , k > 0\ is\ a\ constant, H, M: [0,\infty) \to [0,\infty)$.

$H\ is\ continuous\ and\ \ M\ is\ locally\ bounded, and\ K, H, M\ are\ independent\ of\ x(\tau)$.

(d) $For\ the\ function\ x\ (.)\ in\ (1), x_t\ is\ a\ B-valued\ continuous\ function\ on\ [\alpha, \alpha+a]$;

(2)$The\ space\ B\ is\ a\ complete\ space$.

$Now\ we\ can\ give\ basic\ assumptions\ on\ the\ \ system$ (1.1).

(i) $g: [0,a]x\ B \to x\ is\ a\ continuous\ function, and\ there\ exists\ a\ constant\ \lambda\ \in (0,1)\ and\ P, P_1\ > 0, such\ that\ the\ function\ g\ is\ X_\lambda -\ valued\ and\ satisfies\ the\ lipschitz\ condition$:

$$\|A^\lambda g\ (t_1, \emptyset_1)\ -\ A^\lambda g\ (t_2, \emptyset_2)\ \| \leq P(|t_1 - t_2| + \|\emptyset_1\ -\ \emptyset_2\|_B)$$

$For\ 0\ \leq\ t_1\ , t_2 \leq\ a\ ;\ \emptyset_1\ , \emptyset_2 \in B, and\ the\ inequality$

$$\|A^\lambda\ g\ (t, \emptyset)\| \leq P_1\ (\|\emptyset\|_B\ +\ 1)\ holds\ for\ t \in J = [0,a], \emptyset \in B.$$

(3) $The\ function\ \ f: [0,a]xB\ \to X\ \ satisfies\ the\ following\ conditions$:

(i) $For\ each\ t \in J, the\ function\ \ f(t,.): B \to X\ \ is\ continuous\ and\ for\ each\ \ \emptyset \in B,$

$the\ function\ \ f(.,\emptyset): J \to X\ is\ strongly\ measurable,$

(ii) $For\ each\ positive\ number\ n\ , there\ is\ a\ positive\ function\ \alpha_n \epsilon\ L_1([0,a])\ such\ that$

$$sup\ \|f(t,\emptyset)\|\ \leq\ \alpha_n(t)$$

$$\|\emptyset\|_B\ \leq n$$

and

$$\lim\inf_{n\to\infty}\ \frac{1}{n}\int_0^a\int_0^t \alpha_n\ (s)ds\ \ dt = \gamma < \infty$$

(4) $The\ linear\ operator\ \ W\ \ from\ \ U\ into\ X\ \ is\ defined\ by$

$$Wu = \int_0^a T(t-s)\left[\int_{-h}^0 d_S\ C(s,l)\right]u(s+l)ds$$

$and\ there\ exists\ a\ bounded\ invertible\ operator\ \ w^{-1}\ defined\ in\ L_2\ (J;\ U)/\ker w.,$
$where\ \ C\ \ is\ a\ bounded\ linear\ operator.$

2.01: *Variation of parameters*

$The\ function\ x(.): (-\infty, a] \to X\ \ is\ a\ solution\ of\ system\ (1.1)\ if\ x_0 = \emptyset,$

$then\ the\ restriction\ of\ x(.)to\ the\ interval\ [0,a]\ \ is\ continuous\ and\ for\ each$

$0 \leq t \leq a,\qquad the\ function\ AT(t-s)g\ (s, x_s), s \in [0,t]is\ integrable\ and$

$the\ following\ integral\ equation\ is\ the\ required\ solution\ of\ system\ (1.1).$

$$x(t) = T(t)[\emptyset(0) - g(0,\emptyset)] + g(t,xt) - \int_0^t AT(t-s)g(s,x_s)ds$$

$$+ \int_0^t T(t-s)\left[\int_{-h}^0 (d_S\, C(s,l)u(s+l) + \int_0^s f(\tau,x_\tau)d\tau\right]ds, t \in J \quad \ldots\ldots \quad \ldots.(2.1)$$

$$(2.1) \Longrightarrow x(t) = T(t)[\emptyset(0) - g(0,\emptyset)] + g(t,x_t) - \int_0^t AT(t-s)g(s,\ x_s\ )\ ds$$

$$+ \int_0^t T(t-s)\left[\int_{-h}^0 (d_S\, C(s,l)u(s+l)\right]ds + \int_0^t T(t-s)\left[\int_0^s f(\tau,x\tau)d\tau]\right]ds \ \ldots \ (2.2)$$

The fourth term in the right − hand side of system (2.2)*contains the values of the control* $u(t)$ *for* $t < 0$, *as well as for* $t < 0$.

The values of the control $u(t)$ *for* $t \in [0-h, 0]$ *enter into the definition of the initial complete state* z_{t_0}.

