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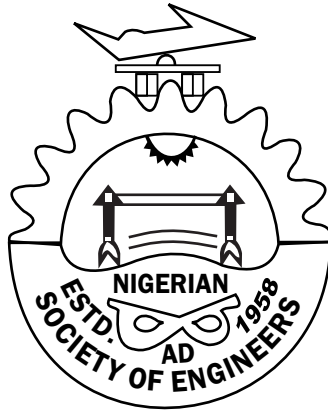


JANUARY – MARCH 2024

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FROM THE EDITORIAL DESK

In keeping with our promise to maintain consistency and in the pursuit of one of the cardinal activities of Nigerian Society of Engineers (NSE), The NSE TT journal continues in this edition to aim at publishing a learned journal to disseminate scholarship in all fields of Engineering and Technology education and practice that parallel its peers globally.

The NSE TT Journal has wide recognition and acceptance among research institution, Universities practitioners, authors, contributors, readers and has come a long way in delivering well research academic and innovative advances in the field of Engineering.

We welcome the new National Executive Committee led by our Publisher, The President of Nigerian Society of Engineers, Engr. Margret Aina Oguntala FNSE.

The journal structure and policy are still being revised to meet contemporary requirements. The NSE Technical Committee frowns at any form of publication misconduct and pledges to institute a mechanism for detecting and appropriately handling of such misconduct. Authors and Reviewers are to educate themselves with all forms of publications misconduct and their consequences.

The Editorial board of NSE TT emphasizes on adherence to the journal guidelines by authors and reviewers that shall enhance the efficiency of processing their manuscripts.

The NSE Technical Committee acknowledges the cooperation and support of all contributors, reviewers and editorial advisers, criticisms and suggestions from the stakeholders, aimed at improving our processes are highly appreciated.

As NSE Technical Committee, we sincerely appreciate the work of the subcommittee chaired by Engr, Dr. Edith Ishidi, FNSE and the hardworking Professional Development Director in the person of Engr. Prof. Joshua Olaoye, FNSE in making the edition possible.

Yours truly,

Engr. Prof. O.A.U Uche FNSE

Editor-in-Chief/Chairman NSE Technical Committee



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PERFORMANCE INDEX OF ALHAMDURI URBAN WATER WORK DISTRIBUTION NETWORK, MAIDUGURI, BORNO STATE

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ABSTRACT

The study assessed and simulated the current condition of the Alhamduri Distribution Network, Maiduguri and checked the discharge and pressure heads in order to provide feasible solution and remedies to the setbacks affecting the distribution network. The network was analysed using hydraulic simulation software "EPANET 2.0". It was observed from the analysis that there is a pressure deficiency which leads to several shortcomings within the distribution network. The maximum pressure of the network ranged from 20 to 36 m. About 40 nodes are within the acceptable limits, while the remaining 200 nodes are below the acceptable limits with about 62 nodes having negative pressures. It was concluded that the present system is not capable of supplying sufficient water to meet up the Daily Average Demand (DAD). The current status of the water work revealed that there is a need for additional improvement on the daily production, redistribution and the distribution network elements. Pipeline monitoring tools should be installed to monitor the condition of the distribution network.

Keywords: Water, distribution, Demand, Network, Alhamduri

1. INTRODUCTION

Water is a very essential and basic necessity indispensable for all living organisms. A life can only live for a matter of a few days without water and its existence on earth without it is factually impossible. Considering the quantity of water, about 2.8% of the total amount of water on earth is freshwater, of which only 0.6% is groundwater. The rest is available in the oceans and mainly seas, while a negligible amount as soil moisture. Out of the 2.2%, 2.15% is found in the form of glaciers and ice sheets, while the remaining 0.05% is available as surface run-off (USBR, 2020). It is estimated that each person on earth required 20 to 50 litres of clean, safe water each and every day (Babar *et al.*, 2020). The quality of water is also a critical factor after quantity and more importantly is the concept of clean water. This clean water is to be used for drinking, cooking, simple hygiene, etc. Providing good and safe drinking-water is world-wide considered to be a fundamental issue for public health protection and must be the primary objective of water supply systems (Babar *et al.*, 2020). Water distribution systems challenges include deteriorating system, leakage and pipeline disruption, incapacity to satisfy demand, poor system design, unreliable systems, abuse and mismanagement. To distribute water to consumers with a sufficient quality, quantity, and pressure, requires a good piping system. However, the distribution of drinking water in distribution networks is a technical challenge both in quantitative and qualitative terms. This is because a huge quantity of treated potable water is lost in its transit within the distribution system as apparent and real losses. One of the disadvantages in water processing and distribution system is the pipe leakage issue (Avila *et. al.*, 2021). Generally, pipe leakage is categorized into two, i.e. technical and non-technical leakages. A technical leakage is a pipe leakage usually referred to that occurring underground. Whereas, the non-technical leakage is in the form of missed registering, illegal consumption connection on water pipes etc (Salam *et al.*, 2014).

Previous researches showed that more scientists and engineers are depended upon computer simulations to design water systems. The speed of the computers and accuracy of certain software is sufficient to provide accuracy to the design of distribution systems, water plant improvements, fire

flow tests, pressure predictions and other aspects of design. Brown's (2007) research analysed the accuracy of pressure dependence on leak detection and determined whether there is a relationship between the pressures within a water system and leakage. With the use of the hydraulic computer simulation software. Dziedzic and Karne (2006) focused on leakage performance index, the geometric average of four performance metrics: reliability, vulnerability, resilience and connectivity were taken, and it was based on the energy efficiency, hydraulic capacity, and structural ability of the system to deliver water under a range of conditions. Even though the index was provisionally applied to only three demand scenarios (normal, fire, and pipe burst), it can be easily adapted to multiple scenarios, including simultaneous failures.

Gajbhiye et al. (2017) established four guidelines for each pipe in terms of age, diameter, length, and service connection. Pipes that are likely to leak can be classified based on their diameter and age. Using the EPANET programme, the network's hydraulic model was created. The study made use of the "demand-driven" assumption, in which the nodal demands are given set values, and it is the task of the researcher to identify pipe flows and nodal pressures that are hydraulically compatible with the nodal demands. According to the water demand, the tank's net inflow was 44.43 LPS, and the system was deemed to be running at a sufficient pressure. EPANET was able to run a simulation with 10% systemic leakage successfully. If the leakage rate exceeded 10%, the system ran into negative pressure and was unable to simulate for 24 hours. Thus, using the EPANET model, it was determined that the system's permitted leakage is 10%.

2. Methodology

2.1 The Study Area

Alhamduri water works is situated within the Metropolis of Maiduguri Local Government Area, Borno State North Eastern Nigeria. It lies between N 11° 49' 7" and E 13° 6' 30". The water Works was constructed in 2019 by the International Committee of the Red Cross (ICRC) in collaboration with Borno State Ministry of Water Resources for the provision of potable water to the populace. Its design production capacity was estimated to be 900,000 l/d (Projects and Support, 2021). The boundary of the study area is presented in Figure 1.

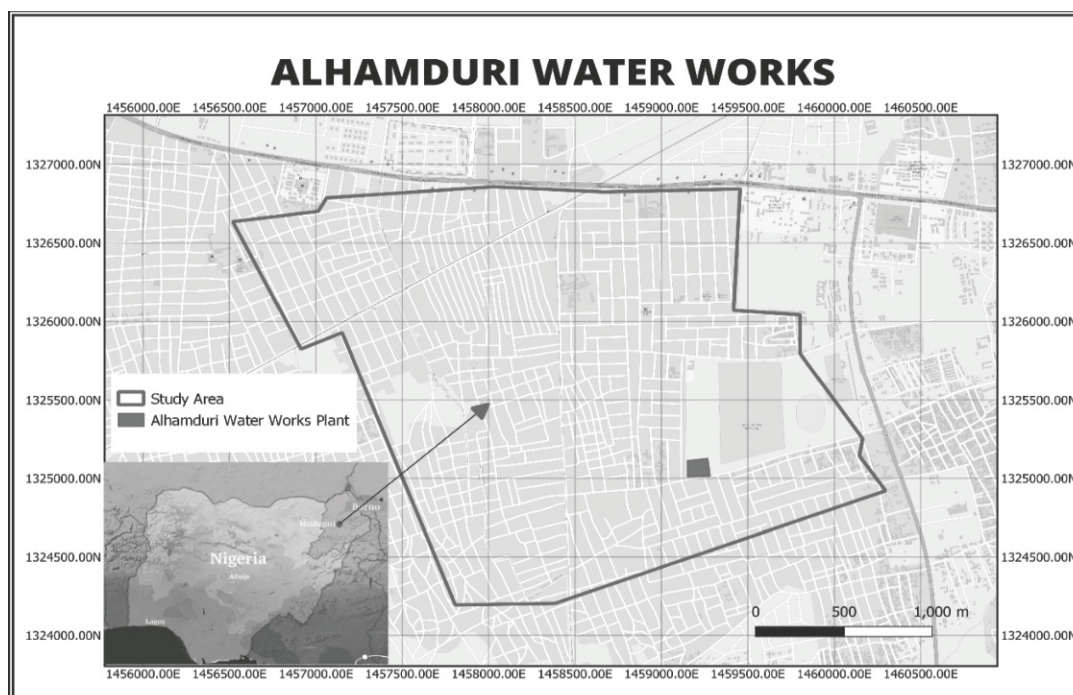


Figure 1: Map showing the location and boundary of the study area

The Water Works was designed to supply water to about 15,000 Household considering 11 person per household (See Table 1). The volume of water that was required to meet the demand of this population (171,000) is around 6,600 m³/d. With the designed production capacity of 9,000 m³/d it currently produces 3,500 m³/d. According to the ICRC report, Alhamduri water works serve approximately 10% (175,821.6 peoples) of the projected year 2022 Maiduguri's population (ICRC estimation based on 2019 polio data collected by "micro-census," which included the number of IDPs who have settled within the host community, and a yearly "natural" urban growth rate of 3% i.e. 1,758,216 people as presented in Table 1).

Table 1: Spatial distribution of population (*Source* : Projects and Support, 2021

CLASS	NUMBER OF OBSERVATION	PERCENTAGE (%)	AVERAGE PERSON PER HOUSEHOLD
Low Income	523	67.1	11.6
Middle Income	228	29.3	11.1
High Income	35	4.5	10.7
TOTAL	786	100	11.4

2.2 Network Layout of the Study Area

The network layout designed in EPANET 2.0 software is presented in Figure 2. The pipes coloured red in the layout represent 200mm diameter, while other pipes coloured yellow, green and blue are 150mm, 100, and 90mm respectively.

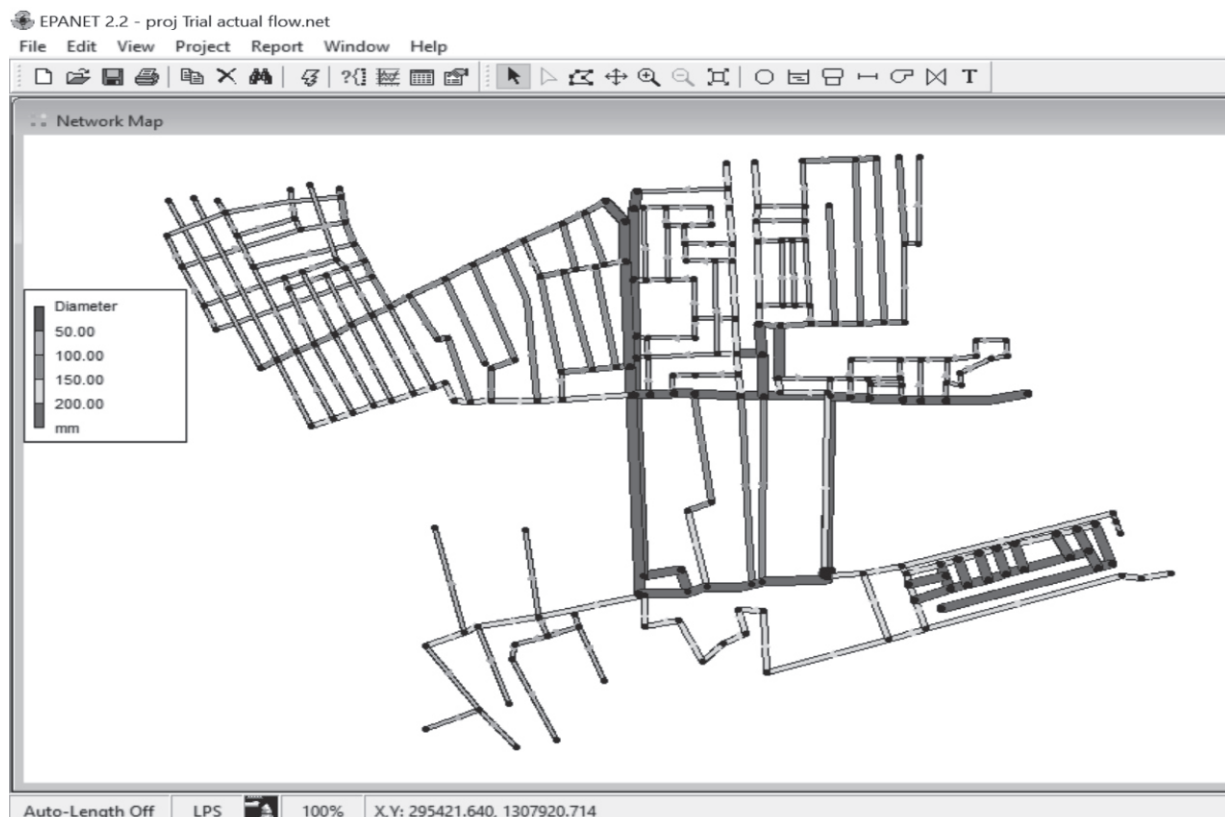


Figure 2: Network Layout of the Study Area

The fittings and base demand of networks are presented in Table 2, which consist of junctions, elevation and base demand with their corresponding Node ID.

Table 2: Nodes, Elevations and Base Demand

NODE ID	DEMAND (LPS)	HEAD (M)	NODE ID	DEMAND (LPS)	HEAD (M)
Junc 226	0.00	1034.88	Junc 12	2.00	1010.75
Junc 227	0.00	1034.81	Junc 20	1.10	998.70
Junc 225	0.00	1034.61	Junc 38	2.00	1005.9
Junc 37	2.00	1034.24	Junc 81	0.60	1005.16
Junc 230	4.00	1032.38	Junc 86	0.70	1005.63
Junc 1	4.00	1024.04	Junc 82	0.60	1005.16
Junc 228	3.00	1021.51	Junc 85	1.00	1005.45
Junc 4	0.50	1020.34	Junc 83	0.60	1005.21
Junc 3	0.80	1020.35	Junc 13	2.20	1006.39
Junc 5	0.30	1020.33	Junc 84	0.60	1005.27
Junc 2	3.00	1020.41	Junc 163	2.10	1006.17
Junc 6	1.20	1019.71	Junc 232	2.00	1006.98
Junc 71	1.20	1019.34	Junc 101	1.20	1005.46
Junc 52	1.20	1019.28	Junc 104	2.10	1005.02
Junc 53	1.15	1019.28	Junc 100	1.50	1004.73
Junc 70	1.00	1019.06	Junc 224	2.10	1005.55
Junc 55	1.20	1019.19	Junc 102	1.20	1005.60
Junc 56	1.15	1019.19	Junc 97	2.00	1004.38
Junc 54	1.15	1019.23	Junc 103	2.00	1004.21
Junc 61	0.70	1019.07	Junc 89	2.20	1002.88
Tank	-274.35	1035.00			

The following steps were employed for the simulation of the distribution network:

- Launching the software
- Calibrating the software e.g. S.I. units, e.t.c
- Importation of the background map
- Placing the NODES and Editing appropriate Data
- Drawing the links (pipe, pump and valves) to connect all the nodes in step iv
- Editing links parameters appropriately (such as elevation, demand, tank and reservoir).

Calibration data were presented in Table 3.

Table 3: Pipes diameter, Length and roughness utilized for the study

LINK ID	L (m)	D (m)	R (mm)	LINK ID	L (m)	D (m)	R (mm)
Pipe 180	3.360	300	0.0015	Pipe 59	81.14	200	0.0015
Pipe 58	167.28	250	0.0015	Pipe 60	239.31	200	0.0015
Pipe 265	71.82	250	0.0015	Pipe 38	127.95	200	0.0015
Pipe 25	76.01	200	0.0015	Pipe 40	118.73	200	0.0015
Pipe 21	73.22	200	0.0015	Pipe 42	104.27	200	0.0015
Pipe 22	156.95	200	0.0015	Pipe 43	106.68	200	0.0015
Pipe 23	77.51	200	0.0015	Pipe 48	111.82	200	0.0015
Pipe 24	105.43	200	0.0015	Pipe 52	783.43	200	0.0015
Pipe 37	124.71	200	0.0015	Pipe 69	293.52	200	0.0015
Pipe 39	110.72	200	0.0015	Pipe 146	116.27	200	0.0015
Pipe 53	98.99	200	0.0015	Pipe 176	72.20	200	0.0015

Pipe 111	186.1	200	0.0015	Pipe 177	790.59	200	0.0015
Pipe 29	139.63	200	0.0015	Pipe 178	3.66	200	0.0015
Pipe 41	117.21	200	0.0015	Pipe 179	3.28	200	0.0015
Pipe 113	228.47	200	0.0015	Pipe 192	90.07	200	0.0015
Pipe 114	87.69	200	0.0015	Pipe 194	65.76	200	0.0015
Pipe 5	179.52	200	0.0015	Pipe 208	89.06	200	0.0015
Pipe 7	53.75	200	0.0015	Pipe 266	88.2	200	0.0015
Pipe 8	581.58	200	0.0015	Pipe 181	5.13	200	0.0015
Pipe 16	48.67	200	0.0015	Pipe 183	872.26	200	0.0015
Pipe 17	68.83	200	0.0015	Pipe 205	71.89	200	0.0015
Pipe 18	66.96	200	0.0015	Pipe 206	108.39	200	0.0015
Pipe 19	75.24	200	0.0015	Pipe 216	70.35	200	0.0015
Pipe 116	163.45	200	0.0015	Pipe 245	125.51	200	0.0015
Pipe 135	317.5	200	0.0015	Pipe 246	459.62	200	0.0015
Pipe 136	248.28	200	0.0015	Pipe 247	168.07	200	0.0015
Pipe 20	68.83	200	0.0015	Pipe 277	43.20	200	0.0015
Pipe 46	109.98	200	0.0015	Pipe 281	697.35	200	0.0015
Pipe 54	128.99	200	0.0015	Pipe 285	123.41	200	0.0015

L = Length, D = Diameter and R = Roughness

3. Results and Discussion

The study area was segmented into three areas (A, B and C) by the management of Alhamduri Water Works. Layout of the distribution network is presented in Figure 3. Furthermore, simulation results of the current status of the Alhamduri Water Works is presented in Table 4.

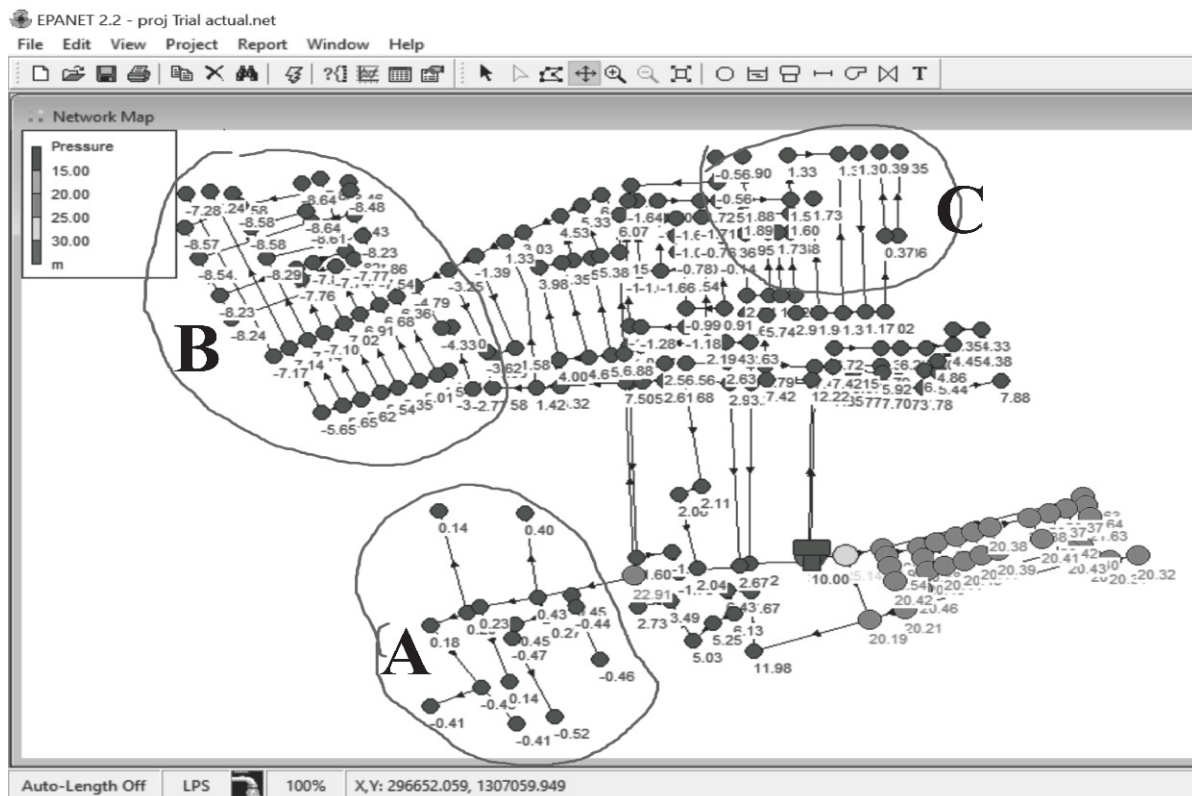


Figure 3: Area with Pressure Deficiency Distribution Network

From Figure 3, the result obtained indicated that there is a pressure deficiency in some nodes. Areas B and C of the distribution network were severely affected. Most household of the areas might not get water due to deficiency in the pressure.

