Chemistry Research Journal, **2018, 3(2):42-48**

Available online www.chemrj.org

Research Article

ISSN: 2455-8990
CODEN(USA): CRJHA5

Comparative Evaluation of *Luffa aegyptiaca* Seed Oil as Insulating Oil in the Nigerian Power Sector

Mustapha AB*, Ekanem EO, Kolo AM

Department of chemistry, Faculty of science, Abubakar Tafawa-Balewa University Bauchi, Nigeria

Abstract United Nations Environmental Programme (UNEP), 2002, observed that mineral insulation oil used in medium voltage equipments contain myriad of problems, with regard to ecological and environmental factors. In line with the myriad of problems associated with mineral transformer/capacitor oil, this research is intended to evaluate the possibility of substituting these mineral oil or Polychlorinated biphenyls (PCBs) containing oils with environmentally friendly ester oils. Percentage yield of the LASO on dry matter bases was 29.15 % of the ground seed. The results of physiochemical properties for the LASO; MIO are; colour, yellowish green;yellow, moisture content, 4.17;3.90 %, cloud point, 5;-10 ^{0}C, pour point, 10/-2^{0}C, density @20 ^{0}C, 0.91;0.90 g/cm^3, viscosity @40 ^{0}C, 10.50;7.57 mm^2/s, at 100 ^{0}C, 4.10;2.40 mm^2/s, specific gravity, 0.88;0.90 J/ kg°C and the corrosive Sulphur test, Negative; Positive. The electrical properties are; dielectric breakdown voltage (DBV), 42.5;40 kV, Shelf-life analysis (SLA) in case of leakage shows a decrease in LASO DBV, relative permittivity/dielectric constant, 2.75;2.74. The health safety and environmental properties, smoke point, 220;145 ^{o}C, flash point, 231;195^{o}C, fire point, 250;200 ^{o}C. The mean results were compared (α=0.05) which shows that the LASO can replace the MIO or even work better but with a lower shelf life as compared to MIO.

Keywords Polychlorinated biphenyls, shelf-life, resistivity, impregnation, Nano-fluids

Introduction

Electromagnetic devices like transformers heat up during operation because of resistive losses in their electrical and magnetic components [2]. This heat is absorbed by the conventional mineral Insulation oil (MIO), thereby cooling the device [4]. MIO was first introduced in 1892 by General Electric as a dielectric coolant in transformer and capacitor. The use of this mineral oils have been described by United State patent (patent number 8,741,187 B2) as having drawbacks with regard to ecological factors although they have good dielectric properties. In recent years, so many studies have been carried out to find an alternative source of environmentally friendly capacitor and transformer oils [17].

The oils used in transformer and capacitor for cooling, impregnation and insulation in Nigeria is mineral transformer oil; alone or mixed with polychlorinated biphenyls (PCB). MIO used in this research are PCB free. MIOs are hydrocarbons derived from crude oil. They are mixtures of aromatics, paraffins, napthenes and olefins. The decomposition of these mineral insulating oils in transformers produces gases that are harmful to the environment [6 and 18]. In transformer (medium voltage equipment), International Electro-Technical Commission (IEC) described that MIO serve as dielectric insulator cooling agents, carbonization reducers and flame quenchers [13].The gases generated include hydrogen (H_2), methane (CH_4), ethane (C_2H_6), ethylene (C_2H_4), acetylene (C_2H_2), carbon dioxide (CO_2) and carbon monoxide (CO) [6].

Nano fluids are also use as additives to mineral oil based transformer oil to improve the thermal and insulation capabilities of these mineral oils. Nano fluidis a fluid containing nanometer-sized particles, called nanoparticles. These oils are engineered colloidal suspensions of nanoparticles in a base fluid [3]. Nano fluids are produce by several techniques that include, Direct Evaporation, Gas condensation/dispersion, Chemical vapour condensation and Chemical precipitation [16]. Several liquids including water, ethylene glycol, and oils have been use as base fluids [13]. Although stabilization can be a challenge, on-going research indicates that it is possible [16]. Nano-materials used so far in Nano fluid synthesis include metallic particles, oxide particles, carbon nanotubes, graphene nano-flakes and ceramic particles [16]. Nano fluids are of three kinds of nanoparticles with distinct conductivities, namely, nonconductive nanoparticle Al_2O_3, conductive nanoparticle Fe_3O_4, and semi conductive nanoparticle TiO_2 [16].

Nano fluids are primarily used as coolants in heat transfer equipment such as heat exchangers, electronic cooling system (such as flat plate) and radiators, due to their enhanced thermal properties [8].