To separate them, the fourth term of system (2.2)*must be transformed by changing the order of integration. Using the unsymmetric Fubini theorem, we have the following equalities*:

$$x(t) = T(t)[\emptyset(0) - g(0,\emptyset)] + g(t,x_t) - \int_0^t AT(t-s)g(s,x_s)ds$$

$$+ \int_{-h}^0 d_S\, C\left(\int_0^t T(t-s)C(s,l)u(s+l)ds\right) + \int_0^t T(t-s)\left[\int_0^s f(\tau,x_\tau)d\tau\right]ds \quad \ldots\ldots\ldots\ldots(2.3))$$

$$= T(t)[\emptyset(0) - g(0,\emptyset)] + g(t,xt) - \int_0^t AT(t-s)g(s,x_s)ds + \int_0^t T(t-s)\left[\int_0^s f(\tau,x_\tau)d\tau\right]ds$$

$$+ \int_{-h}^o d_S\, C\left(\int_{0+l}^{t+l} T(t-s)C(s-l,l)u(s-l+l)ds\right)$$

$$= T(t)[\emptyset(0) - g(0,\emptyset)] + g(t,x_t) - \int_0^t AT(t-s)g(s,x_s)ds + \int_0^t T(t-s)\int_0^s f(\tau,x_\tau)d\tau\, ds$$

$$+ \int_{-h}^0 d_S\, C\left(\int_{0+l}^0 T(t-s)C(s-l,l)u_0(s)ds\right)$$

$$+\int_{-h}^{0} d_S\, C\left(\int_{0}^{t+l} T(t-s)\, C(s-l,l)u(s)ds\right) \ldots\ldots\ldots \quad (2.4)$$

where dcs denotes that the integration is in the Lebesque − Stielties sense with respect to the variable s in the function $C(s,l)$.

Let us introduce the following notation:

$$\hat{\mathrm{C}}(s,l) = \begin{Bmatrix} C(s,l) for\ s < t, l \in R \\ 0 \quad for \quad s > t, \quad l \in R \end{Bmatrix} \quad \ldots\ldots \quad \ldots\ldots\ldots \quad \ldots\ldots \quad (2.5)$$

Hence $x(t)$ can be expressed in the following form:

$$x(t) = T(t)[\emptyset(0) - g(0,\emptyset)] + g(t,xt) - \int_{0}^{t} AT(t-s)g(s,x_s)ds$$

$$+\int_{0}^{t} T(t-s)\int_{0}^{s} f(\tau,x_\tau)d\tau\, ds \quad + \int_{-h}^{0} d_S\, C\left(\int_{0+l}^{0} T(t-s)C(s-l\,,l)u_0(s)ds\right)$$

$$+\int_{-h}^{0} d_S\, C\left(\int_{0}^{t} T(t-s)\hat{\mathrm{C}}(s-l,l)u(s)ds\right) \ldots\ldots\ldots\ldots \quad (2.6)$$

Using again the unsymmetric Fubini theorem, the equality (2.6) *can be rewritten in more convenient form as follows*:

$$x(t) = T(t)[\emptyset(0) - g(0,\emptyset)] + g(t,x_t) - \int_{0}^{t} AT(t-s)g(s,x_s)ds$$

$$+\int_{0}^{t} T(t-s)\int_{0}^{s} f(\tau,x_\tau)d\tau\, ds \quad + \int_{-h}^{0} d_S\, C\left(\int_{l}^{0} T(t-s)Cs-l\,,l)u_0(s)ds\right)$$

$$+\int_{0}^{t}\left(\int_{-h}^{0} T(t-s)d_S\hat{\mathrm{C}}(s-l,l)u(s)ds\right) \quad (2.7)$$

Now let us consider the solution $x(t)$ of system (1.1) *for $t = t_1 = a$.*

$$x(t) = T(t)[\emptyset(0) - g(0,\emptyset)] + g(t_1\,,x_{t_1}) - \int_{0}^{t_1} AT(t\,1-s)\, g(s,x_s)\, ds$$

$$+\int_0^t T(t-s)\int_0^s f(\tau,x_\tau)d\tau\,ds+\int_{-h}^0 d_S\,C\left(\int_{0+l}^0 T(t-s)C(s-l,l)u_0(s)ds\right)$$

$$+\int_0^{t_1}\left(\int_{-h}^0 T(t_1-s)d_S\hat{\mathrm{C}}(s-l,l)u(s)ds\right) \qquad (2.8)$$

Consider system (2.7), *for brevity, let,*

$$\beta(t)=T(t)[\emptyset(0)-g(0,\emptyset)]+g(t,x_t)-\int_0^t AT(t-s)g(s,x_s)ds \quad \ldots\ldots\ldots \qquad (2.9)$$

$$\mu(t)=\int_0^t T(t-s)\int_0^s f(\tau,x_\tau)d\tau\,ds+\int_{-h}^0 dc\,s(\int_{0+l}^0 T(t-s)C(s-l,l)u_0(s)ds \qquad (2.10)$$

$$z(t,s)=\int_{-h}^0 T(t-s)d_S\,\hat{\mathrm{C}}(s-l,l) \quad \ldots\ldots.. \qquad \ldots\ldots\ldots\ldots. \qquad \ldots\ldots\ldots. \qquad (2.11)$$

Substituting (2.9), (2.10), (2.11)*in* (2.7), *we have a precise variation of constant formula for system* (1.1) *as*

$$x(t,x_0,u)=\beta(t)+\mu(t)+\int_0^t z(t,s)u(s)ds \qquad \ldots. \qquad \ldots. \qquad (2.12)$$

Definition* 2.1** (Complete State***)
The complete state for system (1.1) *is given by the set* $g(t)=\{x,u_t\}$.