From the simulation results (Table 4), it was observed that, the velocities ranges between 0.13 and 3.00 m/s, which are within the acceptable range (0.1 – 3.0 m/s). Conversely, the velocities of pipes 284, 178, 181, 181 and 180 are between 6.5 – 3.88m/s above the acceptable range. In such case, the diameter of the pipes are to be increased to meet up the reasonable range to avoid pipe bursts (leakages). Maximum discharge of the pipes are within 1.0 – 70.0 lps (acceptable range). About 32 pipes are below 1.0 lps and one pipe is above 70 lps. The flows in the other remaining pipes are within reasonable value.

Table 4: Showing Demand, Pressure, and total head at each node

LINK ID	FLOW (LPS)	FRICTION FACTOR	LINK ID	FLOW (LPS)	VELOCITY (m/s)
Pipe 284	41.56	0.016	Pipe 139	12.17	1.55
Pipe 178	-137.79	0.015	Pipe 45	26.2	1.48
Pipe 181	-137.79	0.015	Pipe 150	-11.55	1.47
Pipe 184	69.7	0.016	Pipe 280	11.22	1.43
Pipe 180	274.35	0.014	Pipe 290	10.6	1.35
Pipe 52	-94.23	0.016	Pipe 68	-8.35	1.31
Pipe 179	69.7	0.017	Pipe 144	22.41	1.27
Pipe 281	66.86	0.017	Pipe 47	21.8	1.23
Pipe 283	-37.56	0.017	Pipe 151	9.63	1.23
Pipe 1	36.69	0.017	Pipe 59	-37.96	1.21
Pipe 189	16.06	0.019	Pipe 145	21.26	1.2
Pipe 183	-63.86	0.017	Pipe 238	20.56	1.16
Pipe 286	35.56	0.018	Pipe 49	19.4	1.1
Pipe 60	-61.61	0.017	Pipe 140	8.65	1.1
Pipe 287	33.56	0.018	Pipe 32	18.7	1.06
Pipe 249	32.79	0.018	Pipe 272	-8.17	1.04
Pipe 31	32.09	0.018	Pipe 70	4.51	1.02
Pipe 142	30.81	0.018	Pipe 152	-7.98	1.02
Pipe 30	30.4	0.018	Pipe 245	-31.99	1.02
Pipe 248	-29.77	0.018	Pipe 113	30.98	0.99
Pipe 188	-12.92	0.019	Pipe 239	17.46	0.99
Pipe 35	29.01	0.018	Pipe 50	17.2	0.97
Pipe 143	28.78	0.018	Pipe 149	7.46	0.95
Pipe 44	28.4	0.018	Pipe 264	-5.93	0.93

It was confirmed from dwellers of Areas B and C who are little bit far away from the main source as indicated in Figure 3, that since inspection of the Water Works, no drop of water had reached the area. Thus, additional overhead tank should be installed at the proximity of the area to increase the velocity of flow and pressure performance.

In case of meeting all the targeted demands of the three areas, the Water Works requires 6.3 – 7.0 hours operation with 13 – 14 times recharge of the overhead tank. The report obtained from management of the water works indicated that it carried 6 hours operation with recharge of 9 – 10 times in a day. Thus,

the present system is not capable of supplying enough water to meet the Average Daily Demand (ADD) of Areas A, B and C.

Pressure and flow variation of the Distribution Network From is presented in Figure 4. It was observed that the existing Water Distribution Network is plagued with several shortcomings, most striking of which is the diameter of the distribution main (200mm) all over the network. The pressure of Area A (Figure 4) ranges between 12 – 25m for almost every node in the area except few nodes below the acceptable value which accounted for 14% (8 nodes) and 29% (17 nodes) with negative pressure. However, some parts of the system are having very small pipe diameter (as small as 38mm), which resulted in building of negative pressures and insufficient hydraulic head conditions in the network. Negative pressures were observed at some nodes at Areas C and B (Figure 4). The negative pressures due to smaller diameter of the pipes were rectified in the model by hypothetically increasing the diameter.

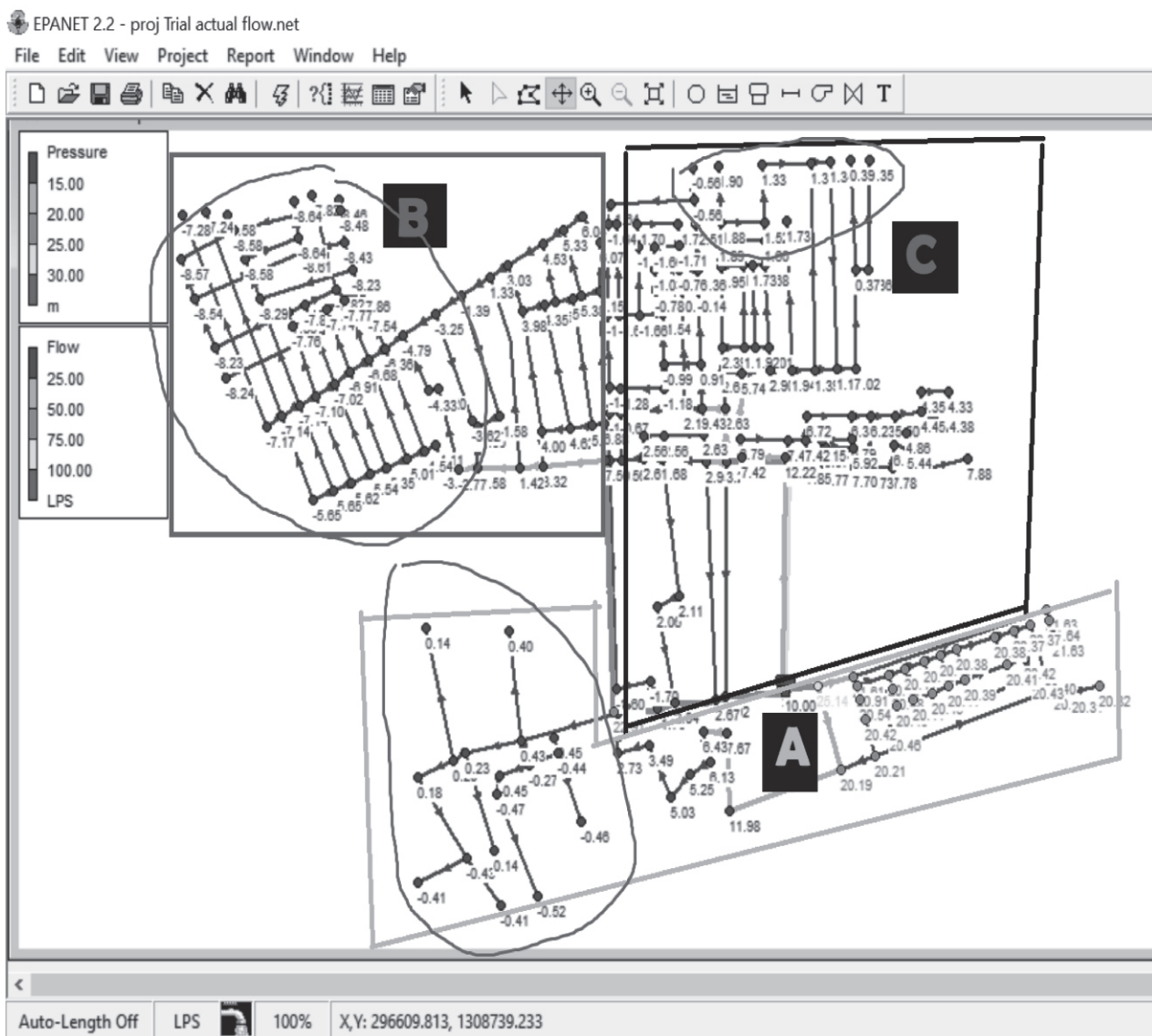


Figure 4: Showing Pressure and Flow Variation of the Distribution Network

Results of total head, pressure and demand (Average Daily Demand, ADD) of each node is presented in Table 5.

Table 5: Pipe Network Analysis Results

NODE ID	DEMAND (LPS)	HEAD (M)	PRESSURE (M)	NODE ID	DEMAND (LPS)	HEAD (M)	PRESSURE (M)
Junc 226	0.00	1034.88	35.38	Junc 12	2.00	1010.75	11.98
Junc 227	0.00	1034.81	35.31	Junc 20	1.10	998.7	10.18
Junc 225	0.00	1034.61	35.11	Junc 38	2.00	1005.9	7.90
Junc 37	2.00	1034.24	34.24	Junc 81	0.60	1005.16	7.86
Junc 230	4.00	1032.38	32.88	Junc 86	0.70	1005.63	7.83
Junc 1	4.00	1024.04	25.14	Junc 82	0.60	1005.16	7.76
Junc 228	3.00	1021.51	22.91	Junc 85	1.00	1005.45	7.75
Junc 4	0.50	1020.34	21.64	Junc 83	0.60	1005.21	7.71
Junc 3	0.80	1020.35	21.63	Junc 13	2.20	1006.39	7.67
Junc 5	0.30	1020.33	21.63	Junc 84	0.60	1005.27	7.67
Junc 2	3.00	1020.41	21.61	Junc 163	2.10	1006.17	7.50
Junc 6	1.20	1019.71	20.91	Junc 232	2.00	1006.98	7.48
Junc 71	1.20	1019.34	20.54	Junc 101	1.20	1005.46	7.46
Junc 52	1.20	1019.28	20.48	Junc 104	2.10	1005.02	7.42
Junc 53	1.15	1019.28	20.48	Junc 100	1.50	1004.73	7.13
Junc 70	1.00	1019.06	20.46	Junc 224	2.10	1005.55	6.88
Junc 55	1.20	1019.19	20.44	Junc 102	1.20	1005.6	6.86
Junc 56	1.15	1019.19	20.44	Junc 97	2.00	1004.38	6.78
Junc 54	1.15	1019.23	20.43	Junc 103	2.00	1004.21	6.71
Junc 61	0.70	1019.07	20.37	Junc 89	2.20	1002.88	5.48
Tank	-274.35	1035.00	10.00				

The acceptable range of pressure (Table 5) for all the nodes was 12 – 40m. The pressure of Area A ranges between 12 – 25m for some few nodes, while the other nodes (174 nodes) are below the acceptable value. The network has 240 nodes, out of which 57% are below the acceptable limit and 26% with negative pressures respectively. The pressure is slightly high at junction 1 due to its proximity to the elevated tank. So, there is high tendency of pipe burst (leakages). To remedy this, a pressure-reducing valve should be installed as suggested by Garcia-Avila et al. (2019), and increasing pipe diameters too reduce the pressure to a reasonable value.

The pressures of majority pipes in Area C are below the minimum acceptable value. Area C has a pressure range of 1.5 – 12 m. This is below the minimum permissible limit except for junction 231, which has 12.22 m. Thus, the area experiences low pressure, and as a result, water doesn't reach households in the area. High pressure causes pipe bursting, and low pressure causes stagnation of water within the pipe network. Based on the hydraulic simulation of the network, Area B is severely affected with negative pressure which clearly indicates the inaccessibility of the water in the area. The maximum pressure in the area was 7.5 m, which is below the acceptable limit.

4. CONCLUSION

Based on findings of the study, the present system (Alhamduri Water Works) is not capable of supplying water and meeting the ADD of the areas intended for. The main is not supplying sub-mains with sufficient pressure based on principle of pressure; as the area increases the pressure reduces. The pressure flow rate is low in the distribution network, so the chances of water stagnation for a long time is high. The chance of leaks in relation to pressure is low except for illegal connections or poor service connections (such as joints, junctions, valves, etc.). Therefore, thorough inspection of the network and

improvement plan should be considered by the management to increase performance of the distribution network. Thus, modifications should be made to increase the pressure, flow rate, velocity, and head loss at some points that are not within a reasonable range. Pipeline condition monitoring tool should be used to monitor pipelines continuously without disrupting normal operation. This will help the management to be alerted on any failure or problem within the distribution network.

It is therefore recommended that:

- i. The present system should be improved to cover the whole area and an additional tank should be set up to cope with the pressure deficiency in the areas affected. In some cases, the diameter of some pipes should be enlarged to increase the flow rate.
- ii. Pressure-reducing valves (PRVs) should be installed where pressure is above the permissible limit.
- iii. Future researchers should simulate the Distribution Network based on 2030 population projection.
- iv. WaterCad or any other hydraulic simulation software should be used to check the performance index of Alhamduri Water Works and compare the results obtained.

REFERENCES

- Avila, C.A.M., Sanchez-Romero, F., Lopez-Jimenez P.A. and Perez-Sanchez M. (2021), Leakage Management and Pipe System Efficiency. Its Influence in the Improvement of the Efficiency Indexes. *Water*, 13(14), 1-25.
- Garcia-Avila, F., Aviles-Anazco, A., Ordonez-Jara, J., Guanuchi-Quezada, C., Flore del Pino, L. and Ramos-Fernandez, L. (2019). Pressure management for leakage reduction using pressure reducing valves. Case study in an Andean city. *Alexandria Engineering Journal*, 58, 1313 – 1326.
- Babar, T. A., Khan, S. N., Muhammad, H., Khan, S., and Nasir, A. (2020). Water Supply Scheme System Design for Peri Urban Areas of Punjab using EPANET. *Pakistan Journal of Geology (PJG)*, 4(1), 34–42.
- Brown, K. (2007). Florida State University Libraries Modeling Leakage in Water Distribution Systems. In K. Brown (Ed.), *Modeling Leakage in Water Distribution Systems* (pp. 23–65). Kristin Brown.
- Dziedzic, R., Ph, D., Karney, B. W., and Asce, M. (2016). Performance Index for Water Distribution Networks under Multiple Loading Conditions. *Journal of Water Resources Planning and Management*, 142(1), 1–11.
- Gajbhiye, A., Reddy, P. H. P., Sargaonkar, A. P., and Scholar, M. T. (2017). Modeling Leakage in Water Distribution System Using EPANET. *Civil Engineering and Environmental Technology*, 4(3), 211–214.
- Salam, A. E. U., Tola, M., Selintung, M., and Maricar, F. (2014). Application Extreme Learning Machine To Predict Location And Magnitude Of Pipe Leak On Water Distribution Network. *Engineering Journal*, 1(9), 303–308.
- Seago, C., Bhagwan, J., and Mckenzie, R. (2002). Benchmarking leakage from water reticulation systems in South Africa. 30(5), 25–32.

IMPACT OF SOLID WASTE DISPOSAL ON ENGINEERING PROPERTIES OF SOIL WITHIN ADO-ODO OTA LOCAL GOVERNMENT OF OGUN STATE, NIGERIA.

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ABSTRACT

The disposal of solid wastes has been a big environmental challenge in Nigeria. The rapid growth of population leads to the increased in Urbanization and Industrialization which in turn increases the rate of generation of solid wastes. As leachates infiltrate into the soil, contaminated liquid substances are migrated into the soil, thereby affecting soil stability and strength. Hence, unscientific dumping pollutes the environment to a large extent. This paper presents the impact of open dumping of Municipal Solid Wastes (MSW) disposal on Soils in Ado-Odo Ota Local Government Area of Ogun State, Nigeria. The study based on the geotechnical investigation comparison of dump soil samples and the natural soil samples collected from outside the accessibility of dumpsites. The soil samples were taken from four trial pits in and outside the dumpsites at a depth of 1m. Three of the trial pits were located within the dumpsites to serve as contaminated soils, while the other trial pits was collected from natural soils to serve as control or uncontaminated soils for the investigation. Samples collected were subjected to Natural Moisture Contents (NMC), Specific Gravity (SG), Consistency Limit, Particles Size Distribution (PSD), Compaction and California Bearing Ratio (CBR) tests. The results indicated that municipal solids wastes (MSW) reduced the CBR (4.5-6.7%), SG (1.8-2.24), Consistency limit (6.2-10.5%), Maximum Dry Density (MDD) (1.59-1.63mg/m³) and increased the NMC (13.5-15.1%) and the fine particles contents (43.5-52.8% fine sand fraction.) as compared to the natural (uncontaminated) soils. This indicated that geotechnical characteristics of the soils at all the three dumpsites have been affected as a result of the contamination by the leachates from MSW.

Keywords: Ado-Odo Ota, Consistency Limit, California bearing ratio, Particle size distribution, solid wastes

1. INTRODUCTION

In our great country Nigeria, dumping ground is habitual due to insufficient trained personnel in proper waste disposals and supervision. The soil that been contaminated by Thrash metals can lead to unfavourable effects on human health and soil formation (Okeke *et al.*, 2019). This was aggravated by increases in industrialization and population growth then decreasing per-capita income leading to the generation of huge solid waste which gives rise to serious threats as large quantities of solid waste are dumped randomly, thereby, set down pressure on scarce land and water resources as well as impacting negatively on the properties of soils (Quadri *et al.*, 2018). Municipal Solid Waste was been disposed in lowland without taking any operational jurisdiction, being the major cause of soil and ground water contamination (Nayak *et al.*, 2007; Amadi *et al.*, 2012). Waste disposal is at a tough level of expansion in Nigeria. Consequently, there is need to develop provision for the proper disposal of highly increased amount of MSW. During rainfall, there is a tendency for the runoff to come in contact with solid waste disposal and form leachate which find its way into subsurface as well as acquifers. Polluted liquid substances originated from the wastes during decaying in the dumping ground, enter into the soil through surface run off, infiltration and then become dangerous to soils and groundwater for a very long time. More so, there are outstanding impacts on the chemical characteristics of the soil by increasing the soil alkalinity, moisture content and organic matters content through decay of organic wastes which are been controlled by the actinivitees of the soil micro organism, recently reported by Akintola *et al.*, (2021). Unselective disposal of waste materials is a

widespread practice among the poor and rich People in many parts of developing countries. Rapid development and unrivalled search for land have pushed some urban residents in building residential homes on abandoned dumping ground. Hence, there is need to evaluate the engineering properties of MSW contaminated soil. A lot of researchers had worked on the characterization and supervision of MSW in our country Nigeria (Alhassan, 2012) and they mainly deals with groundwater, but little observation has been given to the impact of waste on the engineering properties of soils. Almost every day, reasonable quantities of solid wastes are being generated which are frequently disposed irregularly and this tends to constitute environmental degradation (Ugwu *et al.*, 2018). This paper investigated the engineering properties of soil within dumpsite in Ado-Odo Ota Local Government taken samples from Iju, Atan and Owode regions.

2. MATERIALS AND METHODS

The Study Area

The three dump sites used for the research were located along Idiroko road, Ota, in Ogun State, South-Western Nigeria. Iju, Atan and Owode are 14km, 17km and 40km respectively, in the West direction from Ota (Figure 1). Iju town is situated at the coordinates of $6.6817132^{\circ}\text{N}$ and $3.1473809^{\circ}\text{E}$. The Municipal solid waste (MSW) is deposited in an open land in the periphery of the town, surrounded by Plantain Farm, main road, shops and residences. No treatment done to the MSW. Atan town is positioned at the coordinates of $6.6460872^{\circ}\text{N}$ and $3.0818843^{\circ}\text{E}$. The MSW is directly disposed in an open land surrounded by resident drainage, road and shops. Owode town is positioned at the coordinates of $6.7240599^{\circ}\text{N}$ and $2.9955273^{\circ}\text{E}$. The MSW is directly disposed in open landfills in the periphery of the town, surrounded by palm trees, cassava farm, main road and shops. There is no liner or segregation of solid present. The averages temperature and rainfall of the areas are 26.2°C and 2020mm respectively (Figure 2-4). The climatic is hot and humid. Iju, Atan and Owode fall within coastal plain sands, Bounded on North by Ilaro formation, on the South by Lagos State and on the West and East by recent alluvium. Ogun State comprises mainly of basement and sedimentary rock. The sedimentary rock of the State, consist of Abeokuta formations lying directly above the basement complex. Ewekoro, Oshosun and Ilaro formations, which are then in turns overlies the Abeokuta formation, which are all overlain by the coastal plain sands (Adegoke *et al.*, 2020)

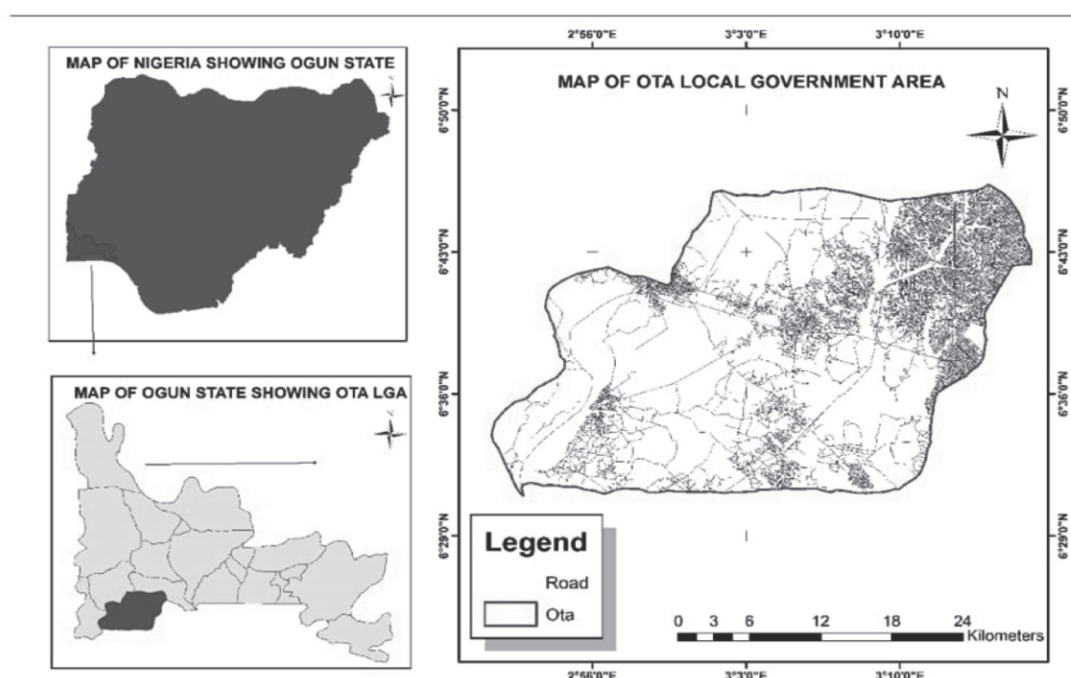


Figure 1: Map of Ota showing the study areas in triangular shape.



