ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24SEP359

Quantitative Analysis of Wood Tar Production Efficiency of Selected Wood Species in Sierra Leone

Mohamed Syed Fofanah (PhD.)
Department of Industrial Technology, School of Technology
Njala University, Sierra Leone

Abstract:- Wood tar is the byproduct that is discharged when wood is carbonized in a charcoal kiln or distilled in a distillation furnace. Burning of charcoal and biomass gasification processes release large quantities of trace gases and particles that contribute to air pollution and climate change.

This study aims at contributing to the identification of woods suitable for wood tar production in Sierra Leone in order to help rural communities involve in charcoal production protect the environment at the same time earning additional income from sale of wood tar.

Carbonization using Tumulus kiln was done on four different weights of the dry wood samples taken at 400kg, 500kg, 600kg and 700kg. The quantities of wood tars produced by the three wood samples (Phyllanthus discoideu, Diallum guinesis and Mangifera indica) determined.

The study revealed that all three wood samples are suitable candidates for wood tar production with Mangifera indica and Phyllanthus discoideu most preferred.

Keywords:- *Wood Tar, Phyllanthus Discoideu, Diallum Guinesis, Mangifera Indica, Carbonization, Pyrolysis, Biomass, Gasification.*

I. INTRODUCTION

Wood tar has been used since ancient times as wood conservative, adhesive, water-repellent, in medicines and cosmetics.Wood tar is the by product of destructive distillation of wood under reduced oxygen which is made up of several polycyclic aromatic hydrocarbons (PAH).

During carbonization of wood, these PAH substances are given off gradually as the temperature rises and at about 450°C the evolution is complete leaving charcoal as the solid residue, charcoal and small amounts of tarry substances. These tars contain phenolic compounds, which are useful antiseptics and preserving agents.

The wood tar consists of more than 400 organic chemicals with a wide range of molecular weights (60–300 g/mol) and oxygenated volatile and nonvolatile components involving organic acids, alcohols, aldehydes, ketones, phenols, furanes, benzenes, sugars, bitumen, and their derivatives (Haiqing Sui et al, 2022).

There are two types of wood tars namely hardwood tars, derived from such woods as oak and beech; and resinous tars, derived from pine wood, particularly from resinous stumps and roots.

The quantity and quality of wood tar produced is influenced by both the physical and chemical properties of wood used during carbonization or pyrolysis. The physical properties include moisture content, density, dimensional stability, thermal and pyrolytic (fire) properties, natural durability, and chemical resistance which affect its combustion and decay resistance. Wood's chemical properties include cellulose, hemicellulose, and lignin, which form its structural components. Cellulose provides strength, hemicellulose binds fibers together, and lignin acts as a natural adhesive (Kristoffer and Barth 2024).

- *Problem Analysis*

The production of wood tar from biomass gasification is not a normal practice in Sierra Leone as in most developing countries despite its many advantage such as wood conservative, adhesive, water-repellent, in medicines and cosmetics. There are many significant advances in wood tar technology in other countries, where Sierra Leone stands in all these development is yet to be determined. Wood tar production technology is not only new in Sierra Loene but unheard of in the entire rural charcoal production communities. Wood tar is regarded as a by product of wood carbonization with no significant value.

Charcoal production and sales are the major sources of rural employment after agriculture. Many studies have shown that charcoal production has negative effects on the environment. It leads to deforestation, soil erosion, reduction in soil moisture and fertility, and decline in vegetation cover which leads to loss of natural woody formations, putting pressure on ecosystems. Additionally,the burning of charcoal and biomass gasification processes release large quantities of trace gases and particles that contribute to air pollution and climate change.

To mitigate this effect, the three commonly used woods for charcoal production in Sierra Leone by rural charcoal producers namely Phyllanthus discoideus, Diallum guinesis, and Mangefera indica were investigated to compare their tar production efficiency. This could help charcoal producers

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24SEP359

not only to earn additional income from wood tar sales but the health of the charcoal producing communities is expected to improve as the inhalation of these carcinogenic substances could be markedly reduced.