Table 1 below shows the IEC 2013 standard value for transformer oil/capacitor oil obtained for the Standard Organization of Nigeria (SON), Bauchi unit. The standards were used to compare the result of MIO used in this research and the threshold value.

Table 1: IEC 2013 standard values for transformer oil/capacitor oil and low temperature switchgears [8]

Property	Threshold level/Standard
Appearance/colour	Clear
Turbidity	Free from sediment and suspended matter
Pour point	Max. -40^{0}C
Moisture content	Max. 30 mg/kg c/ 40 mg/kg
Density at 20^{0}C	Max. 0.895 g/cm^3
Flash point	Min. 135 °C
Corrosive sulfur	Not corrosive
Acidity	Max. 0.01 mg KOH/g
Breakdown voltage	Min. 30 kV
Viscosity at 40 ^{o}C	Max. 50 mm^2/s
Viscosity at 100 ^{o}C	Max. 15 mm^2/s

ISO = International Standard Organization, IEC = International Electrochemical Commission, BS= British Standard DIN=Deutsches Institut fur Normung Germany, SON= Standards Organization of Nigeria, NIS= Nigeria Industrial Standard

Luffa agyptiaca plant is found climbing walls of many building within the Bauchi metropolis. It is an annual plant that grows and a fewer percentage is used while the rest decayed without any potential within the metropolis. The basic uses of the plant within the metropolis is as a sponge, were the seeds are removed and thrown away without any potential. *Luffa agyptiaca* seed oil-modified alkyd resin with 40% and 50% oil length were found to be resistant to Brine and Water with little resistance to Alkali.

Table 2: Sulphur and Sulphur Compounds Found in Crude Oil [19]

Group	Chemical Formula	Reactivity
Elemental (Free) Sulphur	S	Very Reactive
Mercaptans (thiols)	R-SH	Very Reactive
Sulfides (thio-ethers)	R-S-R1	Reactive
Disulfides	R-S•S-R	Stable
Thiophenes	Five-membered ring containing sulfur	Very Stable

R= paraffin with straight or branched chain hydrocarbon or cyclic hydrocarbon

Presence of corrosive Sulphur can cause transformers to prematurely fail. Specifically, Dibenzyl Disulfide (DBDS) is a sulfur compound known to react with the copper in the windings of transformer, creating byproducts that attack the insulation. Eventually, the transformer may fail. The table 2 above shows the chemical formula and reactivity of Sulphur.

Materials and Methods

The result *Luffa agyptiaca* seed oil used for this research were adopted from [14].

Characterization of the oil

Standard methods were used to determine the physiochemical, electrical properties of the oil.

Dielectric breakdown voltage (DBV) determination

In the determination of DBV, 250 ml of the sample was pour into a sample application container of Megger transformer oil tester (MODEL: OTS60PB, Edition 4.4) and the instrument was set to 'BS148:1984' with a continuous stirring and distance of 2.5 mm between the electrodes and then allowed to start reading. The instrument starts the first reading at 3 minutes, while the second, third, fourth, fifth and sixth are at 2 minutes interval between them, after which the instrument displays the average of the six results in kV on the screen of the instrument.

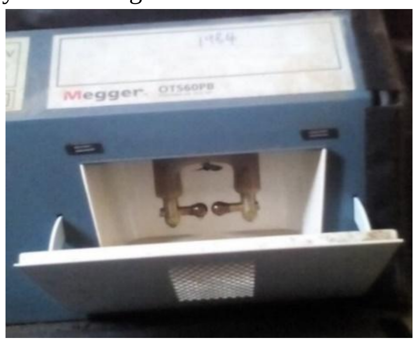

Figure 1: Megger transformer oil tester, showing the electrodes

Determination of corrosive Sulphur

Silver strip test for corrosive Sulphur analysis was carried out. Prepared silver strips were immersed in the oils and allowed to stay for 18 hr at a temperature of 100 ^{o}C in the oil. The appearance of brown colour on the surface of the silver indicates the amount of corrosive Sulphur in the oil.

Shelf-life Analysis (SLA)

To figure out the possible shelf-life of the oils in case of contamination due to tank leaks oil sample of LASO and MIO with a known dielectric breakdown voltage were placed in a barrel, which has two holes on the seal cap, were the oil can have contact with environment, allowing air contact with the oil surface. The oil was tested for breakdown voltage after every 5days for 40days.