Figure 2: Shows Iju Dumping ground



Figure 3: Shows Atan Dumping ground



Figure 4: Shows Owode dumping ground

Collection of Soil Samples

Three (3) dump sites were chosen for the present study (Iju, Atan and Owode) in the month of December 2022. The soil samples were taken from within the dump sites (contaminated) and for the purposed of comparison, natural (uncontaminated) soil samples were taken from a distance of 0.5km outside the accessibility of the dump sites in the selected areas. Based on the residents around the dump sites, the Iju, Atan and Owode Municipal Solid Wastes have been used for more than 25, 20 and 30 years respectively. The samples were collected at 1.0m depth. The soil samples were taken to Laboratory and analysed. The tests conducted include: Natural Moisture Contents, Specific Gravity, Particles Size Distribution, Consistency, Compaction, and California Bearing Ratio using the BS 1377 (1990). Coordinates of each sample locations were identified using Global Positioning System (GPS), as shown in Table 1.

Table 1: Shows coordinate of sample locations

LOCATIONS	SOIL SAMPLES	LATITUDES (0C)N	LONGITUDES (0C)E	HEIGHT (M)
Iju	Contaminated	6.6817132	3.1473809	18.0
	Uncontaminated	6.6813156	3.1574169	44.0
Atan	Contaminated	6.6460872	3.0818843	48.0
	Uncontaminated	6.6520436	3.0897142	44.0
Owode	Contaminated	6.7240599	2.9955273	68.0
	Uncontaminated	6.7237411	2.9930265	76.0

3. RESULTS AND DISCUSSION

3.1 Natural Moisture Content

Natural Moisture Content (NMC) results ranged from 13.5 to 15.1% (contaminated) and 7.5 to 9.4% (uncontaminated), as presented in Figure 5. The results revealed that the values of the natural moisture content of the uncontaminated soil samples collected outside the dumpsites are lower compared to those of contaminated soil samples obtained within the dumpsites. The NMC values of the contaminated soil were higher than the natural soils, the reason is that the contaminated soil is expected to be moister, since the municipal solid waste covered the ground level there by prevent direct evaporation of moisture from the soil under. Again, the trend of these results could be as a result of decomposition of biodegradable wastes percolating into the soil. The results are in agreement with the findings by Alhassan, (2012)

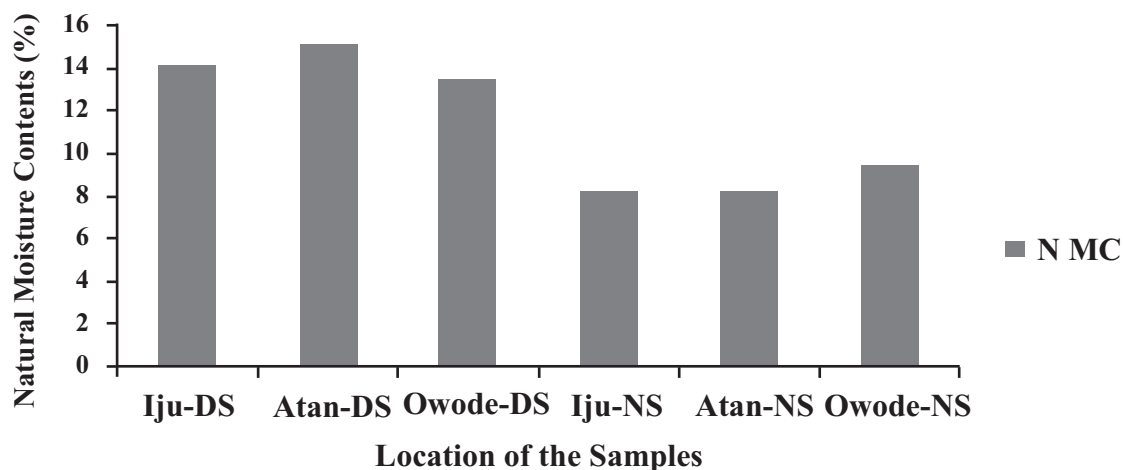


Figure 5: Shows the variations in Natural Moisture Contents of Dump sites (DS) and Natural Soil (NS) from the locations.

3.2 Specific Gravity

Table 2 shows the results of Specific gravity of both contaminated and uncontaminated samples. The results lie in the ranges of 1.8 to 2.24(Contaminated) and 2.53 to 2.57(Uncontaminated), which showed the values of samples collected from the three dumpsite areas were generally lower than that of natural soils, this signifies the presence of high organic matter in the dumpsites. Contrary to findings made by Okeke, et al. (2019) that the SG of contaminated soil sample was relatively high when distinguished with the uncontaminated soil sample, because of higher moisture content of the contaminated soil.

Table 2: Shows Specific gravity (SG)

LOCATION	CONTAMINATED	UNCONTAMINATED
Iju	2.2	2.57
Aton	1.8	2.53
Owode	2.24	2.55

3.3. Particles Size Distribution

The Particle Size Distribution (PSD) results are presented in Figure 6. It was observed that the contaminated soils have more fines than the natural (uncontaminated) soil, attributed to the decomposition of biodegradable waste which increased fine particles that covered the soil. This conforms to work done by Sujatha *et al.* (2013). Based on Unified Soil Classification System (USCS) the contaminated soil samples are classified as silty clay (CL, CL-ML) with their Liquid Limit less than 50%. More so, the curves represented a type of soil in which the particles size has been distributed over a wide range. The fractions of grain size distribution of the soils taken from the dumpsites are: gravel 1.9 to 6.9%, coarse sand 7.1 to 15.2%, medium sand 25.9 to 32.1%, fine sand 43.5 to 52.8% and finest 4.8 to 9.5%. whereas that of natural soils are gravel 2.4 to 17.6%, coarse sand 3.8 to 33.3%, medium sand 27.0 to 37.9%, fine sand 19.3 to 44.8% and finest 2.6 to 8.7. The present study is to investigate the changes in geotechnical properties of dumpsites soil compare with those of natural soils.

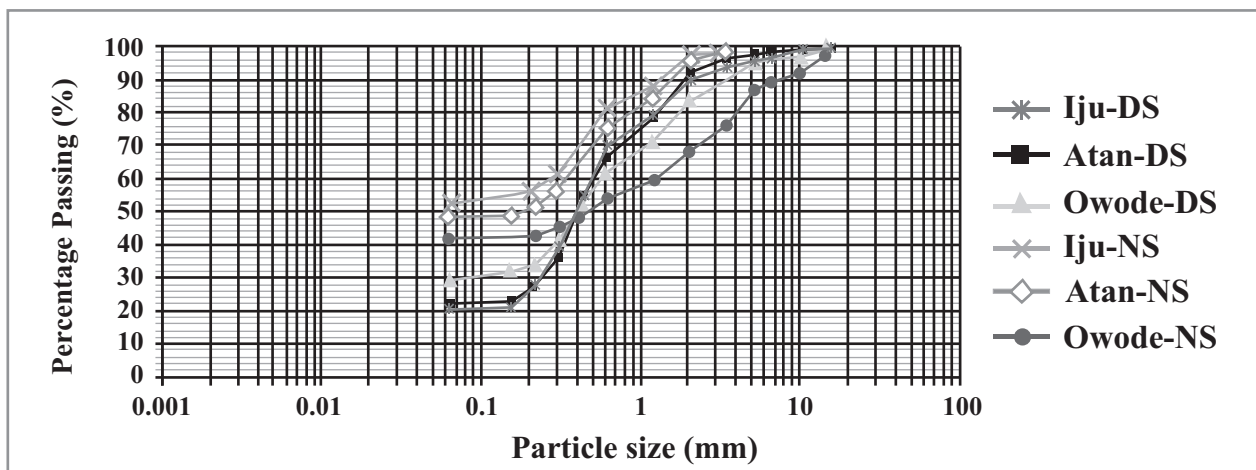


Figure 6: Shows the Grain Size analyses of dumpsites and natural soils from the locations. Where DS (dump site) and NS (natural soil)

3.4 Consistency Limit

Table 3 shows that liquid limit ranged from 23.5 to 37% (contaminated) and 47 to 55% (uncontaminated) whereas the plasticity index ranged from 6.2 to 10.5% (contaminated) and 19.8 to 24% (uncontaminated). The results revealed that the soil samples taken from the dumpsites has lower

consistency limit than the soil samples collected from the natural soils, attributed to percolation of Leachate into the soils thereby affected the soil samples below the MSW. It was also observed from the study that fine soils resulting from compostable wastes have non plastic behaviour. Although, the trends of these results are not in conformity to work done by Ugwu *et al.* (2018) and Sujatha *et al.* (2013). Moreso, it was discovered from the studied areas, that the soil has well graded with more fractions of Clayey content and less fractions of Silty sand.

Table 3: Shows Consistency limit

LOCATION	SOIL SAMPLES	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX (%)
Iju	Contaminated	29	20.5	8.5
	Uncontaminated	47	25	22
Atan	Contaminated	23.5	13	10.5
	Uncontaminated	50	30.2	19.8
Owode	Contaminated	22	15.8	6.2
	Uncontaminated	55	28	24

3.5 Compaction

Compaction is the densification of soil by removal of air (Braja, 2010). The results showed that the MDD of the contaminated soil samples ranged from 1.59 to 1.65Mg/m³ and the OMC varied from 15.5 to 17.1%. But the MDD for uncontaminated soils ranged from 1.68 to 1.73Mg/m³ and the OMC ranged from 13.1 to 15.3%. It was discovered that the MDD of the contaminated soil was lower than that of uncontaminated soil, whereby the OMC of the contaminated soil samples is higher than the natural soil, presented in Figure 7. The results revealed that the compaction curves of the uncontaminated soils collected from outside the dumpsites of Iju, Atan and Owode respectively are almost in line with each other towards right due to their closeness, signifying that the natural soil are Compatible in the present study regions. On the other hand, the curves of contaminated soil samples showed that the decomposition of organic matter leads to increase in the quantity of fine particles to a value more than that requires to fills the voids of the soils resulted to low compaction.

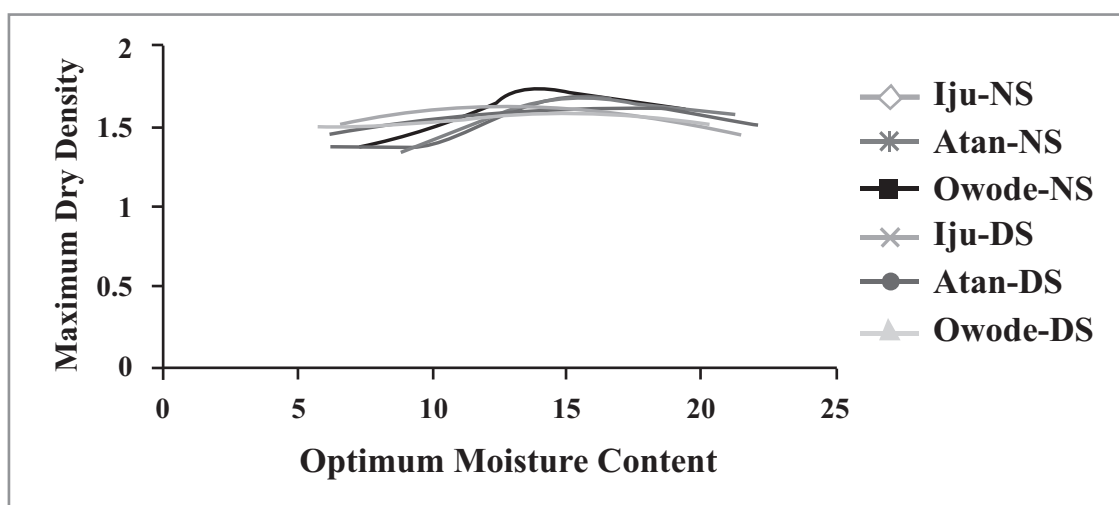


Figure 7: Shows the variations in MDD and OMC of dumpsites and natural soils from the locations. Where: NS (natural soil) and DS (dump site).

3.6 California Bearing Ratio (CBR)

California bearing ratio, it is very important for evaluating the suitability of sub-grade and the materials used in the sub-base as reported by Arora, (2009). The results of CBR were presented in Table 4. The results revealed that CBR varied from 4.5 to 6.7% (contaminated) and 36.8 to 65.3% (uncontaminated). It was discovered that samples collected from Iju, Atan and Owode dumpsites respectively have low CBR values, attributed to the decomposition of organic matter and infiltration of leachate through voids into the soil, which affected the engineering properties of the soils. While, samples collected from the natural soils outside the dumpsites of Iju, Atan and Owode have high CBR values, indicated that the soil samples have low porosity and high strength. Therefore, on the bases of these the soils (natural) can be used as sub-base materials in pavement construction, reason is their CBR values greater than 30% as recommended in Federal Ministry of Works and Housing. Similar observation was made by (Quadri et al. (2018).

Table 4: California Bearing Ratio

LOCATION	CONTAMINATED	UNCONTAMINATED
Iju	4.5	36.8
Atan	6.7	65.3
Owode	5.2	44.7

4. CONCLUSION

Investigation showed that the MDD of contaminated soil samples is lower than that of uncontaminated soil samples, but OMC of contaminated soil was higher than that of uncontaminated soils, attributed to decomposition of biodegradable wastes. The SG of the contaminated soil samples is lower than the uncontaminated soils indicating presence of organic matter in the soil. Base on Unified Soil Classification system (USCS) the samples are classified as Silty clay (CL-ML, CL). The contaminated soil samples in the three study regions have higher NMC and lower consistency limit, as compared to the natural (control) soil samples. California Bearing Ratio of contaminated soil samples are lower than the natural soils, showing that the soil from the dumpsites cannot be used as sub-grade materials, reason is that its CBR values are less than 30%. The rapid growth of population and increase in industrialization are responsible for the increase in size of dumpsites which affect soil properties below it. In general, from the findings made the natural soil located within and outside the dumping ground is relatively homogeneous. So, even though dumping has been completed the soils cannot be used for heavy construction purpose, unless it undergoes effective soil treatment. However, light construction could be applicable.

5. RECOMMENDATION

It is recommended that government should come with an effective idea (such as scientific disposal) that would make waste disposal from the residents easier. Construction of suitable engineering landfill system with liner system, Like Single Geomembrane liner system or double liner system, these would reduce soil contamination from infiltration of leachate. More so, wastes should be collected by the area municipalities to the final dumping ground and disposal management practice should be considered.

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REFERENCES

- Aladeboyeje, A.I., Coker, J.O., Agbasi, O.E. and Inyang, N.J. (2020):** Hydro-geological Appraisal of Basement and Sedimentary Terrain in Ogun State using Geo-electrical Method, *International Journal of Advanced Geosciences (IJAG)*, 8(1): 95-101.
- Alhassan, M. (2012):** The Effect of Municipal Solid Waste on the Geotechnical properties of Soils. *International Journal of Environmental Science Management and Engineering Research*, 1(5): 204-210.
- Amadi, A.N., Olasehinde, P.I., Okosun, E.A., Okoye, N.O., Okunlola, I.A., Alkali, Y.B. and Dan-Hassan, M.A. (2012):** Comparative Study on the Impact of Abuja and Ibeja Dumpsites on Soil Quality in Southeastern Nigeria, *American Journal of Chemistry*, 2(1): 17-23.
- Arora, K.R. (2009):** Soil Mechanics and Foundation Engineering, Standard Publishers Distributions, Delhi. 775-777.
- B.S. 1377(1990):** Methods of testing Soil for Civil Engineering purpose, British standards Institutes, London, England.
- Braja, M.D. (2010):** Principles of Geotechnical Engineering Printed in the United State of America. 43 - 46.
- Federal Ministry of Works and Housing: Standard Specification Requirement (1997).** Map of Ado-Odo Ota Local Government Area: Ministry of Land and Housing, Abeokuta (2018).
- Nayak, S., Sunil, B.M. and Shrihari, S. (2007):** Hydraulic and Compaction Characteristics of Leachate Contaminated Lateritic Soil. *Engineering Geology* 94(3-4): 715-716.
- Okeke, I.E., Okagu, T.T., Okonkwo, V.O. and Ezeagu, A.C. (2019):** Effect of Municipal Solid Waste Leachate on the Geotechnical properties of Soil, *International Journal of Engineering Science Invention (IJESI)*, 7(8): 40-52.
- Oluwatoyin, O.A., Gabriel, O.A., Oluwayemisi, S.O. and Idayat, A.B. (2021):** Impact of Waste on some properties of Soil around an active Dumpsite in Ibadan, Southwestern Nigeria, *Journal of Bioresource management*, 8(3): 27-40.
- Quadri, H.A., Adeyemi, O.A., Obiora, F.I. and Faboro, O.P.** Effect of Open Dumping on the properties of Soils, *Proceeding of NBRRI International Conference on Sustainable Development Goals, and Nigerian Construction Industry* June 2018, 90-97.
- Sujatha, E. R., Gurucharan, R., Ramprasad, C. and Somakumar, V. (2013):** Impact of Municipal Solid Waste Dumping on Geotechnical properties of soil and Ground Water in Ariyamagalam, Trichy, India. *Electronic Journal of Geotechnical engineering*, 18: 2119-2132.
- Ugwu, E.I., Ekeleme, A.C., Awoyera, P.O., Ozioko, H.O. and Osinachi, u. (2018):** Effect of Municipal Solid Waste on some Geotechnical properties of Soil, *Journal of Materials and Environmental Sciences*, 9(2): 585-590.

EFFECT OF ULTRASOUND PRETREATMENT ON DRYING KINETICS, SPECIFIC ENERGY CONSUMPTION AND QUALITY INDICES OF MICROWAVE-DRIED JUTE LEAVES

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ABSTRACT

This study investigates the effect of ultrasound pretreatment on drying kinetics, specific energy consumption and quality indices of microwave-dried jute leaves. Fresh jute leaves were pretreated with ultrasonic cleaner for 30 mins. The effect of the ultrasound pretreated jute leaves (UPJL) and untreated jute leaves (UNJL) on the drying time, rehydration ratio, drying kinetics, specific energy consumption and quality indices (protein, vitamin A, vitamin C, iron and potassium) were determined using standard procedures. Eight drying models (Page, Logarithmic, Henderson and Pabis, Newton (Lewis), Wang and Singh, Parabolic, Midilli, Prakash and Kumar) were used to determine the drying kinetics. UPJL has lower drying time and energy consumption compared to UNJL. However, the UNJL has a higher rehydration ratio than UPJL. The Page model was found to best fit the experimental data compared to other models. The protein content of the dried jute leaves ranged from 12.05% to 12.83%, Vitamin A (2.81 to 2.87 mg/100g), Vitamin C (30.46 to 35.08 mg/100g), iron (5.42 to 6.53 mg/100g) and potassium (213.25 to 215.16 mg/100g), respectively. UNJL gave higher vitamin A, vitamin C and protein while UPJL favours iron and potassium contents. Ultrasound pretreatment enhances jute leaf drying rate and quality, thus showing promising potential.

Keywords: Microwave, Ultrasound, Jute leaves, Quality indices, Drying

1. INTRODUCTION

Jute leaves (*Corchorus olitorius*) are a leafy green vegetable that originate from the Malvaceae family and commonly found in tropical and subtropical regions of the world. They are a member of the hibiscus family and are closely related to other plants such as okra and cotton. Jute leaves are mostly cultivated in Southern Asia, India and Bangladesh specifically cultivated 95% of the world jute leaves (Ghellam *et al.*, 2022). Jute leaves are frequently used as a thickening ingredient in soups, stews, and curries due to their slippery nature (Ahmed and Sarkar, 2022). They come in dry, fresh, or frozen varieties and are highly adaptable. The crop is a great source of antioxidants, fiber, potassium, iron, vitamins A, C and E, fiber, and other essential micronutrients for the body (Islam, 2013). Jute leaves have high moisture content (70% to 90%) and easily wither after harvest. It has a very short shelf life lasting at best for only 2 to 3 days (Yakoub *et al.*, 2018). Due to the short shelf life associated with jute leaves, there is a need for a way to extend shelf life and preserve it.