Definition* 2.2** (Relative Controllability***)
The system (1.1)*is said to be relatively controllable on* $[0,a]$*if for every initial complete state* $g(0)$*and* $x_1\in X$, *there exists a control function* $u(t)$ *defined on* $[0\,,a]$ *such that the solution of system* (1.1) *satisfies* $x(t_1)=x_1$.

2.02: ***Basic Set Functions and Properties***.
Definition* 2.3** (Reachable set***)
The reachable set for the system (1.1) *is given as*

$$R(t_0\,,0)=\{\left\{\int_0^{t_1}\left[\int_{-h}^0 T(t_1-s)\,d_S\,\hat{\mathrm{C}}\,(s-l\,,l)\right]u(s)ds\right\}$$

$$Where\ U=\{u\in L_2\,([0\,,a];X):|u_j|\le .1\,;j=1,2,\ldots\ldots,m\}$$

Definition* 2.4** (Attainable set***)

The attainable set for the system (1.1)*is given as* :

$$A(t\,,0) = \{x(t\,,x_0\,,u)\colon u \in U\}, Where\ U = \{u \in L_2\,([0\,,a];X)\colon |u_j| \leq .1; j = 1,2,\ldots\ldots,m\}$$

Definition* 2.5** (Target set***)
The target set for system (1.1)*denoted by* $G(t_1\,,0)$*is given as*:

$$G(t_1\,,0) = \{x(t,x_0\,,u)\colon t_1 \geq \tau > 0\ for\ fixed\ \tau\ and\ u \in U$$

Definition* 2.6** (Controllability grammian***
The controllability grammian of the system (1.1)*is given as*:

$$W(t_1\,,0) = \int_0^{t_1}\left[\int_{-h}^{0} T(t_1 - s)d_S\,\hat{C}\,(s - l\,,l)\right]\left[\int_{-h}^{0} T(t_1 - s)\,d_S\,\hat{C}\,(s - l,l)\right]^T$$

$$Where\ T\ denotes\ matrix\ transpose.$$

2.03: ***Relationship Between the Set Functions***
We shall first establish the relationship between the attainable set and the reachable set to enable us see that once a property has been proved for one set, then it is applicable to the other.
From equation (2.7),

$$A(t\,,0) = \eta(t) + R(t\,,0)]\ ,for\ \in U, t \in [0\,,a],$$

$$Where \quad \eta(t) = \beta(t) + \mu(t).$$

This means that the attainable set is the translation of the reachable set through $\eta \in X$.
Using the attainable set, therefore, it is easy to show that the set functions possess the properties of convexity, closeness and compactness.
Also, the set functions are continuous on $[o, \infty]$*to the metric space of compact subject of* $X = E^n$. ***Chukwu*** (**1988**)***and Gyori*** (**1982**)*give impetus for adaptation of the proofs of these properties for system* (1.1).

Definition* 2.7** (Properness***)
The system (1.1)*is proper in* $X = E^n$ *on* $[0\,,a]$*if span* $R(t\,,0) = X = E^n$
i.e if

$$C^T\left[\int_{-h}^{0} T(t - s)d_S\ \hat{C}(s - l\,,l)\right] = 0 \quad a.e.$$

$a > o \Longrightarrow C = 0\,; C \in X = E^n$

3. *Main Results*

Here, a new method of approach is derived for the proof of the existence of optimal control.

Theorem 3.1

Consider the system (1.1) *given as* :

$$\frac{d}{dt}[x(t) - g(t, x_t)] + A(t)x(t) = \int_0^t f(s, x_s)ds + \int_{-h}^{0} (d_S\, C(s,l)u(s+l) \quad \ldots\ldots\ldots (3.1)$$

with its standing hypothesis.

Suppose u^* *is the optimal control of the system* (3.1), *then it is unique.*

Proof:

Let u^* *and* v^* *be optimal controls for the system* (3.1), *the* u^* *and* v^* *maximize*

$$C^T \int_0^t \left[\int_{-h}^{0} T(t-s) d_S \hat{C}(s-l, l) \right], \qquad for\ t \in [0, a], \qquad a > 0.$$

over all admissible controls $u \in U$, *and so we have the inequality with* u^* *as the optimal control given below*:

$$C^T \int_0^t \left[\int_{-h}^{0} T(t-s) d_S \hat{C}(s-l, l) \right] u(s)ds \leq C^T \int_0^{t^*} \left[\int_{-h}^{0} T(t-s) d_S \hat{C}(s-l, l) \right] u^*(s)ds \qquad (3.2)$$

Also, using v^* *as the optimal control, we have*

$$C^T \int_0^t \left[\int_{-h}^{0} T(t-s) d_S \hat{C}(s-l, l) \right] u(s)ds \leq C^T \int_0^{t^*} \left[\int_{-h}^{0} T(t-s) d_S \hat{C}(s-l, l) \right] u^*(s)ds \qquad (3.3)$$

Taking maximum of u *over* $[-1,1]$, *the range of definition of* u^* *in* (3.2) *and* (3.3), *we have the equation*

$$C^T \int_0^t \left[\int_{-h}^{0} T(t-s) d_S \hat{C}(s-l, l) \right] max|u(s)|ds, \quad for\ -1 \leq s \leq 1.$$

$$= C^T \int_0^{t^*} \left[\int_{-h}^{0} T(t-s) d_S \hat{C}(s-l, l) \right] u^*(s)ds, \quad for\ u^* \in U \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (3.4)$$