➢ *Aim and Objectives of the Study*

This study aims at contributing to the identification of woods suitable for wood tar production in Sierra Leone in order to help rural communities involve in charcoal production protect the environment at the same time earning additional income from sale of wood tar which is a by product of wood carbonization.

The following objectives are pertinent to this study (1) To determine the physical properties of the woods investigated (2) Determine the quantitiy of wood tar produced of the woods investigated under field condition.(3) To provide recommendation that could help to protect the environment.

II. EXPERIMENTAL METHOD

➢ *Materials*

Three wood species, namely Phyllanthus discoideus, Diallum guinesis, and Mangifera indica were collected from Pelewahun village, three miles from Njala University in Sierra Leone and brought to the Department of Industrial Technology for the field experiments.

Table 1 Wood Species used in the Study

Botanical name of wood species	Botanical family	Mende name	Temne name	Creole
Phyllanthus discoideus	Euphorbiaceae	Tijo (Tinjui)	Ka Saka	Berry
Diallum guinesis	Leguminosae	Mambui	Kabamp	Tamarind
Mangifera indica	Anacardiaceae	Mangoe	Mangoro	Mango

➢ *Phyllanthus Discoideus (Margaritaria Discoidea)*

Phyllanthus discoideus is typically use in Sierra Leone as a wood for cooking and charcoal production.The plants grow in most tropical and subtropical countries. Phytochemical studies on the genus Phyllanthus, revealed the presence of lignin, terpenes, sterols, polyphenolic compounds, tannins, flavonoids, glycosides and alkaloids(Alimboyoguen et al 2022, Osakwe et al 2009, Internet sources). As a result, Phyllanthus species have a wide number of traditional uses including internal use for jaundice, gonorrhea, frequent menstruation, and diabetes and topical use as a poultice for skin ulcers, sores, swelling, and itchiness (www. Tandfoline.org, Internet source)

➢ *Dialium Guineense*

Dialium guineense is a tree found in most tropical countries and many parts of the world It is normally 30 m high, with a densely leafy crown, but often shrubby. Bark smooth, grey; slash reddish, yielding a little red gum (www,foresttreeagroforestry.org, internet source).

The tree is said to make good firewood and charcoal. The bark and leaves are believed to have medicinal properties and are used against several diseases (ftp.academicjournals.org, Akinpelu et al 2011). *D. guineense* stem bark and fruit are excellent source of essential oils, and rich source of dietary fibre, minerals, and vitamins for monogastrics (www.researchgate.net, Ifeanyichukwu 2022). The plant is endowed with beneficial phytochemicals such as alkaloids, tannins, phenols, flavonoids which may serve as natural alternatives to in-feed antibiotics. *D. guineense* has beneficial pharmacological effects including antioxidant and antimicrobial properties. The purpose of this study was to review the body of knowledge on the nutritional and chemical composition of *D. guineense* and its impact in animal production. (www.researchgate.net, Ifeanyichukwu 2022).

➢ *Mangefera Indica*

Mangifera indica, commonly known as mango, is a species of flowering plant in the family Anacardiaceae (Morton,1987) It is a large fruit tree, capable of growing to a height of 30 metres (100 feet) (biodiversity.lums.edu.pk).

The main value of the mango tree is its fruit which has significant economic importance. The bark is used to produce a yellow dye and The mango wood and its bark produce phenolic substances and yellow dye (wiki2.org, Tu, Anthony T. (1983).