Drying is a preservation method that entails the reduction of moisture content, it is one of the earliest method of preservation dating back to ancient times. It is a preservation method mostly used for varieties of food products such as dairy products, meat, vegetables and fruit. According to Ghellam *et al.* (2022), jute leaves are perishable farm products that are affected by post-harvest losses but their shelf life can be extended by reduction of moisture content through the application of drying as a preservation method. However, ineffective drying technique can degrade the end products quality (Wu *et al.*, 2020). Drying can be achieved using different techniques such as sun drying, shade drying,

oven drying, freeze drying, convectional drying and microwave drying etc. Microwave drying is an effective method of drying that has a promising attribute of efficiently drying and shorten the drying time of products. Compared to other conventional method of drying, microwave drying is energy efficient, simple, and minimize loss of volatile compounds in the course of drying the product. In the case of microwave drying, mass, moisture content and volume of the product are function of the power level used and time of treatment (Sunil *et al.*, 2017). Energy is one of the most consumed and relevant factor in food processing industry. High cost of energy and reduction in the ozone layer due to greenhouse gas emission has encourage industries to prioritize other method to reduce energy consumption (Mierzwa *et al.*, 2019). Therefore, the combination of microwave drying with other green processing methods or pretreatment that can significantly reduce the energy consumption in the drying of food products is required.

Ultrasound technique is a green processing method used as a pretreatment method for drying. Ultrasound is a non-thermal technology that has mechanical, cavitational, and sponge effects on food materials (Bhargava *et al.*, 2021). Ultrasound is a sound wave having frequency greater than 20 kHz, which is higher than the upper limit of the audible frequency capable of causing physicochemical changes (Bhargava *et al.*, 2021; Pandiselvam *et al.*, 2022). Ultrasound pretreatment enhances the drying characteristics by producing micro channels in the food tissue, facilitating internal moisture diffusion in the finished product, and lowering the barrier to water migration (Pandiselvam *et al.*, 2022). According to Xu *et al.* (2021), ultrasound pretreatment has significant influence on the drying process, quality attribute of food products and shorten the drying time. According to Wang *et al.* (2019), who used ultrasound as a pretreatment to enhance the drying rate of kiwi fruits slices and concluded that ultrasound pretreatment can preserve high amount of bioactive compound and enhance the drying process. Several researcher has carried out research on ultrasound as a pretreatment method on the functional composition, specific energy consumption and/or drying kinetics of fruits and vegetable which include; carrot (Gambo-Santos *et al.*, 2013; Salehi *et al.*, 2023), mushroom (Zhang *et al.*, 2016), tomato (Horuz *et al.*, 2017), okra (Sunil *et al.*, 2017), garlic (Bozkir *et al.*, 2018), Ceratophyllum demersum Endl (Morakinyo *et al.*, 2020), and green olive (Aydar, 2020). However, literature is sparse on the effect of ultrasound pretreatment and microwave dryer on the drying kinetics, rehydration, specific energy consumption and quality indices of jute leaves. Therefore, studying the effect of ultrasound pretreatment and microwave drying and evaluating the engendered effect could help to choose the suitable technology and of course the quality indices to preserve the composition and beneficial functionality of jute leaves. This study aimed to determine the effect of ultrasound pretreatment on drying kinetics, specific energy consumption and quality indices of microwave dried jute leaves.

2. Materials and Methods

The raw material used for this study was obtained from Aminson farms in Ilorin, Kwara State, Nigeria. The experiment was conducted at the Department of Food Engineering, University of Ilorin, Nigeria. Figure 1 depict the experimental flow process involve in the study.

2.1 Sample Preparation

Fresh jute leaves, free from physical contaminants and homogeneous in colour, were used for this study. The jute leaves were taken from the stems and then sorted to eliminate any damaged leaves or unwanted substances. In order to confirm sample uniformity, jute leaves of $40 \text{ mm} \pm 2$ of length were chosen for this study. The leaves were rinsed to remove external contaminants, such as sand, and left to drain. The initial weight of the jute leaves before pretreatment and drying processes was 90 g. The samples for treatment were classified into two categories: ultrasound-pretreated jute leaves (UPJL) and untreated jute leaves (UNJL).

2.2 Ultrasound Pretreatment Methods

The jute leaf samples were ultrasound pretreated using an ultrasonic cleaner (Model CJ: 008, China) operating at a power and frequency of 50 W and 40 kHz, respectively. The prepared sample was immersed in the ultrasonic cleaner filled with distilled water at a temperature of 29 ± 2 °C for ultrasound pretreatment. The pretreatment time was set at 30 minutes. After the pretreatment, the jute leaf samples were dried in a microwave dryer (LG MOD: MS-2027C China). The samples were dried until equilibrium moisture content is attained.

2.3 Drying Kinetics

The first weight loss in the microwave oven was obtained at a 10 mins interval under a steady state drying microwave power till a constant weight is reached. The drying curves was generated by plotting the graph of Moisture Ratio (MR) against drying time as obtained in the experimental data. The moisture ratio was determined using Eq. 1.

$$MR = \frac{M - M_e}{M_i - M_e} = \exp(kt) \quad \dots\dots\dots (1)$$

where MR is the moisture ratio, M is the moisture content at any time 't' (kg water/ kg dry matter) (% db), M_e is the equilibrium moisture content (EMC) at the conditions of the drying air (kg water/ kg dry matter) (% db), M_i is the initial moisture content of sample (kg water/ kg dry matter) (% db), t is the drying time (min) and k is the drying constant (min^{-1}).

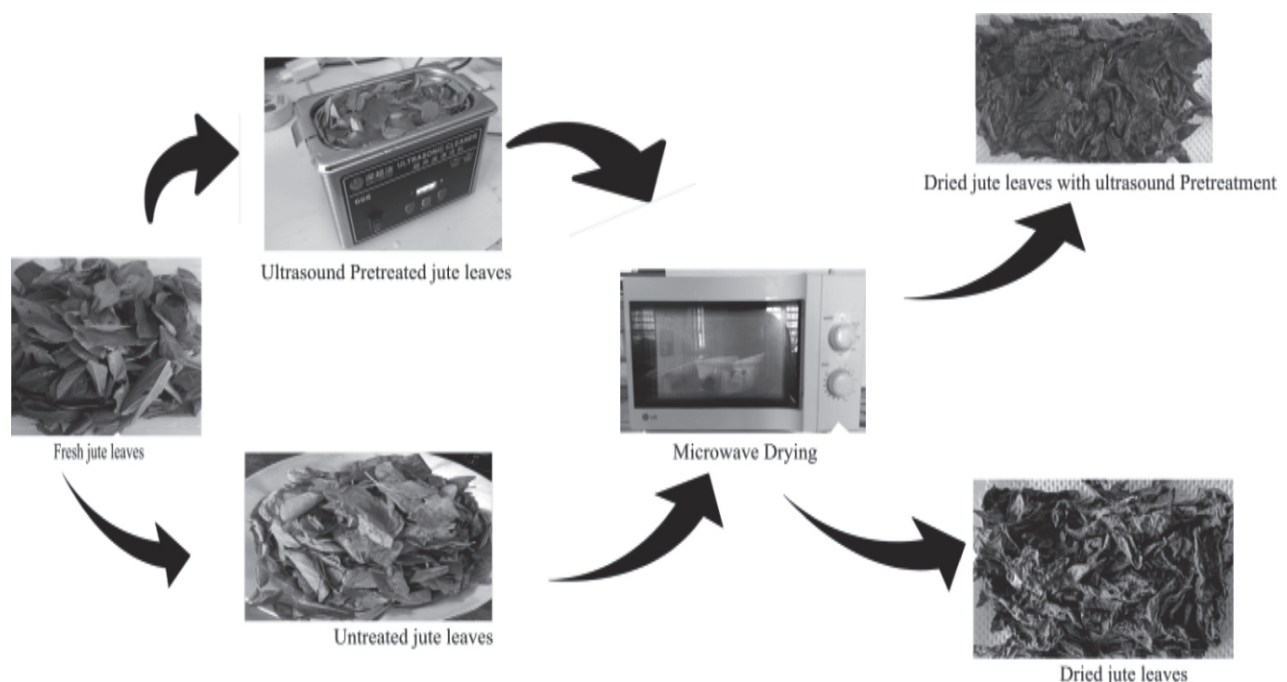


Figure 1. Flow process of producing ultrasound pretreated dried jute leaves and untreated dried jute leaves

2.4 Mathematical Modelling

Table 1 shows the eight mathematical models used for this study. The models are Midili, Page, Logarithmic, Modified page, Henderson and Pabis, Modified Henderson and Pabis, Newton, and a Two-term model was employed to predict an appropriate drying model that suits the drying curve.

Table: Mathematical Models

MODEL	EQUATION
Midili	$MR = a \exp(-kt^n) + bt$
Page	$MR = \exp(-kt^n)$
Logarithmic	$MR = a \exp(-kt^n) + c$
Modified Page	$MR = \exp[(-kt)^n]$
Henderson and Pabis	$MR = a \exp(-kt)$
Modified Henderson and Pabis	$MR = a \exp(-kt) + b \exp(-gt) + c \exp(-ht)$
Newton	$MR = \exp(-kt)$
Two-term	$MR = a \exp(-k_0t) + b \exp(-K_1t)$

MR is the moisture ratio, t is the temperature, k, n, a, b, c, g, h are empirical constant in the drying models.

2.5 Specific Energy Consumption

Specific energy consumption (SEC) can be referred to as the energy required to evaporate 1 kg of water from jute leaves in the drying medium (kJ/kg) (Abbaspour-Gilandeh *et al.*, 2020). SEC is the wave of energy transferred as heat which can lead to the reduction in the moisture content of the product (Abbaspour-Gilandeh *et al.*, 2021). The energy utilized for the pretreatment was evaluated followed by the energy consumed during drying for each treatment method. Table 2 shows the specific energy consumption equation for different treatment method. The SEC of the jute leaves can be evaluated using Eq. 2 as described by (Abbaspour-Gilandeh *et al.*, 2020).

$$SEC = \frac{E_t}{M_w} \dots\dots\dots (2)$$

Where SEC is the specific energy consumption, E_t is the energy consumption (kJ) and M_w is the weight loss (kg)

Energy consumption for ultrasound pretreatment and microwave drying was determined by using Eq. 3 and 4 as described by Motevali *et al.* (2014) and Szadzinska *et al.* (2019) respectively.

$$E_{us} = UP \cdot t \dots\dots\dots (3)$$

$$UP = U \cdot I \cdot \cos\phi \dots\dots\dots (4)$$

$$E_{mw} = (P \cdot t) 3600 \dots\dots\dots (5)$$

Where is E_{us} is the ultrasound energy consumption (kJ), UP is the ultrasound power (W), U and I are the applied voltage (V) and current (A) of the ultrasound generator respectively, $\cos\phi$ is the power factor of the ultrasound (0.8), E_{mw} is the microwave energy consumption (kJ), P is the power of the microwave (W) and t is the drying/pretreatment time (min).

2.6 Quality indices

Rehydration

3g of jute leaves was weighed, and water was heated until a temperature of 60°C was reached. The weighed samples were soaked in the water and stirred to ensure the leaves were properly soaked. The vegetables were soaked for 20 mins, and then water was drained and lightly blotted with tissue paper to remove surface water. The rehydrated samples were weighed.

Rehydration was done for each sample, and the Rehydration Ratio (RR) was calculated in average values using Eq. (6) as described by Wang *et al.* (2019).

$$RR = \frac{W_r}{W_d} \dots\dots\dots (6)$$

Where W_r is the weight of rehydrated sample and W_d is weight of the dehydrated jute leave.

Determination of Protein

The Kjeldahl technique was used to determine the protein content. The nitrogen value was converted to protein using a ratio of 5.5 as reported by Yakoub *et al.* (2018).

Determination of Vitamin C

Vitamin C was quantified through a chemical analysis involving the titration technique using a solution of 2,6-dichlorophenolindophenol. To prepare the samples, 5 grams of the dehydrated jute leaves were ground in a mortar and pestle, mixed with acid-washed sand and a 10% Trichloroacetic acid (TCA) solution. After filtering the mixture, any remaining residue was thoroughly cleansed with TCA solution until it became colourless. A total volume of 100 mL was obtained. This solution was divided into three conical flasks, each containing 10 mL. These flasks were then titrated with indophenol solution until a pink colour appeared, and the results were employed to determine the vitamin C content.

Determination of Vitamin A

The β -carotene was determined by soaking 1 g of the sample in 5 ml of methanol for 2 h at room temperature under dark condition to get a complete extraction. The β -carotene layer was separated using hexane through separating funnel. The volume was made up to 10 ml with hexane and then this layer was again passed through sodium sulphonate through a funnel to remove any moisture from the layer. The absorbance of the layer was measured at 436 nm using hexane as a blank. The beta carotene was calculated using Eq. (7).

$$\beta \frac{\mu g}{100g} = A (436 \text{ nm}) \times V \times D \times 100 \times \frac{100}{W \times Y} \dots\dots\dots (7)$$

Where β is the beta carotene, A is the absorbance, V is the total volume of extract, D is dilution factor; W is sample weight and Y is percentage dry matter content of the sample.

Mineral analysis

Mineral analysis for the iron and potassium was performed using the AOAC method (AOAC, 2012).

2.7 Statistical Analysis

The regression analysis of the drying rate was evaluated using Statistical Package for Social Science (SPSS) version 20.0. The coefficient of determination R^2 , Root Mean Squared Error (RMSE) and reduced χ^2 were used to evaluate the goodness of fit. The evaluated parameter was calculated from Eq. (8) and (9):

$$RMSE = \left[\frac{1}{N} \sum_{i=1}^N (MR_{exp} - MR_{pre})^2 \right]^{\frac{1}{2}} \dots\dots\dots (8)$$

$$\chi^2 = \sum_{i=1}^N \frac{(MR_{exp} - MR_{pre})^2}{N - n} \dots\dots\dots (9)$$

Where MR_{exp} is the moisture ratio observed experimentally, MR_{pre} is the predicted moisture ratio; N and n represent the number of observation and parameters respectively. The statistical result obtained from the non-linear regression of the models which include the criteria for evaluating goodness such as R^2 , χ^2 and RMSE were used to evaluate the effectiveness of the models.

3. RESULTS AND DISCUSSION

3.1 Drying Curve of Jute Leaves

Figure 1 shows the change in moisture content and drying time of ultrasound pretreated jute leaves (UPJL) and untreated jute leaves (UNJL). The drying time of the jute leaves ranged between 14 mins and 16 mins. It was observed that the application of ultrasound as a pretreatment method enhances the drying rate of the jute leaves thereby reducing the drying time. This could be attributed to ultrasound as a pretreatment method which causes pore in the jute leaves and form fine channel on the cell wall which leads to increase in the evaporation rate compared to untreated sample. This result aligns with the findings of Sunil *et al.* (2017), that the drying efficiency of vegetables such as okra can be enhanced by the application of ultrasound combined with microwave. Also, Szadzińska *et al.* (2019), reported that the drying rate of red beetroot can be enhanced by application of ultrasound combined with microwaves thereby reducing the drying time. According to Munoz-Almagro *et al.* (2021), who reported that the drying kinetic of a product can be improved by the application of ultrasound assisted drying, with the magnitude of the improvement depending on various processing techniques employed.

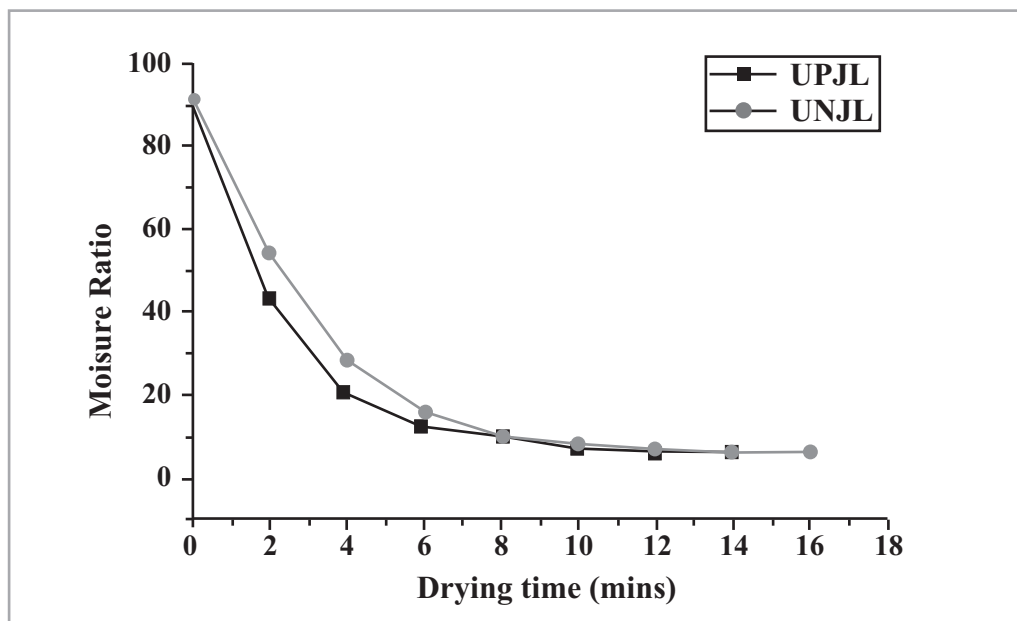


Fig. 1. Drying curves of jute leaves

3.2 Modeling on Drying Characteristics of Jute Leaves

Table 2 shows the summary of the model parameters of the eight thin layer drying model obtained from the non-linear regression model for the drying of jute leaves ultrasound pretreated and untreated. The highest value of R^2 and the lowest value of χ^2 and RMSE are the basis for selecting the best fitting model for predicting the drying characteristics of dried jute leaves. It was observed that the UPJL page and logarithmic model had the highest R^2 (1) value, but the lowest χ^2 and RMSE were obtained from the page model with 0.0000193 and 0.004139, respectively. Also, UNJL had the highest R^2 (1) value from the page and logarithmic model, whereas considering the lowest χ^2 and RMSE, the page model has an edge over the logarithmic model with values of 0.0000319 and 0.005324, respectively. The

overall R^2 (1) for the model was obtained from the Page model and logarithmic model, which is higher than the overall correlation coefficient that was found for Henderson and Pabis (0.999), Newton (0.999), Wang and Singh (0.606), Parabolic (0.721), Midilli (0.597), and Prakash and Kumar (0.908). Therefore, the page model and logarithmic model are the best fit for the experimental dimensionless moisture content data. However, considering the model with the lowest χ^2 and RMSE values, Page model ($\chi^2 = 0.0000193$ and $RMSE = 0.004139$) was the best fitted for the dimensionless moisture content data followed by Logarithmic, Henderson and Pabis, Newton, Prakash and Kumar, Parabolic, Wang and Singh and Midilli with χ^2 and RMSE values of ($\chi^2 = 0.0000232$ and $RMSE = 0.00454$), ($\chi^2 = 0.0000969$ and $RMSE = 0.009283$), ($\chi^2 = 0.0000969$ and $RMSE = 0.009283$), ($\chi^2 = 0.010982$ and $RMSE = 0.0988011$), ($\chi^2 = 0.031134$ and $RMSE = 0.166357$), ($\chi^2 = 0.045705$ and $RMSE = 0.201561$) and ($\chi^2 = 0.125218$ and $RMSE = 0.333624$) respectively. The result above shows that Page model was observed to satisfactorily describe the drying characteristics of dried jute leaves.

Table 2: Estimated parameter and comparison criteria of moisture ratio of dried jute leaves.

MODELS	CONSTANT	TREATMENT METHOD	R2	Chi	RMSE
Page	k=1.908 n=0.431	UPJL	1	0.0000193	0.004139
	k=1.436 n=0.550	UNJL	1	0.0000319	0.005324
Logarithm	k=0.989 a=1.336 b=0.011	UPJL	1	0.0000232	0.00454
	k=0.988 a=1.072 b=0.012	UNJL	1	0.0000366	0.005706
Henderson	k=1.000 a=1.252	UPJL	0.999	0.0000969	0.009283
	k=0.999 a=1.014	UNJL	0.998	0.00016	0.011933
Newton	k=1.252	UPJL	0.999	0.0000969	0.009283
	k=1.015	UNJL	0.998	0.00016	0.011933
Wang and Singh	k=-0.257 c=0.014	UPJL	0.606	0.072444	0.25376
	k=-0.225 c=0.011	UNJL	0.565	0.045705	0.201561
Parabolic	k=0.738 c=-0.188 a=0.010	UPJL	0.721	0.045923	0.202041
	k=0.713 c=-0.158 a=0.008		0.712	0.031134	0.166357
	k=0.481 b=-0.005 a=0.095	UNJL	0.597	0.125218	0.333624
Midilli	n=-1.171x10 ⁻⁷	UPJL	0.555	0.12562	0.334158
	k=0.432 b=-0.006 a=0.130 n=-1.056x10 ⁻⁷	UNJL			
Prakash and Kumar	a=-0.002 b=0.053 c=-0.412 d=0.910	UPJL	0.909	0.033759	0.173229
	a=-0.001 b=0.039 c=-0.349 d=0.890	UNJL	0.899	0.010982	0.098801

3.3 Effect of Ultrasound Pretreatment on the Rehydration Ratio of Dried Jute Leaves

Rehydration is one of the important criteria that show physical changes in dried products. Rehydration can be referred to as a prominent quality to characterize the extent of structural damage to food during drying process (Horuz *et al.*, 2017; Abbaspour-Gilandeh *et al.*, 2020). The elasticity of the cell wall decreases during drying thereby leading to a decrease in the water holding capacity of the dried sample (Ricce *et al.*, 2016). Figure 2 shows the rehydration ratio for dried jute leaves. The highest rehydration ratio was obtained from UNJL with a RR value of 4.5 and the lowest was observed from UPJL (4.2). The reduction in the RR value of UPJL may be attributed to the disruption of cell structures and the release of soluble components during the ultrasound process, leading to reduced water-holding capacity in the sample. This result corroborates with the findings of Sunil *et al.* (2017) that the dried sample pretreated with ultrasound had low rehydration ratio which may be attributed to the ultrasound negation effect. However, this result contradicts the findings of Doymaz (2008) who reported that the combination of ultrasound and microwave causes lower texture damage leading to more porosity thereby leading to increase in the rehydration of the product. Similar contradictory report was reported for carrot (Wiktor and Wiktor-Rajchert, 2020), Kiwifruit (Wang *et al.*, 2019) and pear (Liu *et al.*, 2019).