Also

$$C^T \int_0^t \left[\int_{-h}^{0} T(t-s) d_S \hat{C}(s-l, l) \right] max|u(s)|ds, \quad for\ -1 \leq s \leq 1.$$

$$= C^T \int_0^{t^*} \left[\int_{-h}^{0} T(t-s) d_S \hat{C}(s-l, l) \right] v^*(s) ds, \quad for\ v^* \in U \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (3.5)$$

$for\ u, v^* \in U, \qquad v^*\ being\ optimal\ and\ -1 \leq s \leq 1.$

$Subtracting\ equation\ (3.5)\ from\ (3.4, we\ have$

$$0 = C^T \int_0^{t^*} \left[\int_{-h}^{0} T(t-s) d_S \hat{C}(s-l, l) \right] \{ u^*(s) - v^*(s) \}\, ds$$

$(since\ system\ (3.1)\ is\ controllable\ or\ proper).$

$$\Longrightarrow u*(s) - v*(s) = 0$$

$$\Longrightarrow u*(s) = v*(s)$$

$This\ establishes\ that\ optimal\ control\ is\ unique.$

4. CONCLUSION

In this work, Neutral Functional Integro-differential systems in Banach spaces with Distributed Delays in the control were presented for optimal controllability analysis.

We established that an admissible control energy function of Neutral Functional Integro-differential systems in Banach spaces with Distributed Delays in the control is optimal control energy function of the system if and only if it is unique

The establishment of this uniqueness property of an optimal control energy function provides a new approach to proving the existence of an optimal control energy function of our system of interest..

References

1. **J. J. Oconnor and E. F. Robertson (2005) ,** "Biography of Vito Volterra (1860-1940), Publication of the School of Mathematics and Statistics, University of St Andrew, Scotland
2. **ORAEKIE, P.A., (2014):** Uniqueness of Optimal Control of Linear

Time-Varying Systems with Delay in the Control**, Tropical Journal of Applied Natural Sciences Vol 1 No1 ANSU, ULI Page155-162.**

3. Balachandraand J.P.Dauer(1998), "Controllability of Sobolev-type Integrodifferential Systems in Banach spaces", Journal of Mathematical Analysis and Applications, 217, pp 335-348.

4.K.Balachandranand J.P.Dauer(1997),"Asymptotic Null Controllability of Nonlinear Neutral Volterra Integrodifferential Systems", Journal of Mathematics System, Vol, 7, No.2, pp 1-14.

5. **ORAEKIE, P.A., (2015):** Location of the Target Set on Semi linear Dynamical Systems with Multiple Delays in the Control**, REIKO INTERNATIONAL JOURNAL OF SCIENCE AND TECHNOLOGY RESEARCH, Vol.6. NO.2A SPECIAL EDITION, PAGE 62.**

6. K.Naito (1989), Approximate Controllability for Trajectories of Semi-linear Control Systems", Journal of optimum Theory and Applications, 6, pp 57-65. **.**

7. **ORAEKIE, P.A., (2017):** The Form of Optimal Control of Semi linear Dynamical Systems with Multiple Delays in the Control, ***American Academic & Scholarly Research Journal Vol. 9, No 2, page 48 - 57.***

8. M.Yamamoto and J. Park (1990), "Controllability for Parabolic Equations with uniformly bounded non-linear terms", Journal of optimization theory and Applications, 66, pp 515-532.

9. E.N.Chukwu and S.M Len hart (1991), "Controllability Questions for Nonlinear Systems in Abstract spaces', Journal of optimization theory and Applications, 18, pp 437-462.

10.M.D.Quinn and N. Carmichael (1984-1985), "An Approach to Non-linear Control Problems using Fixed point methods, degree theory and Pseudo-inverses", .Journal of Functional Analysis and Optimization, 7, pp 197-219.

11. **Balachandran (1996, 1998)** Nonlinear Functional Differential System in Banach Spaces" Journal of Optimal Theory and Application,88, pp 61-75. **.**

12. ORAEKIE, P.A., (2017): Form of Optimal Control of Nonlinear Infinitely Space of Neutral Functional Differential Systems with Distributed Delays in the Control, American Academic & Scholarly Research Journal, vol9, No6, pp52-61.

13. Y.Hino,S. Murakami and T. Naito(1991), "Functional Differential Equations With Infinite delay", Lecture Notes in Maths, vol.1473 Springer-Vorlag, Berlin.

14. E.N.Chukwu(1988), "The Time Optimal Control Theory of Linear Differential Equations of Neutral Type", Journal of Computer, Mathematics and Applications

vol.16 pp 851-866.

15. Gyori (1982), "Delay Differential and Integrodifferential Equations in Biological Compartmental Models" Systems Science (Wroclaw) Poland, 8 pp 7-187.