➢ *Experimental Procedure*

The three wood species were sun dried for five weeks in order to lower the moisture content before carbonization process. Four different weights of the dry wood samples were taken at 400kg, 500kg, 600kg and 700kg for each of the wood species as presented in Table 2, which shows data for weight of wood before and after carbonization as well as the wood tar produce for the three wood species investigated.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24SEP359

Table 2 Wood Tar Produced at Various Weights for the Three Wood Species

Parameter	Wood Species											
	Phyllanthus discoideus				Diallum guinesis				Mangifera indica			
	Exp 1	Exp2	Exp3	Exp4	Exp 1	Exp2	Exp3	Exp4	Exp 1	Exp2	Exp3	Exp4
Weight of dry wood before carbonization (kg)	400	500	600	700	400	500	600	700	400	500	600	700
Weight of wood after carbonization (kg)	22.8	34.2	43.4	40.6	47.1	55.1	57.0	57.8	26.8	28.4	27.3	30.0
Total wood carbonzized(kg)	377.2	465.8	556.6	659.4	352.9	444.9	543	642.2	373.2	471.6	572.7	670
Diluted tar collected (Litre)	10.1	12.7	13.4	14.6	3.4	5.0	6.2	7.1	12.4	13.7	14.9	15.0
Dehydrated tar collected (Litre)	2.8	4.2	4.7	5.1	0.6	1.8	2.2	2.9	4,6	5.5	6.3	6.7

➢ *Construction of the Tumulus Kiln*

The dry wood samples drawn from the three wood species were cut into a considerable length of about 1m, These cut wood samples were weighed in batches of 400, 500, 600 and 700kg which were used for the construction of the four experimental kilns per wood specie. A 2m circumference flat floor was cleared for the construction of the kiln and the wood logs parked in the shape of bicycle spokes, leaving a central fire space and four vents left at strategic points below the kiln (www,instructable.com). The chimney pipe was place on this logs followed by addition of logs around the spokes to form a well-ventilated base. More wood was carefully added to form a pyramid like structure covered with grass/rice straws layer followed by clayey soil layer (www,instructable.com) as demonstrated in Figure 1.