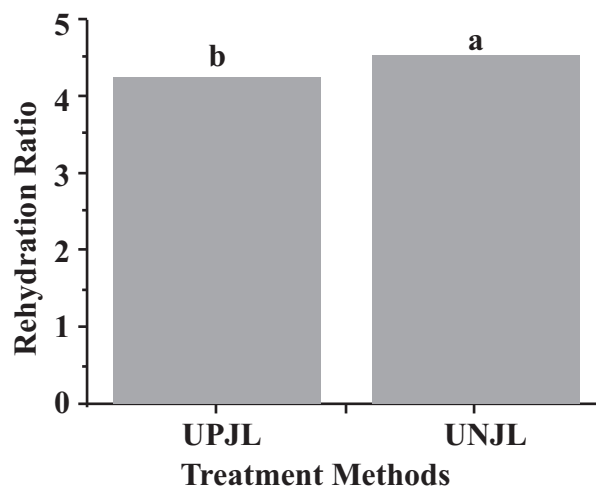


Fig. 2. Effect of treatment method on the rehydration ratio of dried jute leaves

3.4 Effect of Ultrasound Pretreatment on the Specific Energy Consumption of Dried Jute Leaves

Specific energy consumption (SEC) is one of the major factors assessed by the processing industry during drying operations. The increase in energy costs and environmental concerns through greenhouse gas emissions has motivated industries to investigate ways of reducing their energy consumption (Mierzwa et al., 2019). Figure 3 illustrates the effect of ultrasound pretreatment on the specific energy consumption of dried jute leaves. The specific energy consumption (SEC) of the dried jute leaves ranged between 12.94 MJ/kg and 14.79 MJ/kg. The lowest SEC was observed in UPJL (12.94 MJ/kg); this may be attributed to the effect of ultrasound on the jute leaves, which causes disruption in the cellular structure of the jute leaves, leads to faster moisture migration during drying, and reduces energy consumption. This corroborates the findings of Mierzwa et al. (2019), who investigated the SEC of raspberries using ultrasound pretreatment methods employing different drying methods but concluded that ultrasound pretreatment decreases energy consumption. Ultrasound pretreatment also enhances the drying time, thereby reducing the SEC through the prevention of the formation of a hard surface layer, which may slow down the removal of moisture from the surface of the products (Szadzińska et al., 2017; Kaveh et al., 2020). Also, Kowalski et al. (2016) employed different dryers to dry raspberries using ultrasound pretreatment, and they concluded that ultrasound pretreatment can reduce the SEC.

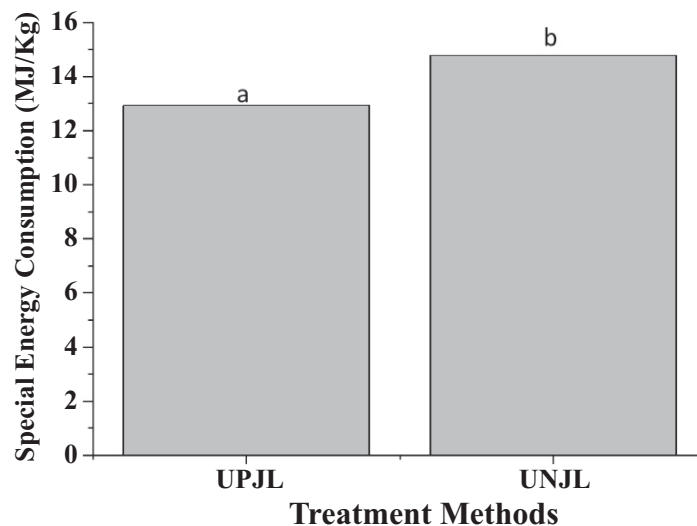


Fig. 3. Effect of treatment method on the specific energy consumption of dried jute leaves

3.5 Effect of Ultrasound Pretreatment on the Crude Protein of Dried Jute Leaves

Figure 4 depicts the effect of ultrasound pretreatment on the crude protein content of jute leaf samples. The crude protein content ranged from 12.05% to 12.83%. It was observed that there was a slight reduction in the protein content of UPJL jute leaves compared to UNJL jute leaves. This may be a result of enzymatic hydrolysis and degradation of proteins during ultrasound pretreatment. This result contradicts the findings of Li *et al.* (2023), who performed an experiment on the ultrasound pretreatment of quinoa protein and reported that ultrasound pretreatment causes no significant change in the protein degradation or secondary protein of the quinoa. However, there was a slight improvement in the protein content, which reduced the dipeptidyl peptidase. Also, Hua and Li (2022) conducted research on the effect of ultrasound pretreatment on the protein isolate of nanofibril. They reported that both the lower and higher amplitude ultrasound pretreatments tend to improve the protein content of the nanofibril. The lower-amplitude ultrasound pretreatment improves the emulsifying activity index, water absorption, and solubility of the protein isolate, while the higher-amplitude ultrasound pretreatment increases the crystallinity and tryptophan.

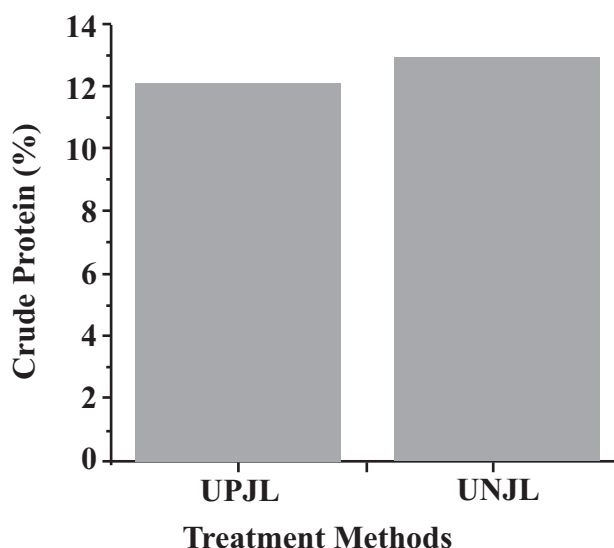


Fig 4. Effect of treatment method on the crude protein of dried jute leaves.

3.6 Effect of Ultrasound Pretreatment on the Vitamin of Dried Jute Leaves

The effect of ultrasound pretreatment on the vitamin C and A content of UPJL and UNJL are depicted in Figure 5a. The vitamin C content of jute leaves ranged from 30.46 to 35.08 mg/100g. It was observed that the vitamin C content of UNJL was significantly higher than that of UPJL. The loss in the vitamin C content of the dried jute leaves using ultrasound pretreatment could be attributed to the use of liquid media that is used in ultrasound treatment, as liquid promote nutrient loss in water soluble nutrient such as vitamin C. This result corroborate with the findings of (Mothibe *et al.*, 2011) that prolonged ultrasound pretreatment leads to decrease in total phenol content, flavonoid, antioxidant as well as of water soluble nutrient which include vitamin C. The vitamin A content of the jute leaves ranged between 2.81 and 2.87 mg/100g. It was also observed that the vitamin A content of UNJL was slightly higher than that of UPJL. This may be attributed to the ultrasound pretreatment and subsequent drying process. This result contradicts the findings of Dash *et al.* (2023) that the application of ultrasound as a pretreatment method before drying was found to preserve the antioxidant properties of dried ponjol fruits.

3.7 Effect of Ultrasound Pretreatment on the Minerals of Dried Jute Leaves

The effect of ultrasound pretreatment on the minerals content of UPJL jute leaves and UNJL jute leave is shown in Figure 5b. The iron content of the jute leaves ranged between 5.42 and 6.53 mg/100g. It

was observed that the iron content of UPJL was slightly higher than that of UNJL. This may be as a result of ultrasound on the nutritional value of the leaves. Similar result was reported by Khan *et al.* (2021), that ultrasound treatment of samples has been found to significantly improve the total phenolic compound and flavonoid content in plants including the iron content. Also Zhao *et al.* (2021) reported that combination of ultrasound and microwave drying may have resulted in better preservation of the nutritional component of vegetables including the iron content. The potassium content of the jute leaves ranged from 213.25 to 215.16 mg/100g. It was also observed that the potassium content of sample UPJL was significantly higher than that of UNJL. This may be attributed to the physicochemical combined effect of ultrasound and microwave treatment. This result corroborates with Yu *et al.* (2020), findings that ultrasound as a pretreatment method before microwave drying improves the efficiency of extraction thereby giving rise to higher level of soluble solid such as potassium.

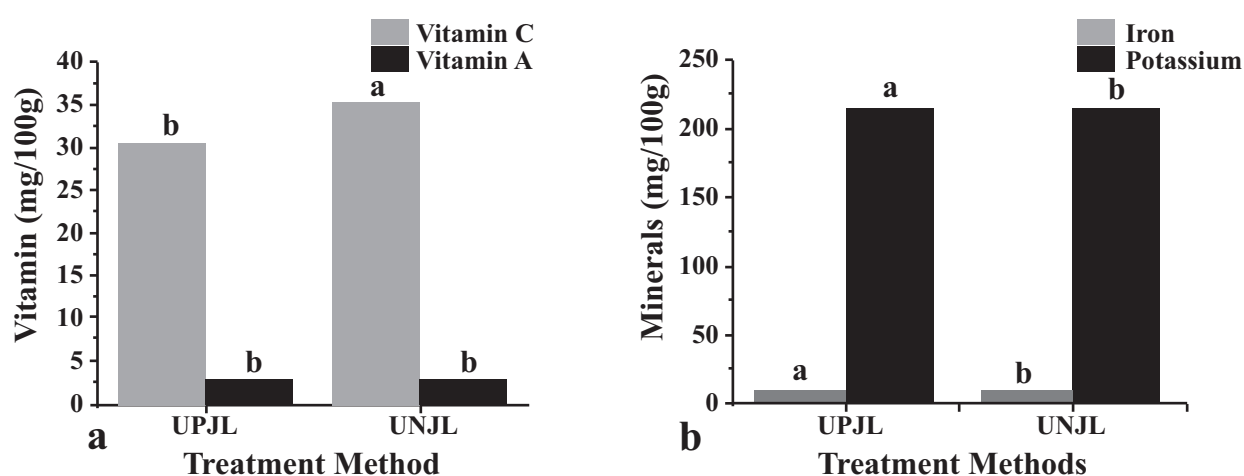


Figure 5: Effect of treatment method on the (a) vitamins of dried jute leaves (b) minerals of dried jute leaves

4. CONCLUSIONS

The effect of ultrasound pretreatment on the drying kinetics, rehydration ratio, protein, vitamin A, vitamin C, iron and potassium of jute leaf were successfully evaluated. The study identifies that ultrasound pretreated jute leaves dried faster compared to untreated jute leaves. The entire drying process occurred in falling rate period until a constant rate period was observed. Eight drying models were used to optimize the goodness of fit to the experimental data and page model was found to best fit the experimental data compared to other models with R^2 , χ^2 , and RMSE value of 1, 0.0000193 and 0.004139 respectively. Also, the drying kinetics, including drying rate and moisture content, were monitored throughout the drying process. Untreated jute leaves favours rehydration ratio, vitamin A, vitamin C and protein, while ultrasound pretreated jute leaves favours specific energy consumption, iron and potassium content of the jute leaves. Therefore, this study demonstrates that ultrasound pretreatment accelerates jute leaf drying, with Page model best fitting the data. It also highlights varied quality outcomes for treated and untreated jute leaves.

REFERENCES

- Abbaspour-Gilandeh, Y., Kaveh, M., and Aziz, M. (2020).** Ultrasonic-microwave and infrared assisted convective drying of carrot: Drying kinetic, quality and energy consumption. *Applied Sciences*, 10(18), 6309.
- Abbaspour-Gilandeh, Y., Kaveh, M., Fatemi, H., Khalife, E., Witrowa-Rajchert, D., and Nowacka, M. (2021).** Effect of pretreatments on convective and infrared drying kinetics, energy consumption and quality of terebinth. *Applied Sciences*, 11(16), 7672.
- Ahmed, Z., and Sarkar, S. (2022).** Review on jute leaf: A powerful biological tool. *International Journal of Scientific Research Updates*, 4(1), 64-85.
- Association of Official Analytical Chemists, & Association of Official Agricultural Chemists (US). (2012).** *Official methods of analysis of the Association of Official Analytical Chemists* (Vol. 2). The Association.
- Aydar, A. Y. (2020).** Investigation of ultrasound pretreatment time and microwave power level on drying and rehydration kinetics of green olives. *Food Science and Technology*, 41, 238-244.
- Bhargava, N., Mor, R. S., Kumar, K., and Sharanagat, V. S. (2021).** Advances in application of ultrasound in food processing: A review. *Ultrasonic sonochemistry*, 70, 105293.
- Bozkir, H., Rayman Ergün, A., Tekgül, Y., and Baysal, T. (2019).** Ultrasound as pretreatment for drying garlic slices in microwave and convective dryer. *Food Science and Biotechnology*, 28, 347-354.
- Dash, K. K., Boro, S., and Bhagya Raj, G. V. S. (2023).** Effect of ultrasound pretreatment and microwave vacuum drying in the production of dried ponjol fruit. *Journal of Food Process Engineering*, e14301.
- Doymaz, I. (2007).** Air-drying characteristics of tomatoes. *Journal of Food engineering*, 78(4), 1291-1297.
- Gamboa-Santos, J., Soria, A. C., Villamiel, M., and Montilla, A. (2013).** Quality parameters in convective dehydrated carrots blanched by ultrasound and conventional treatment. *Food chemistry*, 141(1), 616-624.
- Ghellam, M., Fatena, B., and Koca, İ. (2022).** Physical and chemical characterization of *Corchorus olitorius* leaves dried by different drying techniques. *Discover Food*, 2(1), 14.
- Horuz, E., Bozkurt, H., Karataş, H., & Maskan, M. (2017).** Effects of hybrid (microwave-convective) and convective drying on drying kinetics, total phenolics, antioxidant capacity, vitamin C, color and rehydration capacity of sour cherries. *Food chemistry*, 230, 295-305.
- Horuz, E., Jaafar, H. J., and Maskan, M. (2017).** Ultrasonication as pretreatment for drying of tomato slices in a hot air–microwave hybrid oven. *Drying Technology*, 35(7), 849-859.
- Hu, A., and Li, L. (2022).** Effects of ultrasound pretreatment on functional property, antioxidant activity, and digestibility of soy protein isolate nanofibrils. *Ultrasonics Sonochemistry*, 90, 106193.
- Islam, M. M. (2013).** Biochemistry, medicinal and food values of jute (*Corchorus capsularis* L. and *C. olitorius* L.) leaf: a review. *Int J Enhanc Res Sci Technol Eng*, 2(11), 135-44.

- Kaveh, M., Taghinezhad, E., and Aziz, M. (2020).** Effects of physical and chemical pretreatments on drying and quality properties of blackberry (*Rubus* spp.) in hot air dryer. *Food Science & Nutrition*, 8(7), 3843-3856.
- Khan, M. K. I., Ghauri, Y. M., Alvi, T., Amin, U., Khan, M. I., Nazir, A., and Maan, A. A. (2021).** Microwave assisted drying and extraction technique; kinetic modelling, energy consumption and influence on antioxidant compounds of fenugreek leaves. *Food Science and Technology*, 42.
- Kowalski, S. J., Pawłowski, A., Szadzińska, J., Łechtańska, J., and Stasiak, M. (2016).** High power airborne ultrasound assist in combined drying of raspberries. *Innovative Food Science & Emerging Technologies*, 34, 225-233.
- Li, Y., Wang, W., Wu, T., You, H., Liu, H., Liu, X., and Ding, L. (2023).** Preparation of quinoa protein with ultrasound pretreatment and its effects on the physicochemical properties, structural and digestion characterizations. *International Journal of Biological Macromolecules*, 238, 124202.
- Liu, Y., Zeng, Y., Wang Q., Sun, C., and Xi, H. (2019).** Drying characteristics, microstructure, glass transition temperature, and quality of ultrasound-strengthened hot air drying on pear slices, *Journal of Food Processing and Preservation*, 43(3), e13899
- Mierzwa, D., Szadzińska, J., Pawłowski, A., Pashminehazar, R., and Kharaghani, A. (2019).** Nonstationary convective drying of raspberries, assisted by microwaves and ultrasound. *Drying Technology*, 37(8), 988-1001.
- Morakinyo, T. A., Akanbi, C. T., and Adetoye, O. I. (2020).** Drying kinetics and chemical composition of *Ceratophyllum demersum* leaves. *Int. J. Eng. Appl. Sci. Technol*, 5, 456-465.
- Motevali, A., Minaei, S., Banakar, A., Ghobadian, B., and Khoshtaghaza, M.H. (2014)** Comparison of energy parameters in various dryers. *Energy Convers. Manag.* 2014, 87, 711–725.
- Mothibe, K. J., Zhang, M., Nsor-atindana, J., and Wang, Y. C. (2011).** Use of ultrasound pretreatment in drying of fruits: drying rates, quality attributes, and shelf life extension. *Drying Technology*, 29(14), 1611-1621.
- Munoz-Almagro, N., Morales-Soriano, E., Villamiel, M., and Condezo-Hoyos, L. (2021).** Hybrid high-intensity ultrasound and microwave treatment: A review on its effect on quality and bioactivity of foods. *Ultrasonics Sonochemistry*, 80, 105835.
- Nowacka, M., Wiktor, A., Śledź, M., Jurek, N., and Witrowa-Rajchert, D. (2012).** Drying of ultrasound pretreated apple and its selected physical properties. *Journal of Food Engineering*, 113(3), 427-433.
- Pandiselvam, R., Aydar, A. Y., Kutlu, N., Aslam, R., Sahni, P., Mitharwal, S., and Kothakota, A. (2022).** Individual and interactive effect of ultrasound pre-treatment on drying kinetics and biochemical qualities of food: A critical review. *Ultrasonics Sonochemistry*, 106261.
- Ricce, C., Rojas, M. L., Miano, A. C., Siche, R., and Augusto, P. E. D. (2016).** Ultrasound pre-treatment enhances the carrot drying and rehydration. *Food Research International*, 89, 701-708.
- Salehi, F., Goharpour, K., and Kamran, H. R. (2023).** Effects of ultrasound and microwave pretreatments of carrot slices before drying on the color indexes and drying rate. *Ultrasonics Sonochemistry*, 101, 106671.

- Sunil, C. K., Kamalapreetha, B., Sharathchandra, J., Aravind, K. S., and Rawson, A. (2017). Effect of ultrasound pre-treatment on microwave drying of okra. *Journal of Applied Horticulture*, 19(1), 58-62.
- Szadzińska, J., Łechtańska, J., Kowalski, S. J., and Stasiak, M. (2017). The effect of high power airborne ultrasound and microwaves on convective drying effectiveness and quality of green pepper. *Ultrasonics sonochemistry*, 34, 531-539.
- Szadzińska, J., Mierzwa, D., Pawłowski, A., Musielak, G., Pashminehazar, R., and Kharaghani, A. (2019).** Ultrasound-and microwave-assisted intermittent drying of red beetroot. *Drying Technology*.
- Szadzinska, J., Lechtańska, J., Pashminehazar, R., Kharaghani, A. and Tsotsas, E. (2019).** Microwave- and ultrasound-assisted convective drying of raspberries: Drying kinetics and microstructural changes. *Drying Technology*, 37, 1–12.
- Wang, J., Xiao, H. W., Ye, J. H., Wang, J., and Raghavan, V. (2019).** Ultrasound pretreatment to enhance drying kinetics of kiwifruit (*Actinidia deliciosa*) slices: pros and cons. *Food and bioprocess technology*, 12, 865-876.
- Wang, J., Xiao, H. W., Ye, J. H., Wang, J., and Raghavan, V. (2019).** Ultrasound pretreatment to enhance drying kinetics of kiwifruit (*Actinidiadeliciosa*) slices: pros and cons. *Food and Bioprocess technology*, 12, 865-876.
- Wiktor, A., and Witrowa-Rajchert, D. (2020). Drying kinetics and quality of carrots subjected to microwave-assisted drying preceded by combined pulsed electric field and ultrasound treatment. *Drying Technology*, 38(1-2), 176-188.
- Wu, X. F., Zhang, M., Ye, Y., and Yu, D. (2020).** Influence of ultrasonic pretreatments on drying kinetics and quality attributes of sweet potato slices in infrared freeze drying (IRFD). *LWT*, 131, 109801.
- Xu, B., Chen, J., Tiliwa, E. S., Yan, W., Azam, S. R., Yuan, J., and Ma, H. (2021).** Effect of multi-mode dual-frequency ultrasound pretreatment on the vacuum freeze-drying process and quality attributes of the strawberry slices. *Ultrasonics Sonochemistry*, 78, 105714.
- Yakoub, A. R. B., Abdehedi, O., Jridi, M., Elfalleh, W., Nasri, M., and Ferchichi, A. (2018).** Flavonoids, phenols, antioxidant, and antimicrobial activities in various extracts from Tossa jute leave (*Corchorusolitorus* L.). *Industrial Crops and Products*, 118, 206-213.
- Yu, Y., Cheng, X., Zhang, C., Zhang, J., Zhang, S., and Xu, J. (2020).** Ultrasonic and microwave treatment improved jujube juice yield. *Food Science & Nutrition*, 8(8), 4196-4204.
- Zhang, Z., Liu, Z., Liu, C., Li, D., Jiang, N., and Liu, C. (2016).** Effects of ultrasound pretreatment on drying kinetics and quality parameters of button mushroom slices. *Drying Technology*, 34(15), 1791-1800.
- Zhao, Y., Zhu, H., Xu, J., Zhuang, W., Zheng, B., Lo, Y. M., and Tian, Y. (2021).** Microwave vacuum drying of lotus (*Nelumbonucifera* Gaertn.) seeds: Effects of ultrasonic pretreatment on color, antioxidant activity, and rehydration capacity. *Lwt*, 149, 111603.