Author's Brief Data

Prof. Paul Anaetodike Oraekie is of the Department of Mathematics, Chukwuemeka Odumegwu Ojukwu University, Uli Campus, Anambra State, Nigeria. *Email*: drsirpauloraekie@gmail.com

Appraising Landscaping in Chukwuemeka Odumegwu Ojukwu University, Uli Campus, Anambra State, Nigeria

By

Chukwunonso O. Umeora, Boniface S.A Okoye, Oluchi C. Ifebi & Chijioke C. Onwuzuligbo

ABSTRACT

Amid the growing benefits for proper landscaping design and planning, there is the need for man to be in a decent, well-organised and aesthetically pleasing environment. This could add value to concentration of staff and students in the campus as well as provide relaxation points within the campus. The landscaping quality of Uli campus of Chukwuemeka Odumegwu Ojukwu University deserves attention in view of its state. The objectives of this paper are to appraise the quality of the present status of landscaping in the campus and assess the perception of people on the quality of present landscape in the campus environment. This is with a view to providing a feedback for improved landscape management of the University campus environment. The methodology adopted for this research was survey design. The focus was on academic staff of the Faculty of Environmental Science of the university randomly selected from the research population. This selection was premised on their assumed knowledge of the subject matter. Data was collected from primary sources using questionnaires and observation schedules. Data analysis was done at the univariate level using Statistical Package for Social Sciences (SPSS). The outcomes show that the landscape environment within the campus is not in a good state. Some contributing factors to this were attributed to inadequate maintenance operations, inadequate provision of funds and inadequate equipment for maintenance operations, among others. The study recommends involving professionals in the built environment in the physical planning unit and works department of the institution to handle landscaping concerns within the campus, provision of enough funds for landscape improvement and maintenance operations, incorporating man-made features such as trash cans, street lights, sculpture, defined pedestrian walkways, paving and other road furnishings incorporated into the landscape. The university management may revive an existing landscape committee that would liaise with the horticulture unit of the faculty of Agriculture and have adequate as well as regular supply of new plants for possible replacement of dead plants and/or planting of new ones where they are desired. A redesign of the general landscape of the campus is desirable.

Keywords: assessment, campus, landscaping, maintenance, university

INTRODUCTION

Through designed landscapes, people can attain personal consciousness and responsibilities for the environment while letting go the pressures of everyday life. As such, landscaping plays a vital role in the quality of the environment as well as the physical and psychological wellbeing of the people. There have been tremendous changes in the building professions over time, as new advances brought new challenges that generate opportunities on the one hand, and present the probability of displacing those not prepared for it, on the other hand (Ogeye, Senibi & Akinboboye, 2019).

Landscaping refers to any activity that modifies the visible features of an area including the living elements, natural elements and man-made elements, while the landscape is everything one can see looking across an area of land. Landscape design can be seen as the art of designing and management of the components of landscape (i.e. Landforms, water bodies, vegetation and man-made features) to make good outdoor spaces for aesthetic purposes, useful, healthy and enjoyable purposes through application of cultural and scientific knowledge with concern for resources preservation (Adekunle & Basorun, 2016). Landscape practices comprise of the designing, installation and maintenance of the landscape design. Ayeni, Olotuah and Adedeji, (2013) noted that landscape design compliments architecture and provides the opportunity to contribute to the aesthetics of an area in order to improve the built environment. In addition, the principle of landscape design is to fuse the buildings with the environment, to achieve a well-planned environment.

Landscape design, as a separate discipline and business, is becoming conspicuous in the Architecture profession in Nigeria. Landscaping practices constitute a form of trade, which can be a veritable source of livelihood while serving the function of beautifying the physical environment. This prospect is yet to be fully realized in the country.

University campuses are expected to be distinguished in landscaping. A key way of achieving this is the use of well-defined landscapes, and these could be a means of attracting people to visit and to study. Good landscape design can, therefore, play a vital role in the enhancement of universities' environments and open spaces, by creating a nexus between aesthetics and open space management (Adekunle & Basorun, 2016). In pursuance of this, University campuses ought to denote landmarks as

spaces which indicate attractive spaces that represent campus identity, thus creating impressions of the campus environment as an exceptionally distinct institution. Unfortunately, poor attention has been given to the outdoor spaces around buildings in different university campuses in Nigeria. It can be shown that if considerable attention is given to the surroundings of the building structures, there will be in an improvement in the environment.

Observations of the landscapes of university campus reveal such problems as the lack of outdoor landmark spaces, poor landscape design and poor landscape management. This situation naturally, negatively affects the associated academic and residential activities within the campus. For that reason, this study seeks to appraise the state of existing landscape in the campus, with a view to providing a framework/feedback for improving and sustaining the landscape management of the University campus environment. The objectives are to appraise the quality of the present landscaping in the campus and assess the perception of people on the quality of present landscape in the campus environment of Chukwuemeka Odumegwu Ojukwu University, Uli Campus Anambra State.

LITERATURE REVIEW

WiseGEEK (2012) as cited in Ayeni, Olotuah and Adedeji, (2013) stated that landscape architecture is a branch of architecture that deals with planning and design of land and its relation to the building around it. Wright, (2008) defined Landscape design as an art with the function of creating and preserving the beauty in the surroundings of human habitations as well as broader natural scenery of the country. Architecture ought to transcend the designing of buildings, and incorporate the transformation of the physical environment through proper design. This will improve the quality of the environment, as the combination of hard and soft landscape elements makes the environment ecofriendly.