Determination of Relative Permittivity/dielectric constant of the ester oil

The capacitance of the capacitor without oil, C_o, was calculated and the capacitance with oil, C_p, was calculated with digital meter (ISO 55565). Relative permittivity/Dielectric constant, ὲ, of the ester oils was obtained as;

$$\grave{\varepsilon}= \frac{Cp}{Co}$$

Results and Discussion

The result of LASO and MIO are presented in the Tables3, 4 and 5 below:

Table 3: The result of physiochemical analysis of LASO and MIO

	Property	LASO	MIO
Physiochemical properties	Percentage Yield (%)	29.15	NA
	Appearance	Yellowish green	Yellow
	turbidity	Clear	Clear and bright
	Moisture content (%)	4.17± 0.03	3.90 ± 0.08
	Cloud point (^{0}C)	5 ± 0.5	-10± 0.9
	Pour point (^{0}C)	10 ± 0.5	- 2 ± 0.2
	Density at 20 ^{0}C (g/cm^{3})	0.91±0.01	0.90 ± 0.01
	Viscosity		

@40 ^{0}C	10.50 ± 0.2	7.57 ± 0.02
@100 ^{0}C	4.10 ± 0.1	2.40 ± 0.1
Specific gravity at 25 °C (J/ kg °C)	0.88 ±0.01	0.90 ± 0.01
Corrosive Sulphur	Negative	Positive

n = 3

A single 300 kV transformer tank with its conservator tank can carry up to 330 liters of oil defending on the size of the tank. Therefore, the percentage yield of the LASO shows that the oil can serve as transformer oil since they can give a higher yield to satisfy the high oil requirement by transformers.

Figure 2: 300 kV transformer showing its conservator tank

The standard appearance of transformer/capacitor oil approved by NIS-IEC 60076-14 (2013) is that the colour of the oil to be used as transformer oil should be clear, free from segments and suspended matter. These impurities, segments and suspended matter can be reduced by filtering with membrane filters[15]. The good appearance shown by LASO as compared with that of the standard mineral transformer/capacitor oil show that all the oils can serve as transformer/capacitor oil. Furthermore, the number and size of particles have a major effect on breakdown voltage level of insulating oil. Because, they become polarized particles, which exposed to electrical field and come between electrodes to facilitate the beginning of breakdown. In this research work, the particle effect on breakdown voltage was also reduced by filtering the oils.

Abayeh *et al* [11] described that the lower the moisture content in oil the longer it will stay without deterioration during storage. Higher moisture content in oils lowers the dielectric strength and allows flashovers that can damage the transformer [5]. The mean of the moisture content of LASO when compared with that of the conventional MIO shows that there is a significant difference ($\alpha = 0.05$). The ester oils have higher moisture content than the MIO. The result of the LASO contamination due to tank leakage shows that there is a reduction in the DBV of the ester oil when they are exposed to atmospheric oxygen. The reduction in DBV of the ester oils may not be unconnected with the fact that ester oils undergo rancidification when in contact with atmospheric oxygen, which result in formation of moisture that reduces the insulation capabilities of the LASO. This means that the LASO can serve as transformer oil but with low shelf life as compared to the mineral transformer oil.

The mean results of pour point, cloud point of the LASO in this research shows significant difference ($\alpha = 0.05$) as compared to the MIO, but can still serve since during working hours of a transformer, since heat is generated and it is hard for it reach temperature as low as 20^{o}C. The LASO can serve as transformer oils in Nigeria since it is a country with average environmental temperature of above 20^{o}C [7].

Density and viscosity of oil describes the ability of the oil to flow. The mean result of viscosity and density of LASO when compared with that of MIO shows that there is no significant difference ($\alpha = 0.05$), the LASO will move from the conservator tank to the main tank of the transformer. The lower the value of the density and viscosity, the faster the oil moves in a transformer between the main tank and the conservator tank [5].

The mean result of specific gravity of the LASO when compared with the MIO shows there is no significant difference ($\alpha = 0.05$). The good specific gravity shown by LASO is an indication that LASO can suspend water.

The results of corrosive Sulphur in this research show that the ester oils do not contain corrosive Sulphur as required by NIS-IEC 60078-14 (2013), while the conventional MIO shows presence of corrosive Sulphur.

Table 4: Electrical and Environmental Safety Properties of LASO and MIO

	Test name	LASO	MIO
Electrical properties	DBV (kV) at 2.5mm gap	42.5 ±0.57	40± 0.1
	Relative permittivity/ dielectric constant @25 ^{0}C	2.75 ± 0.02	2.74 ± 0.01
Environmental safety properties	Smoke point (^{0}C)	220 ±3.60	145 ± 2.0
	Flash point (^{0}C)	231 ±1.0	195 ± 1.0
	Fire point (^{0}C)	250 ± 1.0	200 ± 2.0
	Biodegradability	RB	NRB

RB = Readily Biodegradable. NRB = Not Readily Biodegradable. n = 3.