EFFECT OF UNTREATED WASTEWATER REUSE IN AGRICULTURE AND SUSTAINABLE REPROACH FOR MICRO-POLLUTANT REMOVAL USING HYDROCHAR

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ABSTRACT

The scarcity of freshwater resources has prompted millions of smaller agrarian households in Nigeria depend on marginal water for crop irrigation, fishing and domestic purposes. The marginal water is seen as a viable option to augment the perennial scarcity of freshwater for year-round cultivation. Prolong use of untreated wastewater for agriculture poses threat to public and environmental health. The adoption of water quality guidelines for agriculture is highly desirable for implementation; but, in reality it's hard to achieve in Nigeria, which may be due to factor such as high cost of: procurement, operation and maintenance and sustainability. This gap has prompted the need for exploring other sustainable and effective methods. A thermochemical process called hydrothermal carbonisation was employed to produce the needed hydrochar from raw coco-peat, coconut shell, rice hull, lemon peel and chicken eggshell. The hydrochars were characterised using SEM/EDS, FTIR, CHN, BET. The efficiency of each adsorbent was evaluated as follows: Over 90% of Pb²⁺ and Cr⁶⁺ were removed by coco-peat; while 100% of Fe²⁺ and Cu²⁺ were delineated by eggshell; on the other hand, coconut shell performed excellently in decolourising the simulated wastewater. In conclusion, the use of hydrochar for wastewater treatment hold a promise.

Keywords: Freshwater scarcity, wastewater reuse, crop irrigation, health risks, hydrochar, adsorption

1. INTRODUCTION

The use of wastewater for agriculture in developing countries has become increasingly important option to augment the perennial scarcity of freshwater resources. Agricultural productivity in Nigeria just like in many other developing countries has lowered due to scarcity of freshwater resources, which is observed to affect not only the expansion but also the quality of crop production. Several studies have established the presence of micro-pollutants in wastewaters used for crop irrigation in developing countries. Developing countries where reuse of untreated industrial wastewater for crop cultivation include: Nigeria (Akan et al., 2007; Akan et al., 2009; Dan'Azumi and Bichi, 2010), Romania (Lacatusu, 1996), Pakistan (Khan et al., 2013), India (Chhikara and Rana, 2013), Bangladesh (Islam et al., 2013; Sarker et al., 2015) and Turkey (Demirezen and Aksoy, 2006; Halim, 2013). The studies show that the concentrations of micro-pollutants in such wastewaters often exceed the recommended threshold (FAO/WHO, 2006). It is important to note that chemicals have varying industrial applications, so the waste being generated. However, to limit the scope of this study, only wastewater from textile and tannery industries is in focus.

Production in textile and tannery industry requires large amount of water; hence, generating corresponding volume of wastewater. Municipal wastewater combined with untreated textile and tannery wastewater are often reported to be indiscriminately discharged into adjoining rivers in Kaduna, Kano and Zaria Cities. Farming communities located along the fringes of river Jakara in Kano, Nigeria are known for extensive irrigation activities and producing perishables to feed the local markets with untreated wastewater. Regrettably, Nigeria wastewater infrastructure is either non-existent, inadequate or obsolete. The wastewater often contains both organic and inorganic pollutants. Unlike organic pollutants, which are susceptible to biodegradation, the inorganic pollutants such as heavy metals are non-biodegradable and usually have long decay and mobile half-life in biological tissues. Based on documented studies, Ademoroti et al. (1992) reported that about 75% of industries in Lagos State discharge effluents directly into nearby surface waters; 15% into surrounding bushes and 10% into drainage and gutter systems without any form of treatment. Ademoroti et al., (1992) further reported that 42% of the total textiles industries in Nigeria are sited in Lagos, concentrating mainly in Apapa, Ilupeju, and Ikeja; whereas 27% culminating (Bompai, Challawa, and Sharada) in Kano; 20% in Kaduna (Kakuri and Kaduna South); and remaining 11%, are sparsely distributed within the South-East cities of Aba and Onitsha and Asaba from South-South.

Conversely, the northern parts of Nigeria (Kano, Kaduna, Maiduguri) have the largest tannery industries (NBS, 2010). Effluents from these industries contain reagents such as carboxylic acids, alkalis, dyes, sodium bisulphate, soda ash, hydrogen peroxide, dextrin-starch, gums and resins, waxes, surfactants, dispersing agents, soaps and heavy metals (Holkar et al., 2016). The presence of these pollutants at varying concentration levels, above their recommended threshold has been a subject of concern among researchers due to their pervasive health accumulative and impact both ecological systems and public health (FAO/WHO, 2006; Ensink and Van Der Hoek, 2009; Sorsa et al., 2015). Regrettably, this type of wastewater is currently being used for crop irrigation in Nigeria (Bichi et al., 2013; Mohammed, A.S. 2021). Micro-pollutants in irrigation water, agricultural soil and plants are impediments to safe agricultural practice and farmers' productivity. Notably, documented reports have shown that farmers exposed to prolonged contact with wastewater and the consumers of crops irrigated with untreated wastewater are likely to suffer a wide range of diseases, these include: sclerosis, skin lesion, cancer, cardiovascular disorder, neurological dysfunctions illnesses and shrinking of the bones (itai itai) (FAO/WHO, 2006). Scholars have also established some epidemiological links between consumption of food crops irrigated with untreated wastewater and individual or communal illnesses (Ensink and Van Der Hoek, 2009). For instance, a study from Romania by Lacatuşu et al. (1996), reported that the typical life expectancy of the inhabitants of Copsa Mica reduced by 9-10 years due to the consumption of crops and vegetables grown with wastewater containing Cu^{2+} , Cd^{2+} , Pb^{2+} at concentration levels exceeding the recommended thresholds.

To this end, policymaking Organisations such as Food and Agriculture Organisation (FAO), World Health Organisation (WHO), United State Department of Agriculture (USDA), International Commission of Agricultural and Biosystems Engineering (CIGR) have been devising modalities in safeguarding humans from excessive exposure to micro-pollutants through wastewater reuse. The FAO and WHO jointly issued some guidelines to regulate the concentration of micro-pollutants contaminants in surface water used for crop irrigation, agricultural soils and plants (FAO/WHO, 2006). The acceptance of water quality guidelines is highly desirable for implementation; however, in reality their adoption in developing countries is hard to achieve (Giller et al., 1998, FAO/WHO, 2006; Ensink and Van Der Hoek, 2009). While these guidelines recorded tremendous success on its implementation mandate in developed countries; opposite is the case in developing countries (Mateo-Sagasta et al., 2013). The following may be among the notched reasons for the non-compliance to these guidelines in developing countries. 1) most of the cottage industries do not have the financial strength to acquire and maintain sophisticated wastewater treatment facilities (reverse

osmosis and nanotechnology); 2) the wastewater treatment facilities may either obsolete or non-existent; and 3) poor enforcement of rules and regulations governing the discharge of effluents into industrial wastewater (Mateo-Sagasta et al., 2013). Hence, this paper stems to proffer an alternative, sustainable and affordable technology for the treatment of wastewater using hydrochar of biomass waste.

To achieve this research goal, a cost-effective thermochemical process known as hydrothermal carbonisation (HTC) is used to convert the biomass wastes into carbon-rich, coal-like derivative commonly called 'raw biomass waste' at saturated pressure, thereby releasing CO₂ and other volatiles (Funke and Ziegler, 2010). HTC involves dehydration and decarboxylation of biomass in order to raise the carbon content which increases its energy value (Libra et al., 2011). During hydrothermal carbonisation of biomass, decomposition of carbohydrate takes place through hydrolysis, resulting in an exothermic reaction, which breaks down the biomass to form glucose, fructose and other by-products (Holgate et al., 1995). Hydrothermal carbonisation of biomass wastes has many advantages compared to other biochemical and thermochemical (conventional methods) processes for char production. HTC can take from a few minutes to hours, against days or even months as required by other conventional methods (Titirici et al., 2007; Libra et al., 2011). The sorption potentials of the hydrochar were exploited via pilot studies based on functionality tests. The objectives of the study is to: i) evaluate the % adsorption of the interacting metal ions of each hydrochar; ii) determine the residual concentration of interacting metal ions in the filtrate; iii) job creation (turning waste-to-wealth).

2. Materials and Methods

2.1 Materials

The materials used in conducting the experiments include the following:

- i. The conical and volumetric flasks
- ii. pH meter
- iii. Mechanical Shaker
- iv. Whatman paper
- v. A magnetic stirrer (polygon F371220040 spin bar)
- vi. ICP-AES or ICP-OES
- vii. photometer
- viii. Biomass waste (eggshell, rice hull, lemon peel, coco-peat and coconut shell)
- ix. Berghof high-pressure bioreactor (Br-300 ml, Germany) for hydrothermal carbomisation
- x. Reagents (methylene blue, ICP stock and standard solutions of heavy metals)
- xi. Anhydrous sodium sulphate (Na₂SO₄)
- xii. Corn starch
- xiii. Set of sieves
- xiv. Grinder with cutting pulverised-14 machine
- xv. Waring Variable Speed Laboratory Blender (LB20EG-EA)
- xvi. Acids (H₂SO₄, HNO₃, HCl), Alkali (NaOH and KOH) and droppers
- xvii. Test tubes
- xviii. Malvin 2000 Master-sizer for Particle Size Distribution
- xix. CHN analyser
- xx. Scanning Electron Microscopy (SEM)
- xxi. BET for surface determination
- xxii. FTIR analyser for functional group determination
- xxiii. Electron Disperse Spectrometry (EDS) for elemental analysis
- xxiv. De-ionised water

- xxv. Digital weighing balance
- xxvi. Oven

2.2 Methods

2.2.1 Reagents and simulated wastewater preparation

All reagents used in the experiments were of analytical grade, purchased in Loughborough, Leicestershire County, England. These include: Inductively Coupled Plasma (ICP) stock solutions of 10,000 ppm for copper sulphate and lead nitrate; 1000 ppm for iron sulphate and potassium dichromate. Other constituents bought for the experiment include 2 g/kg of corn starch, 6.13 g/kg of anhydrous sodium sulphate (industrial salt) and 0.09466 g/kg of methylene blue. A standard solution was made from the stock solution for metals of interest needed for the experiments. The procedure used for the synthetic wastewater preparation was based on APHA (2012). From the standard solution, 5 ppm of what constitute the heavy metal ions (Cr^{6+} , Cu^{2+} , Fe^{2+} and Pb^{2+}) was prepared and transferred into the volumetric flask followed by addition of salt, corn starch, methyl-blue and then de-ionised water to make 1 L.

2.2.2 Sources of adsorbents and preparation for adsorption

The biomass used in this study originates from plants and poultry waste. The plant wastes include biomass waste of coir, coconut shell, rice hull and lemon peel; while eggshell is from poultry. These wastes are readily available in large quantities and can be sourced locally in Nigeria. The technique used in converting the raw biomass into raw biomass waste is through HTC. The raw biomass wastes were ground in a blender and sieved to aperture size of 0.850 mm and 0.600 mm. The raw biomass wastes were effectively washed with clean water and rinsed with de-ionised water before air drying each in an incubator-oven set at 40 °C for 24 h. The incubator temperature was set in order to maintain the surface characteristics of each raw biomass without being de-natured before conversion into raw biomass waste. This was done in order to retain the surface functionality groups on each adsorbent. The air-dried raw biomass wastes were subjected to carbonisation through HTC (See Figure 4). The carbonisation for each biomass waste was carried out under the same conditions; these include a temperature of 200 °C, under an autogenous pressure of 20 bar for 1200 min (20 h) as the reaction time. One hour is a recommended time to heat up the process and raise the temperature to 200 °C (Danso-Boateng et al., 2015). The process involves weighing a known mass of biomass waste and mixing it with de-ionised water in specified ratio, this is based on the procedure described by Titirici et al. (2007). The authors suggest that for a solid concentration of 7-33.3%, a total volume of 200 mL of water is required for effective carbonisation. Based on that suggestion, the present study has considered using a mass of solids within the specified range in relation to water mix ratio for each material. Specifically, for the CP, the percentage of solids was 7%, for the RH and LP 20% and for the ES and the CS was 33.3 %. The sample of raw biomass waste mixed with water were then transferred into a non-stirred 195 mL durable polytetrafluoroethylene (PTFE) Teflon vessel with 40 mm inner diameter and 158.7 mm inner height. The PTFE was then inserted into a core stainless steel SS 316TI (Berghof high-pressure reactor, BR-300, Germany) with 44 mm internal diameter and 166.7 mm inner height. After carbonisation, the reactor was allowed to cool down to (25 ± 2) °C before loosening the autoclave knob to release CO_2 and other volatiles produced during the thermochemical process (see Figure 1). The raw biomass wastes produced were then washed in methanol to remove available organic residues before being thoroughly rinsed with de-ionised water. Then, the hydrochar was dewatered and filtered using Whatman Paper of 2.5µm pore size for the desired product. The hydrochar was further oven-dried at 105 °C for 24 h before being cooled stored in air-tight container for future use. Note: all the sorbents were dried on the basis of constant weight. During which there is no further reduction in weight of the sorbent and then the final sample weight is taken and considered completely dried.

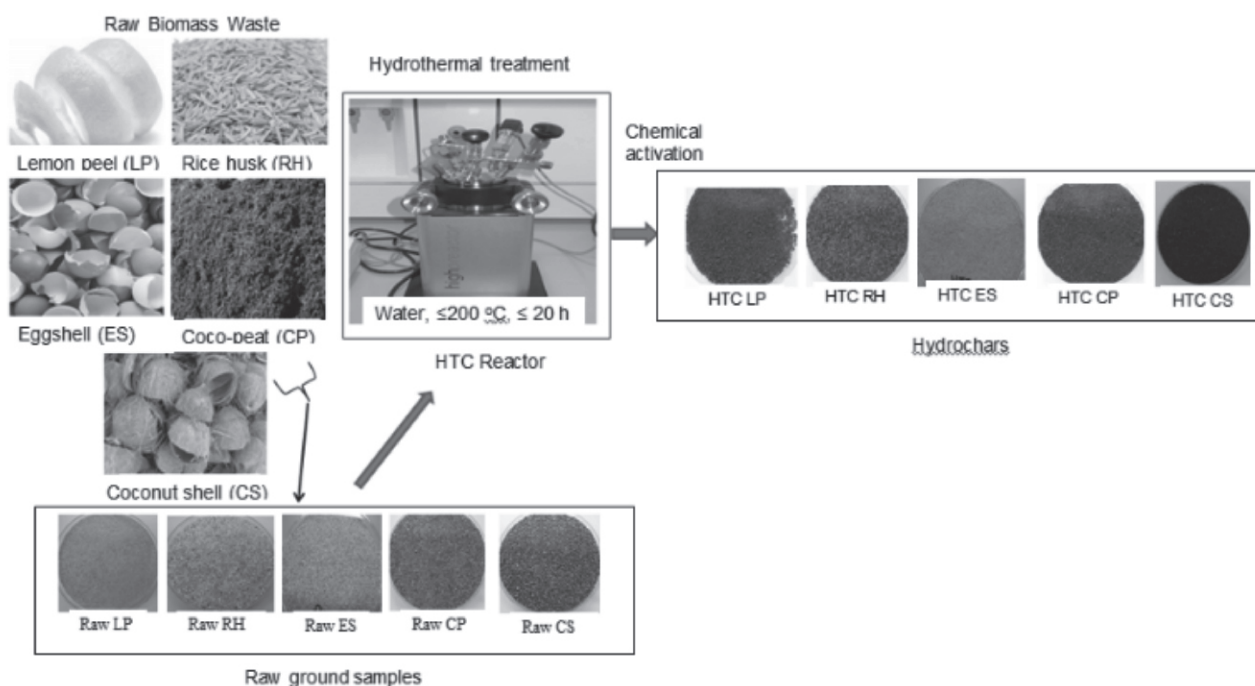


Figure 1: Graphical illustration of the hydrothermal carbonisation process

2.3 Experimental Measurements and Instrumentation

All glassware needed to carry out the batch experiments were washed with detergent, followed by addition of 10% of nitric acid and rinsed thoroughly with de-ionised water and dried. The **batch experiments were carried out** using 1.5 g of hydrochar in a conical flask followed by addition of 50 mL of de-ionised water. A baseline concentration of elements present in each hydrochar was analysed in order to quantify the inherent ions before been subjected to the aqueous solution.

2.4 Batch adsorption

Three batch experiments with synthetic wastewater were conducted in triplicates with corresponding control tests using clean water to establish the baseline concentration of inherent elements. The pH values used for the experiments ranges from 5 to 6 (*slightly acidic*), 9 and 11; while the contact time are 2, 4, and 6 h respectively.

2.5 Heavy metal removal efficiency

To evaluate the sorption ability of each adsorbent, the following equation was used.

$$R = \left[\frac{(C_i - C_f)}{C_i} \right] \times 100 \quad \dots\dots\dots (1)$$

Where:

- C_i = initial concentration (ppm)
- C_f = final concentration (ppm).
- R = adsorption efficiency (%)

2.6 Characterisation of adsorbents using BET, SEM/EDS and FTIR techniques

2.6.1 Determination of surface area using BET

Surface area, pore size and pore volume of each hydrochar were analysed using BET TriStar 3000, Micromeritics with the sample handler occupying an area of 10 – 20 m² set for about 1 - 2 h at temperature of 200 °C.

2.6.2 SEM/EDS

Characterisation of the hydrochar were carried out using SEM for surface morphology at varying

magnifications (100x, 250x, 1000x and 5000x). The EDS was to determine elemental composition in each of the hydrochar.

2.6.3 FTIR

The Fourier Transformed Infrared-Ray Spectrometry (FTIR) for all hydrochar (HTC-ES, HTC-CP, HTC-RH, HTC-LP and HTC-CS) are very essential, because it would enable the functional groups in each adsorbent to be determined.

3. Results and Discussions

3.1.1 Surface Characterisation of hydrochars

The results of surface characterisation for the SEM, EDS, BET and FTIR were for determination of surface morphology, elemental composition, surface area/pore size/pore volume and functional groups respectively. The changes observed on the fibrous and cellular appearance as well as hollow and stack type were shown on the SEM images was due to the thermal application. Details on this can be found via the following link <https://doi.org/10.1007/s42452-021-04273-5> (Danso-Boateng et al. 2021).

3.1.2 Effect of pH on metal adsorption by hydrochar

The preliminary results for the batch experiments are presented in Figures 5 – 9. Figure 5 (b), (c) and (e) shows very low adsorption of Cr^{6+} ions by hydrochar of eggshell (HTC-ES) and turn the samples colourless. This may be attributed to poor surface functionality of the HTC-ES for Cr ion due to speciation at all pH levels but progressive removal of Cu^{2+} , Fe^{2+} and Pb^{2+} as 95%, 98% and 97% respectively. Figure 6 is hydrochar of coco-peat (HTC-CP) which depicts adsorption of about 92% Cr, 94% Cu, 87% Fe and 95% Pb. Similarly, Figure 7 is hydrochar of rice hull (HTC-RH) shows good adsorption of Pb ions except for Cr, Cu and Fe, while Figure 8 represents hydrochar of lemon peel (HTC-LP), which demonstrate high affinity for removal of Cu^{2+} and Fe^{2+} by over 98%, Pb^{2+} was removed by 92% and Cr^{6+} by 73%. Finally, Figure 9 is hydrochar of coconut shell (HTC-CS) also shows 98% of Cu^{2+} , 99% Fe and 92% Pb, while only 73% Cr^{6+} were effectively removed by the adsorbent. This could be attributed to speciation and ion exchange between light metal Ca^{2+} contained in eggshell and heavy metals present in the wastewater. Some adsorbents attained optimum adsorption in weak acidic conditions, whereas most adsorption were achieved at slight alkaline (pH9) phase. Generally, the effectiveness of each sorption media was based on its ability to reduce the concentration of heavy metals in the wastewater by over 90% and also exhibit the potentials in decolourising the synthetic wastewater.