The art of landscape practice pulls together elements to create an aesthetically pleasing extension of interior to outdoor living spaces (Asiedu, Buah, & Blankson, 2010). Hard landscape elements are non-living hard materials used by landscape designers to develop landscape designs. Examples of these are: rocks, stones, paving, gravel, steps, garden furniture and other man-made components of landscape. Soft landscape elements refer to living things brought into the landscape. Examples of these are plant materials such as: lawn, borders created with

trees, flowers and shrubs (Ogunsote, Adedeji, & Prucnal-Ogunsote, 2011).

Landscaping entails some of the following activities- growing/installation of plants, planning beautiful gardens, mow lawns, prune shrubs, erect fences (as enclosures), among others. Elf, (1996) as cited in Adekunle and Basorun, (2016) noted that a well-designed landscape helps to reduce erosion and global warming as well as prevent pollution of the environment. This is achieved since soft landscape elements used for landscape designs can improve air quality. Amongst several factors, landscaping, as an aspect of campus development and beautification needs to gradually gain acceptance and be transformed into a culture, which would gradually influence the university campus environment. Most of the plants that could be found on the University campus are native to the local environment, and could thus aid in the modification of the microclimate of the environment.

Good landscape management involves right plants selection, appropriate timing of plantings and plant maintenance techniques, maintenance of hardscapes when broken, among others. These are important towards realizing an attractive environment. Principally, the selections should be based on the functional roles the elements would play in the landscape (Ayeni & Adedeji, 2014). Maintenance involves the care and upkeep of the landscape after installation. Since landscapes change appearance and size over time, different types of maintenance works are required. These may include: weeding in lawns, replacement of dead plants, spraying of insecticides for insects and disease control, mowing of lawn, irrigation of lawn, repairing of paved surfaces, pruning of trees/shrubs, cleaning of fountains, repainting of outdoor furnishings and preventive maintenance on the equipment. Also of great importance is the quality of maintenance tools and equipment used in carrying out the exercise. Some of the tools/equipment used in the maintenance can be grouped into sophisticated and simple equipment. Examples include hand trowel, shears, shovel, crosscut saw, rake, wheel barrow, transplanting hoe, mower, sprinkler, hedge trimmer, shears, and cutlass.

STUDY AREA

Chukwuemeka Odumegwu Ojukwu University, Uli Campus, is situated in Uli, Ihiala Local Government Area of Anambra state. It is located on latitude 5˚46'11"N and longitude 6˚50'10"E. The University was established in year 2000 by the Anambra State Government with the name Anambra State University. The University was renamed to the

current name in the year 2014. Chukwuemeka Odumegwu Ojukwu University has three-campus arrangement – Igbariam (which is the seat of administration), Uli and Awka. There are six faculties in the Uli campus and they are: Engineering, Natural Sciences, Physical Sciences, Environmental Sciences, Basic Medical Sciences and Education. The Uli campus has lecture halls/classrooms, laboratories, library, offices, hostel, chaplaincy, banks and other businesses.

METHODOLOGY

The sources of data for this study were primary and secondary. The primary data were obtained through the administration of questionnaires and observation schedule. The secondary data were obtained from documents and research materials on staff strength and university campus master plan. The target population for this study are academic staff of the Faculty of Environmental Science of the university. This selection was premised on their assumed knowledge of the subject matter. Samples would be taken from each of the departments that make up the faculty. Owolabi, Ogunsajo, Bodunde and Olubode (2020) stated that landscaping is greatly valued by people with education of the environment based on their knowledge of elements used and the important roles they play in man's environment.

Below is the number of academic staff of faculty of Environmental Science obtained from the university.

Staff Population in Sampled Unit

Target Population:	Academic Staff of the Faculty of Environmental Science of Chukwuemeka Odumegwu Ojukwu University, Uli Campus
No. of Academic Staff:	41

Source: Authors field survey, 2023

30% of this research population was chosen as the sample size. In sampling ratio, St. Olaf College (2023) noted that for populations under 1,000, a minimum ratio of 30% is advisable to ensure representativeness of the sample. This gives a figure of 12, so 12 copies of questionnaire were randomly administered across the lecturers across the four (4) departments in the faculty.

FINDINGS AND DISCUSSION

Types of landscape elements dominant on campus

The results shown in Table 1 indicate that 41.7% of the respondents stated that softscape elements were dominant on campus, 25% stated that hardscape elements were dominant on campus while 33.3% stated that both hardscape and softscape elements are balanced on campus.

Table 1: Data on types of landscape elements dominant on campus

Value Label	Frequency	Valid Percent	Cumulative Percent
Softscape	5	41.7	41.7
Hardscape	3	25	66.7
Both hardscape and softscape	4	33.3	100.0
Total	12	100.0	

Source: Authors field survey, 2023

Quality of Landscaping Perception on Campus

The data obtained show that bulk of the respondents (58.3%) rated the quality of landscaping on campus as poor, 33.3% rated it as very poor. Also, a small percentage (8.3%) of the respondents rated it as good. These are illustrated in Table 2.