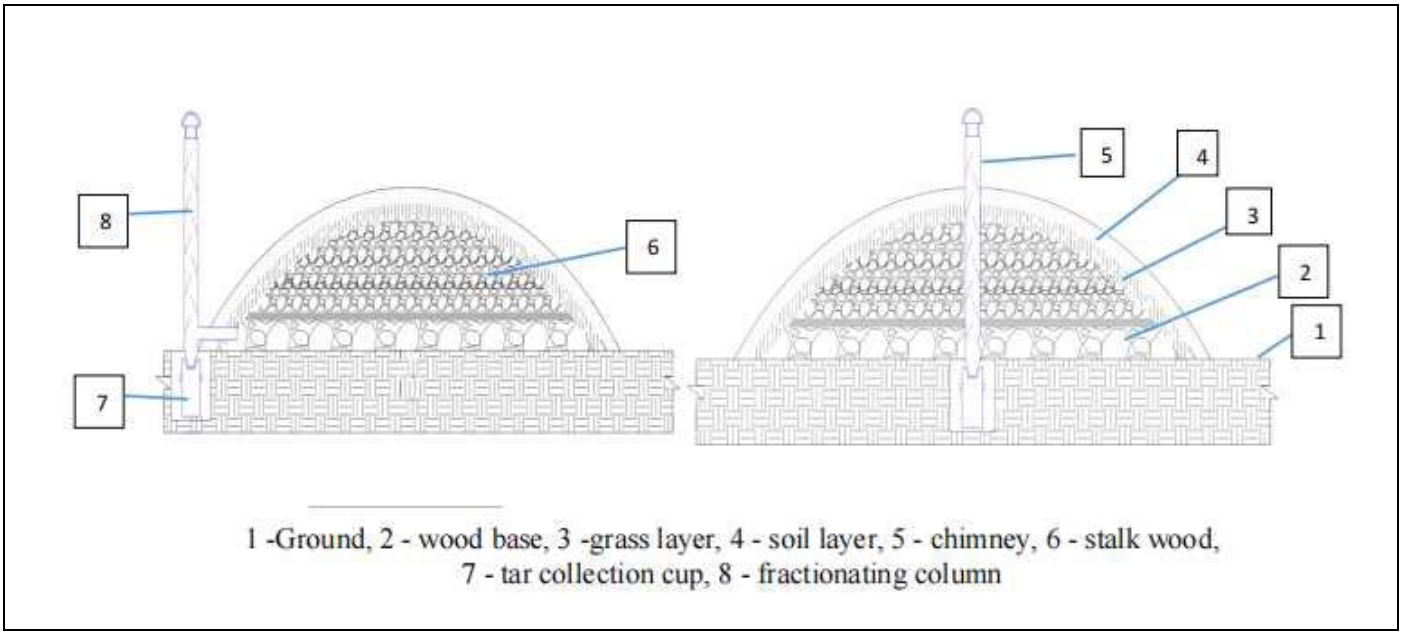

Fig 1 Sketch of Tumulus Kiln showing Chimney Position
Source: Fofanah et al 2024

The carbonization process was completed in 5 days when no significant amount of smoke was seen with temperature range of 400-550^{o}C. The kilns were allowed to cool for 6 days and opened to determine the quantity of (a) charcoal produced (b) wood not carbonized and (c) liquid tar yield collected from the chimney.

III. RESULTS AND DISCUSSION

➢ *Wood Carbonization/Pyrolysis*

The four initial weights of 400kg. 500kg, 600kg and 700kg for each of the three wood samples were subjected to carbonization using the tumulus kiln. The weights of both the carbonized and wood which remained after carbonization were determined and results presented in Figure 2.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24SEP359