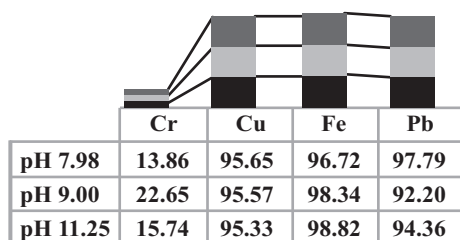


Figure 5: Amount of heavy metal ions adsorbed (%) by HTC-ES

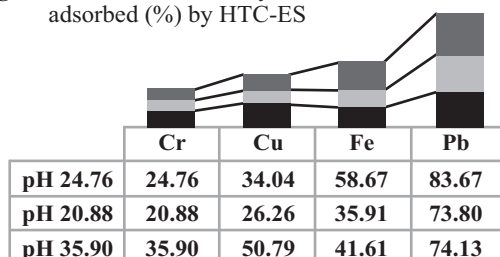


Figure 7: Amount of heavy metal ions adsorbed (%) by HTC-RH

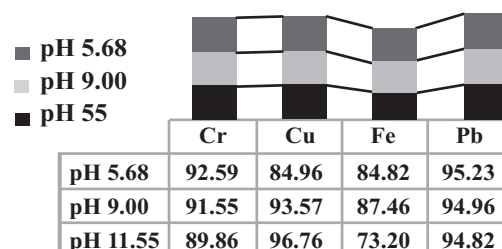


Figure 6: Amount of heavy metal ions adsorbed (%) by HTC-CP

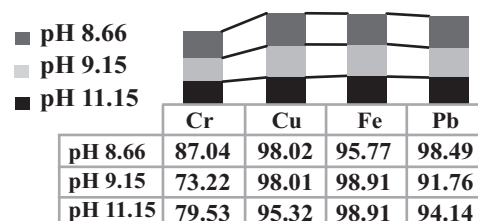


Figure 8: Amount of heavy metal ions adsorbed (%) by HTC-LP

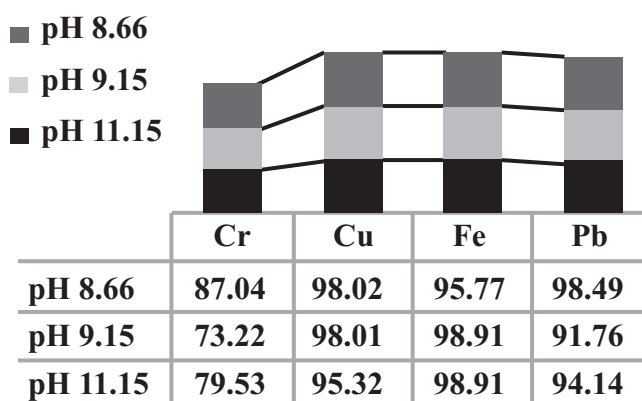


Figure 9: Amount of heavy metal ions adsorbed (%) by HTC-CS

3.1.3 Effect of contact time on adsorption

The amount of metal uptake per adsorbent is observed to increase with time to a point where it attained a constant value where there is no more adsorption any more. At this stage, the amount of metal ions adsorbed per adsorbent is in equilibrium state.

3.2 Discussions

The amount of metal adsorbed at equilibrium reflects the maximum sorption capacity of each adsorbent under specific operating conditions. Figures 6 – 9 illustrate rapid metal adsorption within the first 10 mins followed by a gradual increase up to 20 mins and remained almost constant. There is a trend in almost all the adsorbents whereby the results showed that the adsorption of metal ion increases with time up to 2 h. Figure 2 shows rapid removal of Cr^{6+} by HTC-CP HTC-LP and HTC-CS. However, HTC-ES did not perform well. The poor performance of ES may be due to the complex electrostatic cooperating effects and the bonding interactions to construct a stable linkage between the ES with the Cr^{6+} ions. The hydrochar of LP has demonstrated its ability to remove more Cr ions compared to raw biomass for the same experiments, indicating the presence organics in LP affects its sorption ability which has to be denatured during thermochemical reaction. Surprisingly, Figure 6 shows that 100% of Fe^{2+} ions were completely adsorbed by HTC-ES after 120 mins to reach equilibrium. The removal of Pb^{2+} follows similar pattern for all the hydrochars.

4. CONCLUSIONS

The use of hydrochar as adsorbent for the removal of heavy metal ions from wastewater originating due textile and tannery hold a promise. The work presented in this research has set a roadmap for the development of a simple, affordable and effective wastewater purification process. This research has successfully explored the potentials of hydrochar produced from selected biomass wastes in reducing the concentration of heavy metals from simulated textile and tannery wastewater. Over 90% of Pb^{2+} and Cr^{6+} were removed by coco-peat; while 100% of Fe^{2+} and Cu^{2+} were delineated by eggshell; on the other hand, coconut shell performed excellently in decolourising the simulated wastewater. If this technique is adopted, implemented and efficiently utilised; it can significantly reduce human exposure to varying concentrations of heavy metal ions and other organics tenable through food chain. The farmers, consumers of farm produce, policymakers and other relevant stakeholders need to be adequately informed about the dangers of using untreated wastewater for crop irrigation. The use of hydrochars derived from biomass waste as potential adsorbents for micro-pollutants in wastewater treatment hold a promise. Based on the in-depth analysis of these hydrochars as adsorbents for micro-pollutants is recommended for real practical application of textile and tannery wastewater.

REFERENCES

- Adebayo, O. T., Balogun, A. M. and Olubiyi, O. A. (2007)** 'Chemical Analysis of some Industrial Effluents that discharge into Lagos Lagoon, Nigeria', *Research Journal of Environmental Sciences*, 1(4), pp. 196–199.
- Ademoroti, C. M. A., Ukponmwan, D. O. and Omode, A. A. (1992)** 'Studies of textile effluent discharges in Nigeria', *International Journal of Environmental Studies*, 39(4), pp. 291–296. doi: 10.1080/00207239208710704.
- Akan, J. C., Moses, E. A., Ogugbuaja, V. O. and Abah, J. (2007)** 'Assessment of Tannery Industrial Effluents from Kano State, Nigeria.pdf', *Journal of Applied Sciences*, 7(19), pp. 2788–2793.
- Akan, J. C., Abdulrahman, F. I., Ayodele, J. T. and Ogugbuaja, V. O. (2009)** 'Impact of tannery and textile effluent on the chemical characteristics of Challawa river, Kano state, Nigeria', *Electronic Journal of Environmental, Agricultural and Food Chemistry*, 8(10), pp. 1008–1032.
- APHA. (2012).** *Standard Methods for the Examination of Water and Wastewater.* (E. W. Rice, R. B. Baird, A. D. Eaton, & L. S. Clesceri, Eds.) (22nd ed.). Washington, DC: American Public Health Association, American Water Works Association, Water Environment Federation.
- Awomeso, J. A., Taiwo, A. M., Gbadebo, A. M. and Adenowo, J. A. (2010)** 'Studies on the pollution of water body by textile industry effluents in Lagos, Nigeria', *J. Appl. Sci. Environ.* 5(4), pp. 353–359. Available at: <http://trisanita.org/jases/asespaper2010/ases34v5n4y2010.pdf>.
- Chhikara, S. and Rana, L. (2013)** 'Physico-chemical Characterization of Textile Mill Effluent: A Case Study of Haryana, India', *International Journal of Science and Technology*, 8, pp. 19–23.
- Dan'Azumi, S. and Bichi, M. H. (2010)** 'Industrial Pollution and Heavy Metals Profile of Challawa River Kano, Nigeria', *Journal of Applied Sciences in Environmental Sanitation*, 5(56–62).
- Danso-Boateng, E., Shama, G., Wheatley, A. D., Martin, S. J. and Holdich, R. G. (2015)** 'Hydrothermal carbonisation of sewage sludge: Effect of process conditions on product characteristics and methane production', *Bioresour. Technol.* Elsevier Ltd, 177, pp. 318–327. doi: 10.1016/j.biortech.2014.11.096.
- Danso-Boateng, E., Mohammed, A. S., Sander, G., Wheatley, A. D., Nyktari, E. and Usen, I. C. (2021).** *Production and characterisation of adsorbents synthesised by hydrothermal carbonisation of biomass wastes.* Springer Nature (2021) 3:27. <https://doi.org/10.1007/s42452-021-04273-5>
- Das, M., Ahmed, K., Islam, S., Islam, M. and Akter, M. S. (2010)** 'Heavy Metal in Industrial Effluents (Tannery and Textile) and Adjacent Rivers of Dhaka City , Bangladesh', *Terrestrial and Aquatic Environmental Toxicology*, 5(1), pp. 8–13.
- Demirezen, D. and Aksoy, A. (2006)** 'Heavy metal levels in vegetables in Turkey are within safe limits for Cu, Zn, Ni and exceeded for Cd and Pb', *Journal of Food Quality*, 29(3), pp. 252–265. doi: 10.1111/j.1745-4557.2006.00072.x.

- Ensink, J. H. J. and Van Der Hoek, W. (2009)** 'Implementation of the WHO guidelines for the safe use of wastewater in Pakistan: Balancing risks and benefits', *Journal of Water and Health*, 7(3), pp. 464–468. doi: 10.2166/wh.2009.061.
- FAO/WHO (2006).** Guidelines for the Safe use of Wastewater, Excreta and Greywater 2: Wastewater Use in Agriculture. Geneva, Switzerland.
- Funke, A. and Ziegler, F. (2010)** 'Hydrothermal carbonisation of biomass: A summary and discussion of chemical mechanisms for process engineering', *Biofuel, Bioproducts and Biorefining*, 4, pp. 160–177. doi: 10.1002/bbb.198
- Halim, A. (2013)** 'Heavy Metals in Vegetables Irrigated with Wastewaters in Gaziantep, Turkey: A review of Causes and Potential for Human Health Risks Wastewaters in Gaziantep
- Holkar, C. R., Jadhav, A. J., Pinjari, D. V., Mahamuni, N. M. and Pandit, A. B. (2016)** 'A critical review on textile wastewater treatments: Possible approaches', *Journal of Environmental Management*. Elsevier Ltd, 182, pp. 351–366. doi: 10.1016/j.jenvman.2016.07.090.
- ICPE-Shimadzu-Corporation (2012)** 'Multitype ICP Emission Spectrometer ICPE-9000', C113-E012G, pp. 1–16.
- Islam, S., Islam, F., Bakar, M. A., Das, S. and Bhuiyan, H. R. (2013)** 'Heavy Metals Concentration at Different Tannery Wastewater Canal of Chittagong City in Bangladesh', *International Journal of Agriculture, Environment and Biotechnology*, 6(3), p. 355. doi: 10.5958/j.2230-732X.6.3.003.
- Jiménez, B., Drechsel, P., Koné, D., Bahri, A., Raschid-Sally, L. and Qadir, M. (2010)** 'Wastewater, sludge and excreta use in developing countries: an overview', *Wastewater Irrigation and Health: Assessing and Mitigating Risk in Low-Income Countries*. doi: 10.4324/9781849774666.
- Khan, K., Lu, Y., Khan, H., Ishtiaq, M., Khan, S., Waqas, M., Wei, L. and Wang, T. (2013)** 'Heavy metals in agricultural soils and crops and their health risks in Swat District, northern Pakistan', *Food and Chemical Toxicology*. Elsevier Ltd, 58, pp. 449–458. doi: 10.1016/j.fct.2013.05.014.
- Lacatușu, R., Rauța, C., Cârstea, S. and Ghelase, I. (1996)** 'Soil-plant-man relationships in heavy metal polluted areas in Romania', *Applied Geochemistry*, 11(1–2), pp. 105–107. doi: 10.1016/0883-2927(95)00101-8.
- Libra, J. A., Ro, K. S., Kammann, C., Funke, A., Berge, N., Neubauer, Y., Titirici, M., Fühner, C., Bens, O., Kern, J. and Emmerich, K. (2011)** 'Hydrothermal carbonisation of biomass residuals: A comparative review of the chemistry, processes and applications of wet and dry pyrolysis', *Biofuels*, 2(1), pp. 89–124.
- Mohammed, A.S. (2021).** Human Exposure to Carcinogens and Associated Health Risks: "My Concern and Contributions to Reducing Disease Burden in Nigeria". A Public Lecture delivered at the 1000 Seater Capacity Auditorium, Main Campus, Gidan Kwano, Federal University of Technology, Minna, Niger State on 18th November 2021.
- NBS (2010)** National Bureau of Statistics, Federal Republic of Nigeria. Abuja. Available at: <http://www.nigerianstat.gov.ng>.

- Randall, D. G., Zinn, C. and Lewis, A. E. (2014)** 'Treatment of textile wastewaters using Eutectic Freeze Crystallization', *Water Science and Technology*, pp. 736–741. doi: 10.2166/wst.2014.289.
- Sarker, B. C., Batten, A., Ul-Haque, E., Das, A. K., Hossain, A. and Hasan, Z. (2015)** 'Heavy Metals ' Concentration in Textile and Garments Industries ' Wastewater of Bhaluka Industrial Area , Mymensingh , Bangladesh', *Current World Environment*, 10(1), pp. 61–66. doi: 10.12944/CWE.10.1.07.
- Sorsa, S., Chibssa, Y., Tilahun, G. and Fitamo, D. (2015)** 'Heavy Metal Concentrations and Physicochemical Characteristics of Effluent along the Discharge Route from Hawassa Textile Factory, Ethiopia', *Journal of Environmental & Analytical Toxicology*, 5(4), pp. 1–7. doi: 10.4172/2161-0525.1000285.
- Titirici, M. M., Thomas, A., Yu, S. H., Muller, J. O. and Antonietti, M. (2007)** 'A direct synthesis of mesoporous carbons with bicontinuous pore morphology from crude plant material by hydrothermal carbonisation', *J. Chem. of Mater.*, 19(17), pp. 4205–4212. doi: 10.1021/cm0707408.

POTENTIAL NIGERIAN SEED OILS FOR ALKYDS PRODUCTION: A REVIEW

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ABSTRACT

Alkyds have been considered as vital raw materials useful for production of surface coatings in the paints industry. Currently, in the Nigerian paints industries, alkyds are obtained mainly by importation since the traditional vegetable oils for making alkyds are not really available. The influence of oil type is significant in the composition of alkyds and the alkyd resin properties. This work attempts to review some reports on locally available seed oils and their properties for application in alkyd resin production. The opportunities and challenges of adopting these indigenous seed oils for alkyd resin manufacture in Nigeria were summarized. More research towards the commercial production of indigenous seed oil and its adoption in the alkyds production will have a positive effect on the promotion of foreign exchange conservation..

Keywords: Alkyds, resins, paints, non-conventional vegetable oil, Nigeria

1. INTRODUCTION

Vegetable oils have been broadly applied as popular feedstock in the chemical industry (Awolola *et al.*, 2023; Ezema *et al.*, 2023; Selim *et al.*, 2022; Zhang *et al.*, 2017). Mitigation of the challenge of climate change is driving the consideration of green feedstocks like vegetable oils. They are widely used in various industries due to environmental concerns (Gao *et al.*, 2019; Awolola *et al.*, 2023). The increasing oil demand in the oleochemical industry has paved the way for investigating more of the indigenous seeds for oil production, especially when the conventional oil supply is limited

In many reports that span over two decades, myriads of investigations have indicated the physicochemical properties of non-conventional vegetable oil originating from the Nigerian flora. However, it has been observed that majority of these oils are not yet produced at commercial scale or utilized as industrial feedstock despite the fact that they have been recommended in earlier works and by various researchers (Akintayo *et al.*, 2020; Bora *et al.*, 2014; Essien *et al.*, 2012; Kolade *et al.*, 2019; Kyenge *et al.*, 2012; Mohammed *et al.*, 2023; Ogunniyi and Odetoye, 2008; Odetoye *et al.*, 2008; Odetoye *et al.*, 2010; Odetoye *et al.*, 2013; Okoli *et al.*, 2012). These indigenous seed oils have been found suitable as potential industrial feedstock in the oleochemical industries and precisely for alkyd resins processing.

One of the significant materials used in the constitution of paints and varnishes is alkyd resins. These alkyds have been described as polyesters which have been formed through the polymeric condensation of polyhydric alcohol, polybasic acid and monobasic fatty acids. Alkyd resin-based paints and varnishes are essential component in the decoration and protection of various surfaces (Mohammad *et al.*, 2023; Odetoye *et al.*, 2013; Uzoh *et al.*, 2018). They have found application as decorative finishes for various factory-made products. Alkyd paints are highly essential in the construction industry especially for finishing works in industrial and residential edifices.

Surface coatings consist mainly of pigments, solvents and binding agents. Alkyd resins have found wide application as the binder of choice in preparation of paints. Although, there are quite a number of

paints industries in Nigeria, this important binder is mainly sourced by importation because the potential indigenous seeds oils are still generally neglected, as they have not attained commercial status as feedstock for resin production. There is need to harness our indigenous seed oils for local production of alkyd resins. Hence, this work attempts to review some reports on locally available seed oils and their properties for potential application in alkyd resin production.

2. SEED OILS AS SIGNIFICANT FEEDSTOCK FOR ALKYDS PRODUCTION

The exploitation of suitable conventional oils such as soybean as industrial feedstock has led to increased demand with attendant rising prices while, varieties of our indigenous Nigerian seed oils not adequately harnessed as industrial feedstock. Intentional efforts are to be directed towards the replacement of oils that are serving dual purposes for food and raw material for oleochemical industries with non-edible oils. This is more pertinent in a well-populated developing country like Nigeria so as ease the problem of food shortage.

Vegetable oils have unique chemical structure that favour modification to other desired industrial products with the hydroxyls and unsaturated bonds yielding epoxies, esters owing to the functional units. Vegetable oils are important in the production of oil-based polymeric alkyds, since vegetable oils are environmentally friendly. It is a basic feedstock for the production of alkyd nanocomposites, alkyd-epoxy blends, water reducible and hyperbranched alkyds and some polymeric nanomaterials (Selim *et al.*, 2022).

The main reactants for producing alkyd resins are polyhydric alcohols, polybasic acids and monobasic fatty acids. Seed oils are the sources of the fatty acids which act as monobasic moieties in the composition. Fatty acids may constitute about 70% of the feedstock based on the alkyd resin type (Awolola *et al.*, 2023). The role of the oil as a constituent in the alkyd feedstock is to act as a modifier, imparting flexibility, drying characteristics and hardness of films on the resulting alkyds.

These vegetable oils and fats are mainly triglycerides while triglycerides are the glyceryl esters of long chain fatty acids (Zhang *et al.*, 2017). Most oleochemical reactions are established on chemical modification of either or both the carboxyl and unsaturated groups of the fatty acids. For alkyds synthesis, the polycondensation reaction occurs at the carboxylic ends. However, unsaturated groups on the fatty acids alkyl chains are quite responsible for the drying characteristics, experienced when it is applied on surfaces (Odetoye *et al.*, 2013).

3. SELECTION OF VEGETABLE OILS AS ALKYD RESIN FEEDSTOCK

In the selection of seed oil as feedstock for alkyd resin production, the product specification for the resulting alkyd has to be borne in mind. This is an important consideration since oil selected for production will heavily impart the properties of the alkyds.

Some of the mainly desired characteristics are drying rate, gloss retention and color retention. Figure 1 indicates the oil-modified glycerol-phthalate structure of a typical oil-based alkyd resin, parinari oil-based alkyd (Odetoye *et al.*, 2013). Various properties are imparted by the fatty acid moiety of the oil. The drying rate and the loss retention properties increase with higher degree of unsaturation in the oil while the colour durability decreases with higher iodine value.

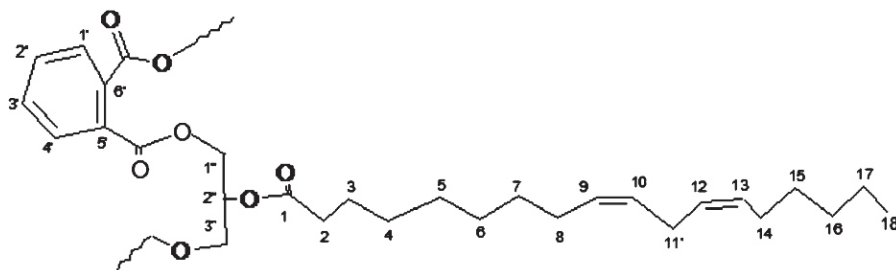


Figure 1: Structure of a typical oil-modified alkyd resin (Odetoye *et al.*, 2013)

1.1. Iodine values of seed oils

The iodine value is stated as the number of grams of iodine absorbed by 100 grams of the oil (Zhang et al., 2022). It is a major consideration in the selection of oil for alkyd resin preparation. This is because iodine value corresponds to higher level of unsaturation which is indicative of the drying property of the oil, a property that will eventually be imparted on the resulting alkyds.

Based on the iodine value and subsequent film-forming attributes, seed oils have been categorized into three main classes; non-drying (iodine value that is less than 90), semi-drying (iodine value within the range of 90 – 130) and drying (iodine value that is above 130). A good drying oil has a high iodine value of about 150. Eleostearic, linoleic, linolenic and oleic, acids are the major conjugated fatty acids associated with such drying oils.

1.2. Classes of alkyds

The kind and quantity of selected seed oil used for alkyd production will determine the class of alkyds to be produced (Awolola et al., 2023). Alkyds can be produced as drying oil-based alkyds or non-drying oil based alkyds depending on the type of seed oil selected for production. However, semi-drying and drying oils are more popularly used in the production of drying alkyds. The drying alkyds have desirable film-forming characteristics which are displayed by the polymerization of film due to oxygen available in air at room temperature. Non-drying alkyds have found application as blending agents (Odetoye et al., 2012).