Table 2: Data on Quality of Landscaping Perception on Campus

Value Label	Frequency	Valid Percent	Cumulative Percent
Very poor	4	33.3	33.3
Poor	7	58.4	91.7
Neutral	-	0.0	0.0
Good	1	8.3	100.0
Very good	-	0.0	0.0
Total	12	100.0	

Source: Authors field survey, 2023

Factors Influencing the Quality of Landscaping on Campus

Data analysis on the factors influencing the quality of landscaping on campus and the perception of the respondents vary. Majority of them (58.3%) are of the opinion that inadequate provision of funds affects the quality, 25% attributed the quality to lack of capacity to carry out landscaping maintenance operations. 16.7% opined that the factor affecting the landscaping quality is poor maintenance culture as shown in figure 1. Akin to this, 75% of the respondents noted that there are no landscape maintenance operations done on campus while 25% stated that landscape maintenance operations done as need arises. This finding is

consistent with the opinions of Forbes and Kindle (2013) which stated that landscape should be properly maintained to sustain its quality.

Similarly, 83.3% suggested that both man-made elements and plant materials be incorporated into the landscaping to improve the beauty of the campus. 16.7% were of the view that only man-made elements are needed to improve the beauty of the campus.

The usage of softscape and hardscape elements can aid in regulating the microclimate around buildings and outdoor environment within the campus. The use of these softscape elements – trees and shrubs – is important in providing shades, wind breaking, improving air quality and adding to the beauty of the environment. The use of hardscape elements with less maintenance cost are important in order to prevent threats of floods and soil erosion as well as define car path within the campus.

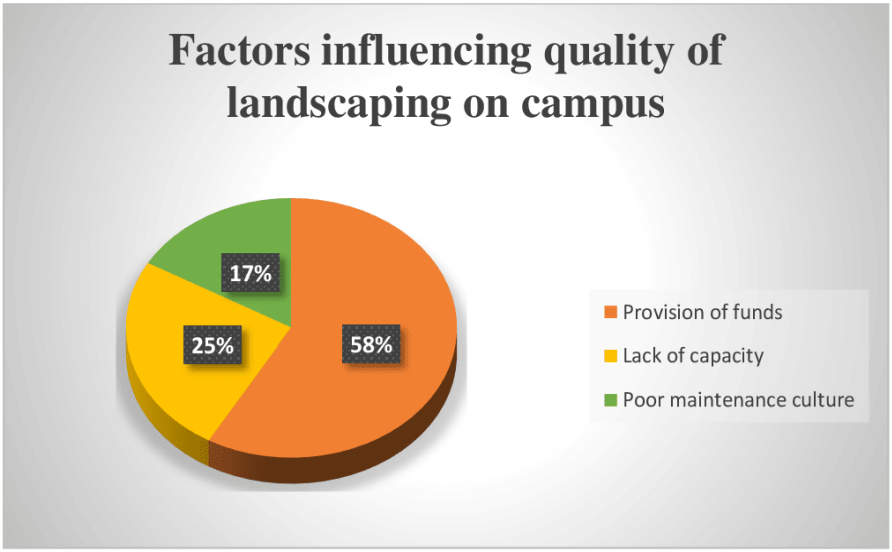


Figure1: Data on Factors Influencing the Quality of Landscaping on Campus

Source: Authors field survey, 2023

Type of equipment predominantly used in maintenance operations on Campus

The results from the analysis on type of equipment predominantly used in maintenance operations on campus show that majority (91.7%) of the respondents stated that simple equipment are used in the maintenance operations. 8.3% of the respondents stated that sophisticated equipment are used in the maintenance operations as shown in Figure 2. The simple equipment identified are machete/cutlass, hand shears and hoe are used in maintenance operations. The sophisticated equipment identified normally used is the riding mower.

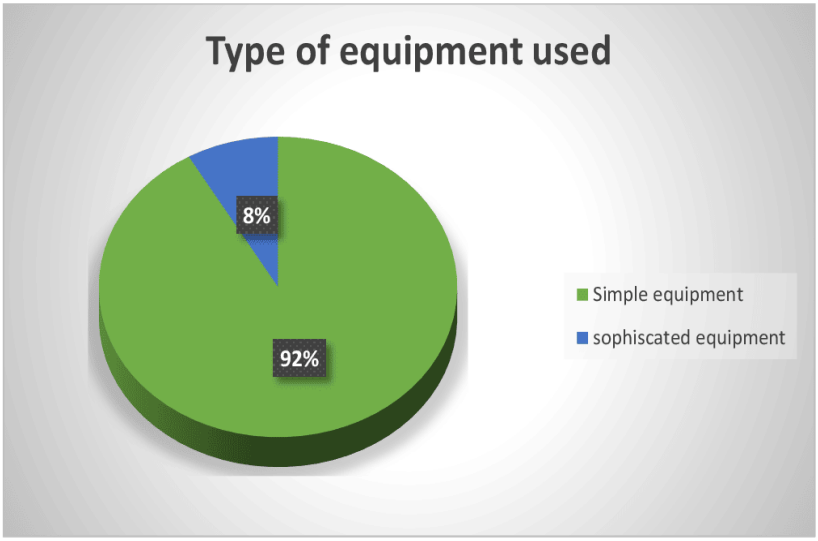


Figure 3: Data on type of equipment predominantly used in maintenance operations on campus

Source: (Authors' field survey, 2023)

CONCLUSION AND RECOMMENDATION

Proper landscaping practices have great potentials to uplift aesthetic status of campuses. There is the general acknowledgement of good landscaping as a suitable tool for improving environmental value of Uli campus, COOU. This can be achieved by devising a feasible idea to change the existing campus environment by the introduction of landscape features for good microclimate within the campus, neatness of the environment and for aesthetic purposes. Spaces that are not built up within the campus need to be designed and planned; structured management will entail proper maintenance practices.