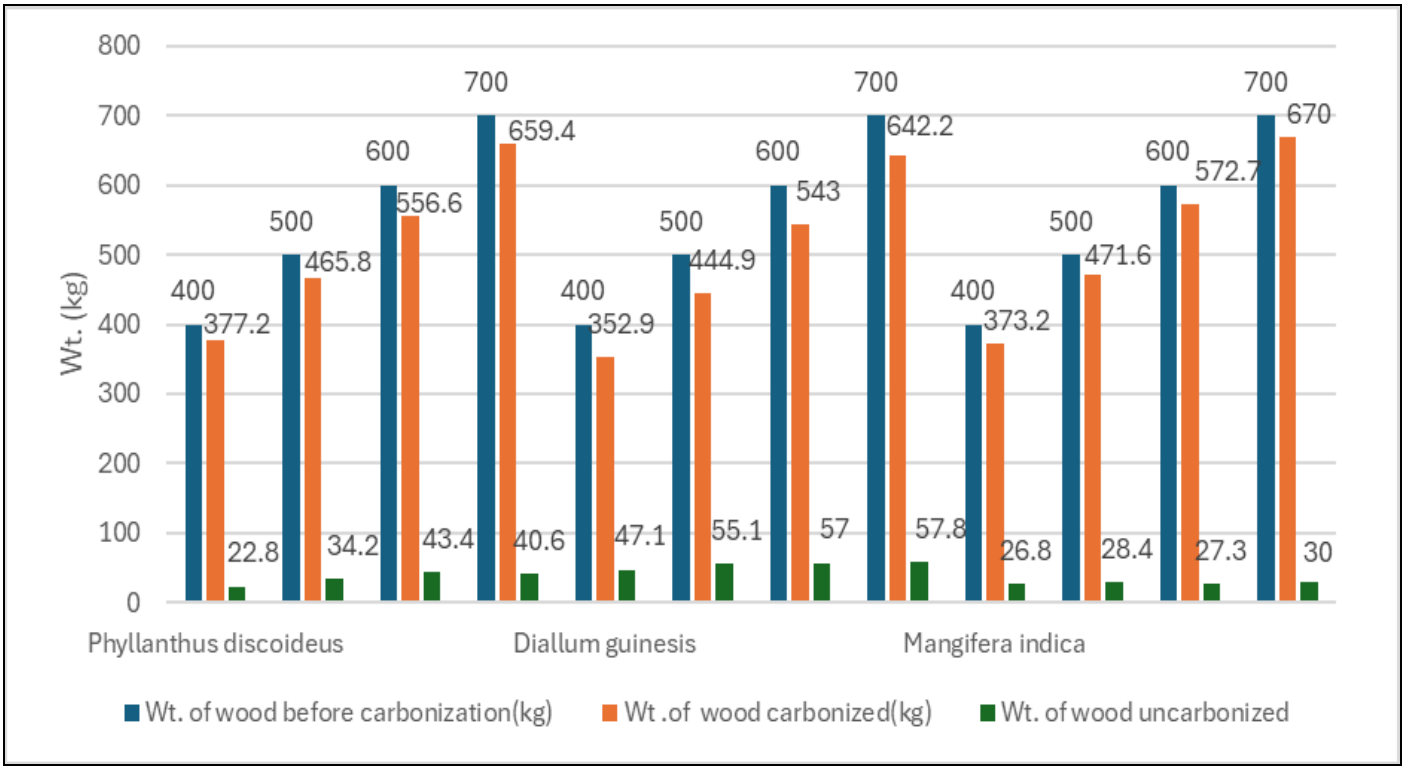

Fig 2 Weight of Wood before and after Carbonization

Comparatively, Mangifera indica shows high carbonization potential than P. discoideus and D. guinesis as evident from the weights of wood left after the carbonization process for the four experiments conducted for each of the three wood samples. The uncarbonated wood for M. indica ranged from 26.6 to 30kg as compared to 47.2 to 57.8kg for D.guinesis and 22.6 to 43.4kg for P. discoideus.

➢ *Wood Tar Yields*

The results for both the diluted and dehydrated wood tar yields for the three wood species are presented in Figures 3 and 4.