When oil content is considered, the main classes of alkyds are short oil (35%), medium oil (40-55%) oil, long oil (56-70%) and extra-long oil alkyds (greater than 70%).

4. NIGERIAN SEED OILS AS SUITABLE FEEDSTOCK FOR ALKYDS SYNTHESIS

In order to conserve the foreign exchange reserves, there is a need to make more alkyd resins locally with our indigenous seed oil and provide the feedstock for the paints industry. Available seed oil such as soya should get replacement from other non-edible oils. There is a need to give more attention to other non-conventional oils, especially semi-drying and drying seed oils and develop them as source feedstock in commercial quantities.

4.1. Some conventional seed oils for alkyds synthesis

The utilization of oil depends mainly on its characteristics which are determined by its composition (Usman et al., 2009). The conventional oil used for alkyd resins in the industry today is based on the fatty acid composition of the semi-drying and drying oils.

The popular oils for alkyd resin production have been soya, safflower, linseed and dehydrated castor oil. However, while linseed oil is primarily grown in temperate regions of the world, using soya oil as industrial feedstock strains the food supplies.

4.2. Some indigenous Nigerian seed oils

Some indigenous Nigerian seed oils that have been recommended as alkyds feedstock in various earlier works as shown in Table 1. Cassava seed oil was recommended for alkyds synthesis because it is a semi-drying oil (Popoola, 2009). It predominantly consists of linoleic fatty acids (47%). The level of unsaturation indicated by the iodine value, 141gI₂/100g, presents the oil as a good substitute to conventional oils. Its desirable oxidative stability and peroxide value are quite of good advantage for storage purpose.

Table 1: Physiochemical properties of some indigenous semidrying and non-drying oils

S/No.	Seed oil	Oil yield%	Iodine value (g I ₂ per 100 g)	Acid value (mg/KOH)	Saponification Value (mg/KOH)	Peroxide Value (mequiv/kg)	Refractive index	Viscosity (cP)	Sources
1	Adenophous breviflorus	56.3	112.1	-	-	-	1.472	-	(Akintayo et al., 2020)
2	Blighia sapida	47	116.5	4.914	252	9.44	1.449	-	(Tsado et al., 2020)
3	Canarium schweinfurtii	45.3	67.3 - 114.3	20.0	155	19	1.46	-	(Mohammad et al., 2023)
4	Cassava seeds	25.2	90 -141	7.8	7	<6.3	1444	-	(Poopola,2009)
5	Cucumeropsis mannii (Melon seed oil)	40.8 -57.3	111.1	7.1	192.03.	2.6	1.46	53.0m ² /s	(Ezema et al., 2023)
6	Grape seed	10-20	124-143	2.2	-	2.2	-	37.3 40 oC (cSt)	
7	Jatropha	46.8	99.8	2.8	277.8	-	1.433	21.7	(Odetoye et al., 2014)
8	Monodora myristica	52.0	177.5	16.3	74.3	-	-	-	
9	Tobacco seed	35.0	139	26.4	212.	-	-	-	Odetoye et al., 2008
10	Parinari polyandra	59.1	168.5	2.2	215.3	-	1.4644	48.4	Odetoye and Udoh et al., 2023
11	Parkia biglobosa (African locust bean)	26.5	104	4.37	176	-	-	-	(Odetoye,2009)
12	Plukenetia conophora	49.6	204.5	11.6	92.2	-	1.484	-	Odetoye et al., 2008
13	Pterocarpus santalinoides	7.9	106	-	-	<6.3	-	-	
14	Sandbox tree (Huracrepitan)	53.6	177	27	246	3.8	1.4683 (30 oC)	-	
15	Sclerocarya- birrea	11	100.3	33.7	162.7	-	1.46	-	(Odetoye et al., 2013)
16	Sesamum indicum L.	48	103	0.5	189	8	-	-	(Awolola, 2013)
17	Terminalia catappa L	56.3	82.4	0.5	207	0.1	-	32 (38oC)	Odetoye et al., 2013)
18	Thevetia nerifolia	67.5	92	4.8	123.42	4.12	1.464	22.45	(Odetoye et al., 2008)
19	Thevetia peruviana	63.4	79.4	-	123.3	3.4	1.461	20.1	(Akintayo et al., 2020)
20	African Breadfruit	20.8	111.9	13.4	146.4	-	-	-	(Odetoye et al., 2008)

Additionally, sandbox tree seed oil (*Hura crepitans*), was found to be suitable as a substitute for conventional drying oils in alkyds synthesis (Okoli *et al.*, 2012). Its high degree of unsaturation (66.5%) was indicated by the relatively high iodine number of 177gI₂/100g. The oil consists of 63.2% oleic acid as the predominant fatty acid. The percentage oil yield of 53.6% is of utmost advantage towards its adoption as industrial feedstock.

Melon seed oil (Essien *et al.*, 2012) having 62% linoleic acid, possess a higher level of unsaturation. This property makes it appropriate for alkyds synthesis. Since, it is a food condiment; its industrial application may compete with food source. It can also serve as feedstock for metallic driers used in paint formulations (Essien *et al.*, 2012). Likewise, conophor seed oil plant (African walnut), was found suitable for alkyds synthesis. Conophor oil has been found to give alkyd based paints desirable characteristics when applied on surfaces. (Asiagwu *et al.*, 2008).

Thevetia peruviana oil is prospective oil associated with high oil yield in the range of 61 - 64% (Usman *et al.*, 2012). It is a semi-drying oil found suitable for alkyds synthesis. Furthermore,, *Thevetia nerifolia* seed oil having a yield of 67.5% (Kyenget *et al.*, 2012) has been found suitable for the synthesis of non-drying alkyd resins.

Parinari polyandra Benth seed oil (Odetoeye *et al.*, 2013) has been found appropriate for four types of alkyd resins, 35%, 50%, 60% and 75% oil lengths. The parinari alkyds displayed similar characteristics compared to commercial standards, when formulated into white gloss paints with 20.67% pigment-volume concentration. They exhibited similar drying characteristics, water and acid resistances, solubility.

5. POTENTIAL EXPLOITATION OF INDIGENOUS SEED OILS FOR ALKYDS PRODUCTION

There are various reports on the utilization of some indigenous oils for the production of alkyd resins. African locust bean seed oil was reported by Aigbodion and Okiemen, 2001. Three grades of alkyds comprising of 27%, 50% and 60% oil were synthesized. The semi-drying oil was extracted and used to prepare reacting with phthalic anhydride and glycerol employing the alcoholysis method. The kinetic studies show that the initial stages of the reaction followed a second-order rate law while the latter stage featured deviation. The second-order rate constants for the linear portion were 6.05×10^{-5} , 10.51×10^{-5} and $5.98 \times 10^{-5} \text{ g(mg KOH)}^{-1} \text{ min}^{-1}$ for samples containing 27%, 50% and 60% oil respectively. The extent of reaction determined ranged from 57.9% – 63.5%. The average degree of polymerization ranged between 2 and 3.

Likewise, tobacco seed oil alkyds were investigated by Ogunniyi and Odetoeye, 2008. The oil was extracted, characterized and subsequently used for the synthesis of short (35%), medium (50%), long (60%) and extra-long (80%) oil alkyd resins. The alkyds were characterized by IR spectroscopic methods. The physico-chemical properties, such as drying times, viscosity, colour, solubility, thickness of film were also evaluated. The alkyds were formulated into white gloss paints which exhibited good drying characteristics when compared with commercial standards. Other workers also reported the suitability of *Jatropha curcas* seed oil for alkyd resin production.

Akintayo and Adebawale (2012) synthesized chlorinated medium oil alkyds using *Albizia benthamiana* seed oil. Medium oil alkyds were synthesized using the seed oil, phthalic anhydride, pentaerythritol and glycerol. The chlorinated alkyds were synthesized by direct chlorination. It was confirmed from IR spectroscopy that chlorine enters only into the aliphatic portion of the alkyd chain by addition and substitution reactions. The mechanical and chemical film properties of the unchlorinated and chlorinated *Albizia benthamiana* oil alkyd were determined. The results revealed that the chlorinated resins

possessed superior drying properties, scratch hardness and water, acid and alkali resistances than the unchlorinated alkyds. While the impact resistance of the Albizia benth oil alkyd remained satisfactory, the flexibility and adhesion decreased on chlorination.

The uses of Plukenetia conophora and Adenopus breviflorus seed oils for the production of alkyd resins have been suggested (Akintayo and Bayer, 2002). The analyses of the two non-conventional tropical seeds revealed that they possess high iodine values due to their high unsaturated acid contents. Plukenetia conophora seed oil had 98.8% unsaturated fatty acids with linolenic acid (70.1%) predominating, indicating an iodine value of 204.5 while Adenopus breviflorus seed oil had 85.1% unsaturated fatty acid with linoleic acid (65.3%) being most abundant.

Similarly, the production of alkyd resins from dehydrated castor oil having an iodine number of 132.93 was described (Ogunniyi and Njikang, 2000). The main raw materials used were dehydrated castor oil and phthalic anhydride. The alkyds were reported to have good gloss retention and drying performances. Alkyd resins were also obtained from the seed oils of Canarium schweinfurtii, Vitex doniana and Xylopia aethiopica seed oils using an alcoholysis method. The iodine values of the seed oils were 114.3, 114.4 and 115.5 respectively.

Okieimen and Aigbodion, 2001 investigated rubber seeds oil as alkyds feedstock. Solubility properties were found to depend on the molecular weight and polarity of the alkyds and solvent. Samples of 40%, 50% and 60% oil length alkyd resins were also prepared from rubber seed oil (Aigbodion and Pillai, 2001), phthalic anhydride and glycerol. Molecular weight averages and the molecular weight distribution of the finished alkyds were determined by GPC, cryoscopy and end-group analysis. It was reported that the narrower the size distribution, the better the quantity of the alkyd.

6. OPPORTUNITIES AND CHALLENGES OF ADOPTING INDIGENOUS SEED OILS OR ALKYD RESINS SYNTHESIS

6.1 Opportunities

- i. More jobs will be created especially for seed farmers.
- ii. Development will be experienced in the Nigerian oleochemicals and paints industries.
- iii. Production of alkyds from seed oils enhances environmental friendliness.
- iv. Reduction in alkyd resin importation will boost the Nigerian economy and strengthen the currency.

6.2 Challenges

- i. There is lack of organized, adequate information and data base on the production of indigenous seed oils in Nigeria.
- ii. Majority of these potential oilseeds are not readily available in the markets.
- iii. There is dearth of information on the profitability of utilizing these indigenous oils.

7. RECOMMENDATIONS

- i. Additional research work on non-conventional feedstock should be conducted towards establishing new indigenous feedstocks for oleochemical industry. Process development from bench to commercial stage should be embarked on.
- ii. The government and private bodies in Nigeria should direct concerted efforts towards indigenous alkyds production.
- iii. The Federal Ministry of Agriculture, Federal Ministry of Science and Technology and other relevant government establishments are encouraged to invest into plantation cultivation of these

- potential oilseeds in commercial quantities.
- iv. Relevant regulatory body should be established to monitor and regulate the role of harnessing indigenous oilseeds, providing information and recommending them for suitable industrial purposes.
 - v. Exploitation of these indigenous oils should be done to conserve Nigerian foreign exchange in the importation and production of alkyd resins which are based mainly on foreign seed oils.
 - vi. More consideration should be directed towards harnessing indigenous seed oils as cash crops for international markets

8. CONCLUSION

Many indigenous Nigerian seed oils have not been well-harnessed despite the fact that they are well-researched and found suited for alkyd synthesis. There is a need to develop the sources of these non-conventional oils into commercial scales so as to meet the increasing oil demands and enlarge the existing supplies of vegetable oil. Adopting these seed oils for industrial utilization especially for alkyd preparation will go a long way to conserve the plunging Nigerian foreign exchange reserve.

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REFERENCES

- Aigbodion A. I. and Pillai C. K. (2001).** Synthesis and Molecular Weight Characterization of Rubber Seed Oil Modified Alkyd Resins. *Journal of Applied Polymer Science*. 79: 2431-2438.
- Aigbodion A.I. and Okieimen F.E. (2001).** An Investigation on the Utilization of African Locust Bean Seed oil in the Preparation of Alkyd Resins. *Industrial Crop and Products*. 13: 29 – 34.
- Akanni M.S., Adekunle A.S. and Oluyemi, E.A. (2005).** Physicochemical Properties of Some Non-conventional Oilseeds. *Journal of Food Technology*. 3(2):117-181.
- Akintayo C.O. and Adebowale K.O. (2004)** Synthesis, Characterization and Evaluation of Chlorinated *Albizia benth* Medium Oil Alkyds, *Progress in Organic Coatings*. 50: 138 – 143.
- Akintayo C.O., Akintayo C.O., Oluwaleye I.O., Ajaja O. and Beuermann S. (2020).** Synthesis and Characterization of Azidated *Adenopus breviflorus* benth Seeds Oil, *Green Chemistry Letters and Reviews*, 13(2)117-128.
- Akintayo, E.T. (2020)** Characteristics and composition of *Parkia biglobossa* and *Jatropha curcas* oils and cakes, *Bioresource Technology*, 92: 307-310
- Akintayo, E.T. and Bayer, E. (2002).** Characterisation and Some Possible Uses of *Plukenetia conophora* and *Adenopus breviflorus* Seeds and Seeds Oils. *Bioresource Technology*. 85: 95-97
- Asiagwu A.K., Omuku P.E., Okoye P.A.C., Olisa M.A. and Ajiwe V.C.E. (2008)** Evaluation of the Suitability of Conophor oil for the Production of Alkyd Resins and Surface Coatings. *Oriental*

Journal of Chemistry. 24(2):405-408

- Awolola, G.V., Francis, P.U. and Odetoye, T.E. (2023)** Synthesis of alkyd resins from black sesame (*Sesamum radiatum*) seed oil, FUOYE Journal of Engineering and Technology, 8(2) 223-227.
- Bora M.M., Gogoi P., Deka D.C. and Kakati, D.K.(2014).** Synthesis and characterization of yellow oleander (*Thevetia peruviana*) seed oil-based alkyd resin. **Industrial Crops and Products.** 52: 721-728.
- Essien E. A., Umoren S. A., Essien E. E., Udoh A. P. (2012)** Preparation and Evaluation of *Cucumeropsis mannii* Naud. Seed Oil Metallic Soaps as Driers in Gloss Paint. *J. Mater. Environ. Sci.* 3 (3) 477-484.
- Ezeagu, F.E., Petzke, K.J., Lange, E and Metges C.C. (1998).** Fat content and fatty acid composition of oils extracted from selected wild-gathered tropical plant seeds from Nigeria. *JAOCS.* 75 (8), 1031-1035
- Ezema O.B., Omeje K.O., Ozioko J.N., Fenadez-Castane A. and Eze S.O. (2023)** Biodiesel potential of *Cucumeropsis mannii* seed oil: A neglected and underutilized resource in Nigeria, *Heliyon*, 9(6)e16799.
- Gao S., Tang G., Hua D., Xiong R., Han J., Jiang S., Han J., Jiang S., Zhang Q., Huang C. (2019)** Stimuli-responsive bio-based polymeric systems and their applications. *J. Mater. Chem. B*, 7: 709-729.
- Ibiyemi S.A., Fadipe V.O., Akinremi O.O., Bako S.S. (2002).** Variation in oil composition of *Thevetia peruviana* Juss (Yellow Oleander) fruits seeds, *J. Appl. Sci. Environ. Mgt. (JASEM)*. 6 (2): 61–65.
- Kolade, B.T., Egwim E.C. and K.O. Shittu (2019)** Physicochemical properties of oil extracted from selected underutilized oil seeds, *The international Journal of Science and Technoledge* 7, 89-94.
- Kyenge B. A., Anhwange B. A., Ageh J. T., Igbum G. O. (2012)** Comparative Analysis of Soybean Seed Oil modified Alkyd Resin and Epoxidized Soybean Seed Oil modified Alkyd Resin, *International Journal of Modern Organic Chemistry.* 1(2): 66-71.
- Kyenge B.A. Ageh J.T., Anhwange B.A. and Nyiatagher D.T. (2012).** Synthesis and Characterization of Vegetable Oil-Based Polyol from (*Thevetia Nerifolia*) Seed Oil
- Liang D., Zhang Q., Zhang W., Liu L., Liang H., Quirino R.L. (2019)** Tunable thermo-physical performance of castor oil-based polyurethanes with tailored release of coated fertilizers *J. Clean. Prod.* 210:1207-1215
- Muhammad H.S., Agada R., Ogaji I.J. and Ngwuluka N.C. (2023)** Physicochemical Characterization and Fatty Acids Compositions of Four Indigenous Plant Oils, *Scientific African*, 220 e01669.
- Odetoye T.E., Ogunniyi, D.S., and Olatunji G.A. (2008).** Preparation and evaluation of tobacco seed oil-modified alkyd resins. *Bioresource Technology.* 99: 1300-1304.

- Odetoye T.E, Ogunniyi, D.S. and Olatunji, G.A. (2013)** Studies on the Preparation of Parinari polyandra Benth seed oil alkyd resins, *Journal of Applied Polymer Science*. 127 (6): 4610–4616.
- Odetoye T.E. & Udoh A.J. (2022):** Parinari as a potential bio-based feedstock: A Review. *FUW Trends in Science and Technology Journal* 7 (1); 233-238.
- Odetoye T.E., Ogunniyi D.S. and Olatunji G.A. (2008).** Vegetable Oils as Industrial Raw Material. Proceedings of the First Kwara Chapter Conference of the Chemical Society of Nigeria (CSN), Ilorin, Nigeria, 74-79
- Odetoye, T.E., Ogunniyi, D.S. & Olatunji, G.A. (2010):** Preparation and evaluation of *Jatropha curcas* Linneaus seed oil alkyd resins. *Industrial Crops and Products*. 32 (3); 225 – 230.
- Odetoye, T.E , Ogunniyi, D.S. and Olatunji, G.A. (2012).** Improving *Jatropha curcas* Linneaus Seed Oil Alkyd Resins. *Progress in Organic Coatings*. 73 (4): 374–381.
- Ogbobe, O. 1992.** Physico-chemical composition and characteristics of the seed and seed oil of *Sclerocarya birrea*
- Ogunniyi D.S. 2006.** Castor oil: a vital industrial raw material, *Bioresource Technology*. 97: 1086-1091.
- Ogunniyi, D.S., and Odetoye T.E. (2008)** Preparation and Evaluation of Tobacco Seed Oil-Modified Alkyd Resins, *Bioresource Technology*. 99: 1300-1304.
- Ogunniyi, D.S., Njikang, G.N., (2000).** Preparation And Evaluation of Alkyd Resins from Castor Oil. *Pak. J., Sci. Ind. Res.* 42, 378-380.
- Okiemen F.E. and Aigbodion A.I. (1997).** Estimation of Dilute Solution Viscosity Parameter of Rubber Seed Oil Alkyds, Symposium on the Technology and End Uses of Natural Rubber, Institute of Rubber Research, Beruwela(U.K), p113 – 118.
- Okolie, P.N., Uaboi-Egbenni, P.O., Ajekwene A.E. 2012.** Extraction and quality evaluation of sandbox tree seed (*Huracrepitan*) oil
- Olatunji, G.A, Ogunleye, A.J. and Lawani, S.A. (1996)** Studies on the seed oil of *Parinari polyandra Benth*, Proximate Chemical Composition. *N. J.Sc.* 177-179
- Onyeike, E.N. and Acheru, G.N. (2002).** Chemical Composition of Selected Nigerian Oil Seeds and Physico Chemical Properties of the Oil Extracts, *Food Chemistry* 27: 431-437
- Otabo G.O, Ifijen I.H., Mohammed F.U. , Aigbodion A.I., Ikhuori E.U. (2019)** Alkyd resin from rubber seed oil/linseed oil blend: A comparative study of the physiochemical properties, *Heliyon* 5 (5): e01621
- Popoola, S.A. (2009).** Studies on Seeds, Seed Oils and Alkyd Resins Derivatives of *Pterocarpus santalinoides* and *Manilhot esculenta*, M.Sc. dissertation submitted to the Department of Chemistry, University of Agriculture, Abeokuta, Nigeria. p iv-v, Unpublished.
- Selim M.S., El-Safty S.A., Shenashen, M.A. Higazy S.A. and Hashem A.I. (2022)** Vegetable Oil



–Based Biodegradable Alkyd Materials for Ecofriendly Coatings Applications. In: Ali G.A.M., Makhlouf A.S.H. (eds) Handbook of Biodegradable Materials, Springer Nature, Switzerland, p 1-35.

Tsado D.B., Ndamitso M.M. and Ajai, A.I.(2020) Determination of physicochemical properties and fatty acid profile of *Blighia sapida* fruit from selected areas in Niger State, Nigeria, , Nigerian Journal of Chemical Research, 23(1), 21-34.

Usman L.A., Oluwaniyi O.O., Ibiyemi, S.A., Muhammad, N.O. and Ameen O.M. (2009). The Potential of Oleander (*Thevetia peruviana*) in African Agricultural and Industrial Development: a Case Study of Nigeria Journal of Applied Biosciences 24: 1477 – 1487.

Uzoh C.F., Obodo N.J., Onukwuli O.D. (2018) Exploring the effect of styrene and anhydride ratio on the coating properties of non-drying vegetable oil based alkyd resin J. King Saud Univ. – Eng. Sci. 30: 12-21

Zhang C., Garrison T.F., Madbouly S.A., Kessler M.R. (2017) Recent advances in vegetable oil-based polymers and their composites, Prog. Polym. Sci. 71 (2017): 91-143.



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