The maintenance routine practices should be reviewed so there could be improvement in the state of the landscape within the campus. This can be achieved by involving professionals in the built environment in the physical planning unit and works department of the institution to handle landscaping concerns within the campus. The professionals should draft a programme chart of landscaping features for the improvement and sustenance of the beauty of the campus. The university administration may need to allocate more resources (human and funds) towards improvement of the campus. They can plan the release of funds in tranches based on the planned chart.

The equipment such as bush cutter, pruning shear, sprinkler, and hedge trimmer can be incorporated to the existing equipment in use for better output. Man-made features such as trash cans, street lights, road benches for sit-out, sculpture, defined pedestrian walkways, controls/ barriers

created to direct flow of movement, paving, road signs, etc can be incorporated into the landscape. Similarly, plant materials such as trees of diverse species, flowers of different colours, lawns should be improved upon to advance the aesthetic appeal of the campus. From the environmental point of view, these elements can serve as wind breakers; inhibit soil erosion and control ponding during the rainy season; as well as help to regulate the effect of global warming by maintaining in the atmosphere in the campus.

Since landscaping practices constitute a form of trade, which can be a source of income, the university management may consider opening horticulture unit where plants can be grown in the nursery and sold to members of the public.

References

Adekunle, O.J. & Basorun, J.O. (2016). The Evolving Roles of Landscaping in Campus Space Management: Ekiti State Uni versity, Ado-Ekiti, Nigeria in Focus. *Journal of Environmental Protection*, 7, 1380-1388. http://dx.doi.org/10.4236/jep. 2016. 710119

Asiedu, J.B.K.; Buah, J.N. & Blankson, J.E. (2010). The landscape industry and practice in Ghana. Proceedings of the International Horticultural Congress on Science and Horticulture for People on Advances in Ornamentals Landscape and Urban Horticulture, 5(38), 1023-1032

Ayeni, D.A. & Adedeji, Y.M.D. (2014) Controlling Urban Sprawl through Sustainable Landscaping in Nigeria. In: Fadamiro, J.A., Olujimi, J.A.B. and Okedele, O. Eds., Urban Environmental Sustainability: Livable Cities. Urban Design Research Team (UDRT), Department of Architecture, School of Environmental Technology, Federal University of Technology, Akure, Nigeria.

Ayeni, D.A.; Olotuah, A.O. & Adedeji, Y.M.D (2013). Appraising Landscape Design Education in Architecture Departments in Nigerian Universities. *International Journal of Education and Research, 1(5), 1-10*

Elf, D. (1996) Enhancing our Environment through Landscaping. VCE Publication, 429-721.

Forbes, S. and Kendle, T. (2013) Urban Nature Conservation; Landscape Management in Urban Area, London, UK. E and FN spon and Imprint of Thompson Professional, 2-6.

Ogeye, O.O.; Senibi, J.G & Akinboboye, O.O (2019). The Miseducation of the Nigerian Architect, *Arts and Design Studies*, 76, 56-61

Ogunsote, O.O., Adedeji, Y.M.D. & Prucnal-Ogunsote, B.P. (2011). Combating Environmental Degradation through Sustainable Land scaping in Emerging Mega Cities: A Case Study of Lagos,Nigeria. In: Cox, L., Ed., *Proceedings of the 24th World Congress of Architecture "UIA2011 TOKYO",* 25 September-October 1 2011, 16-21.

Owolabi, C.O., Ogunsajo, O.O, Bodunde, J.G., Olubode, O.O (2020). Assessment of designed landscapes and their management practices in selected capital cities in Nigeria. *Ornamental Horticulture.* 26(1), 95-108

St.Olaf College (2023). Sample size- institutional effectiveness and assessment. Retrieved from www.stolaf.edu/iea/sample-size Accessed on 12/2/23.

WiseGEEK (2012). What is Landscape Architecture? Retrieved from www.wisegeek.com/what-is-landscape-architecture.htm Accessed on 12/11/12.

Wright, R.T. (2008) Environmental Science: Toward a Sustainable Future. PHI Learning, New Delhi.

Authors' Brief Data

Author Information: Chukwunonso O. Umeora is of the Department of Architecture, Chukwuemeka Odumegwu Ojukwu University, Anambra State, Nigeria.
Email: co.umeora@coou.edu.ng

Boniface S.A Okoye is affiliated to the Department of Architecture, Chukwuemeka Odumegwu Ojukwu University, Anambra State, Nigeria.

Oluchi C. Ifebi is affiliated to the Department of Architecture, Chukwuemeka Odumegwu Ojukwu University, Anambra State, Nigeria.

Chijioke C. Onwuzuligbo is of the Department of Architecture, Chukwuemeka Odumegwu Ojukwu University, Anambra State, Nigeria.