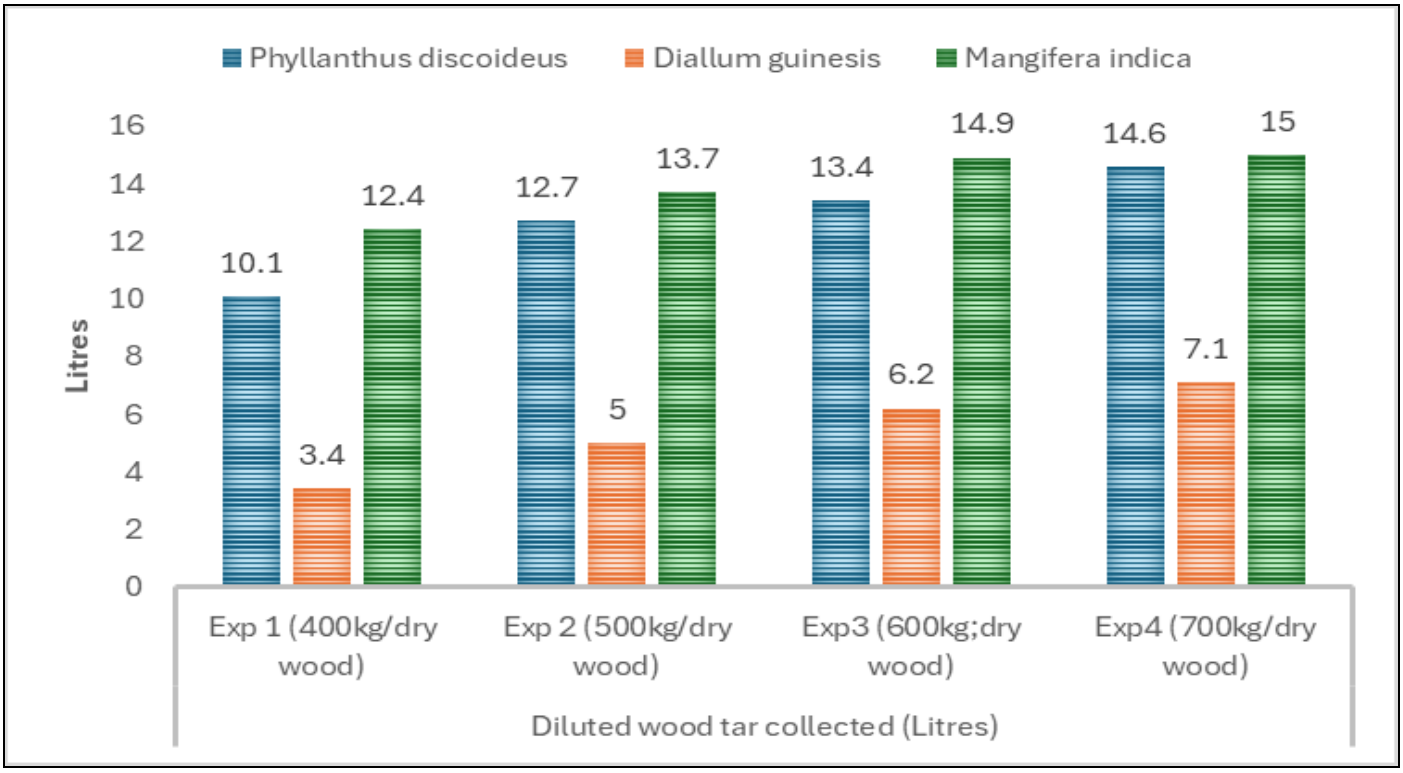

Fig 3 Diluted Wood Tar Produced at various Wood Weights

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24SEP359

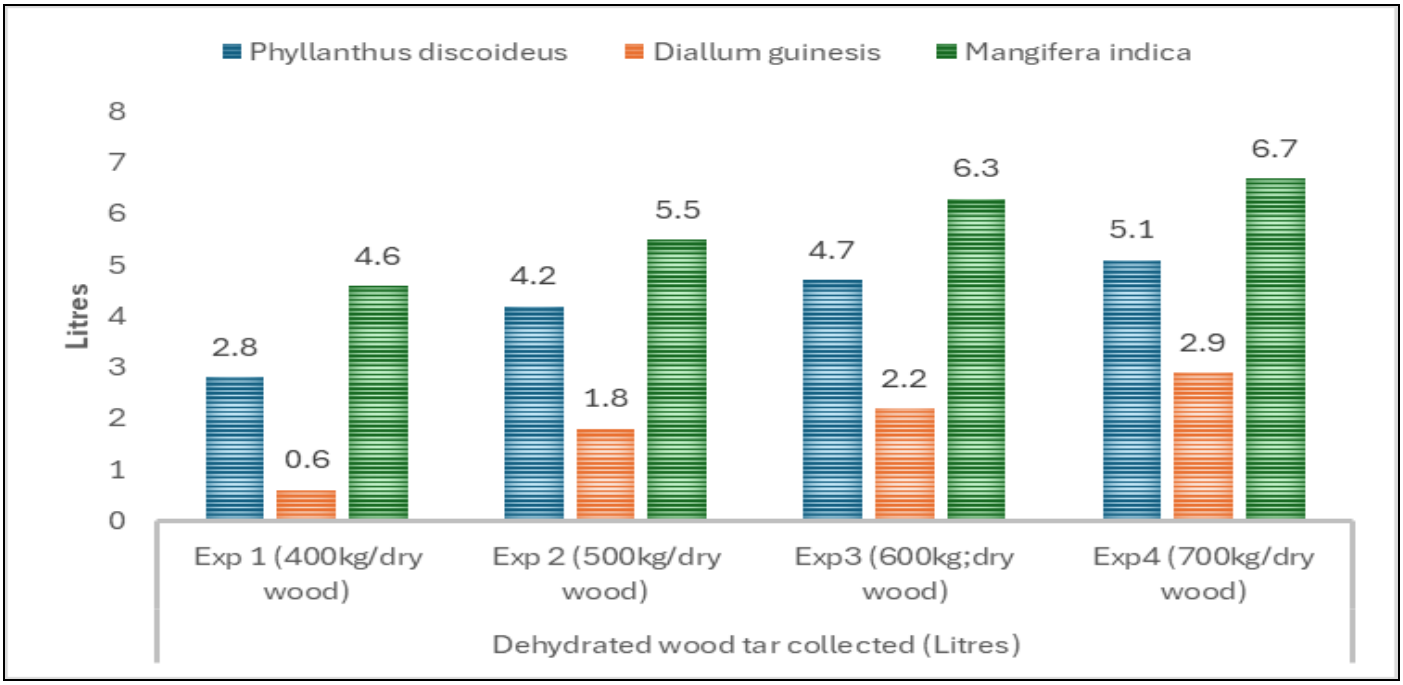

Fig 4 Dehydrated Wood Tar

For all the four experiments conducted,M.indica and P.discoideus have comparatively higher yields of both diluted and dehydrated wood tars than D. guinesis. This could be attributed to the degree of volatile compounds and resins in the wood samples. The quality of the tar is influenced by the amount of resin in the wood, the age of the tree and the type of method used to extract the tar (Süleyman Arı (2014, www.ncbi.nlm.nih.gov).

Onaifo et al investigated the prospect of copyrolysis of *Mangifera indica* (MNS) and *Annona muricata* (SSS), as a source of quality bio-oil using slow pyrolysis at 350–500 °C, heating rate of 5 °C min^{-1} and a residence time of 60 min, which created the bio-oil. For SSS, MNS, and SSS-MNS, respectively, the best bio-oil yields were determined to be 36.48%, 20.54%, and 26.16% at 400 °C. According to their results of the GC–MS analysis, the primary compounds in MNS bio-oil were ether (60.32%) and carboxylic acid (16.16%). The study demonstrated that the ether present in SSS and MNS was suppressed during copyrolysis, resulting in SSS–MNS bio-oil rich in ester, hydrocarbons, and phenolic compounds (www.link.springer. com, Onaifo et al 2023).

IV. CONCLUSION

Wood tar has been used since prehistoric times for different purposes such as wood conservative, adhesive, water-repellent, in medicines and cosmetics. Burning of charcoal and biomass gasification processes release large quantities of trace gases and particles that contribute to air pollution and climate change.

To mitigate this effect, the three commonly used woods for charcoal production in Sierra Leone by rural charcoal producers namely Phyllanthus discoideus, Diallum guinesis, and Mangefera indica were investigated to compare their tar production efficiency.This could help charcoal producers not only to earn additional income from wood tar sales but the health of the charcoal producing communities is expected to improve as the inhalation of these carcinogenic substances could be markedly reduced.

This study aims at contributing to the identification of woods suitable for wood tar production in Sierra Leone in order to help rural communities involve in charcoal production protect the environment at the same time earning additional income from sale of wood tar.

Carbonization using Tumulus kiln was done on four different weights of the dry wood samples taken at 400kg, 500kg, 600kg and 700kg. The quantities of wood tars produced by the three wood samples (Phyllanthus discoideu, Diallum guinesis and Mangifera indica) determined.

A general conclusion could be made that all the three wood samples are suitable candidates for wood tar production with Mangifera indica and hyllanthus discoideu most preferred.

REFERENCES

[1]. Haiqing Sui, Chao Tian, Jiali Chen, Steven Fullmer, Zhichao Zhang (Dec 2022): Characterization and separation of wood tar by full temperature range fractional distillation Separation and Purification Technology Volume 302, 1 122098. https://doi.org/10.1016/j.seppur.2022.122098

[2]. *Akinpelu AD, Awotorebo TO, Agunbiade OM, Aiyegoro AO, Okoh IA. Anti-vibrio and preliminary phytochemical characteristics of crude methanolic extracts of the leaves of Dialium guineense (Willd). J Med Plants Res. 2011;5:2398–404.Search in Google Scholar.*

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24SEP359

[3]. *AlimboyoguenAgnes B, Kathlia A De Castro-Cruz, Evangelina M Fidel, Chien-Chang Shen, Po-Wei Tsai (Apr-Jun, 2022): Chemical Constituents of Phyllanthus acidus (L.) Skeels. Indian Journal of Pharmaceutical Education and Research | Vol 56 | Issue 2 | Ifeanyichukwu Princewill Ogbuewu, Morwaledi Morategi Cornelia Modisaojang-Mojanaga , Baitsholetsi Gloria Mokolopi and Christian Anayo Mbajiorgu (2022): Nutritional and chemical composition of black velvet tamarind (Dialium guineense Willd) and its influence on animal production: A review. Open Agriculture. https://doi.org/10.1515/opag-2022-0174*

[4]. Biodiversity.lums.edu.pk

[5]. *Fofanah Mohamed Syed , Felix Koroma, Haja Isata Kamara, Lahai Maada Sundufu (2024):Simple Technology to Reduce Carbon Emission in Rural Charcoal Production In Sierra Leone. International Journal of Engineering Research and General Science Volume 12, Issue 3.*

[6]. ftp.academicjournals.org,

[7]. *Ifeanyichukwu Princewill Ogbuewu, Morwaledi Morategi Cornelia Modisaojang-Mojanaga , Baitsholetsi Gloria Mokolopi and Christian Anayo Mbajiorgu (2022): Nutritional and chemical composition of black velvet tamarind (Dialium guineense Willd) and its influence on animal production: A review. Open Agriculture. https://doi.org/10.1515/opag-2022-0174*

[8]. *Kristoffer Mega Herdlevaer. Tanja Barth (2024): Optimizing Formic Acid Assisted Co-HTL of Digested Sewage Sludge andLignocellulosic Waste for Emhanced Bio Crude Yield and Energy Recovery. Energies,*

[9]. Morton, Julia F.(1987): Mango Mangifera indica. In Fruits of Warm Climates, New Crops Resource Online Program.Center for New Crops and Plant Products.Purdue University pp221-239

[10]. *Onaifo, J.O., Ikhuoria, E.U., Ifijen, I.H. et al. Co-pyrolysis of Soursop (Annona muricata) and Mango (Mangifera indica) Seeds: A Route to High-Quality Bio-oil. Chemistry Africa 6, 1015–1023 (2023). https://doi.org/10.1007/s42250-022-00536-9*

[11]. *Osakwe I. I., H Steingass H., W Drochner (2009):The chemical composition of Phyllanthus discoideus and its effect on the ruminal ammonia and volatile fatty acid concentration when fed to west African dwarf sheep. DOI: 10.1080/17450390009381946.*

[12]. *Süleyman Arı, Mustafa Kargıoğlu, Mehmet Temel & Muhsin Konuk (2014): Traditional Tar Production from the Anatolian Black Pine [Pinus nigra Arn. subsp. pallasiana (Lamb.) Holmboe var. pallasiana] and its usages in Afyonkarahisar, Central Western Turkey. Journal of Ethnobiology and Ethnomedicine volume 10.*

[13]. *Tu, Anthony T. (1983). Handbook of natural toxins. New York: Dekker. p. 425. ISBN 0824718933.*

[14]. wiki2.org,

[15]. www,foresttreeagroforestry.org, internet source)

[16]. www.ncbi.nlm.nih.gov

[17]. www. Tandfoline.org, Internet source)