The mean results of dielectric breakdown voltage of LASO at room temperature is significantly different ($\alpha = 0.05$) with that of the MIO, the ester oil has higher DBV than the MIO. The higher the value of DBV the more the insulation capabilities of the oils and the more suitability to server as insulation oil.

Relative permittivity is an ability of oils to store charge. When the mean results of the ester oils were compared ($\alpha = 0.05$) with that of the MIO it shows there is no significant difference between the means. The ester oils can equally store the charge that MIO stores.

The higher result of smoke point, flash point and fire points of the LASO as compared ($\alpha = 0.05$) to MIO shows that the ester oil possess higher thermal performance capability and fire safety.

The result of biodegradability of the LASO shows that the ester oil is readily biodegradable while the MIO is not readily biodegradable. This is also an indication that the LASO is not persistence to the environment as compared to the MIO.

Table 5: Chemical and SLA Properties of LASO and MIO

	Test name	LASO
SLA	Iodine value (g iodine/100g of oil)	132
	Free fatty acid (%)	10.45
	Acidity (%) (mgKOH/g)	20.80
	Peroxide value (Meq/kg)	278
	Oil's DBV after 40days (kV)	42

The mean result of shelf-life analysis (SLA) in case of leakage shows a slight decrease in the DBV of LASO meaning that it will have a lower shelf-life when used in a transformer with leakage.The mean result iodine value of the LASO in this research shows that it can help prevent corrosion in transformer. Since ester oils with iodine value (degree of unsaturation) of 80-120 g iodine/100g of oil, are considered as non-drying oil, 120 -150 g iodine/100g of oil, are semidrying oils and those with ≥150 g iodine/100g of oil are drying oils [1].

Acid value is an indicator of its suitability for industrial use [1]. Plant oils rich in polyunsatured fatty acids have a limited shelf life. In this research, work the result of the acid value show that the ester oils have higher acid value and cannot stay long in a transformer as compared to the conventional MIO.

The peroxide value of ester oil state the level of deterioration on the ester oils. Lower peroxide value of ester oil indicates less exposure to oxidation by atmospheric oxygen [1], and the higher their oxidative stability. The results of the peroxide value of the LASO in this research show that the oil have not been subjected to too much oxidation during extraction and storage. In a transformer tank and its conservator tank no leakage is allowed, therefore, there is no direct contact of the oil in the transformer tank with the atmospheric oxygen that causes increase in peroxide value of vegetable oils.

Oxidation inhibitors used in transformer oil such as DBPC (2, 6 Di-tertiary Butyl Para-Cresol) proved to be inadequate for the oil with regard to the transformer environment [20].The level of inhibitor content for conventional transformer oil is kept below 0.3 percent, at least in the United States [20].

Conclusion

The comparative ($\alpha = 0.05$) evaluation between LASO and MIO shows that the ester oil is better than MIO in terms of environmental safety and electrical properties while the MIO is better in terms of shelf-life.

References

1. Abayeh O.M, Garba I.H, Adamu H.M and Abayeh O.J (2013). Quality Characteristics of *Luffa aegyptiaca*seed oil. *International Journal of Scientific & Engineering Research*. 4 (4) 11-16.
2. Bashi, S. M., Abdullahi, U. U, Robia, Y., and Amir N., (2006). 'Use of natural vegetable oils as alternative dielectric transformer coolants'. *Journal - The Institution of Engineers, Malaysia.* 67 (2) 4-10.
3. Buongiorno, J. (2006). "Convective Transport in Nanofluids". *Journal of Heat Transfer*. American Society of Mechanical Engineers. 128 (3): 240. doi:10.1115/1.2150834. Retrieved 27 March 2010.
4. Darwin C., (2007). "The use of natural ester fluids in transformers" an online material. http://2011.matpost.org/ matpost2007/docs/MATPOST07_0036_paper. pdf.
5. Davood Herfati, Babak A. Kamvar, Ali Tavakkol and Karim R. Milani (2007). Paper presented at 19th International Conference on Electricity Distribution. Paper 0309 pp 1-6.
6. Derick Njombog Tanteh., Shafiq Yousef al-liddawi., Daniel ssekasiko, (2014). Properties of transformer oil that affect efficiency. Undergraduate project, School of Engineering, Department of Electrical Engineering, Blekinge Institute of Technology, S-371 79 Karlskrona.
7. http://www.nigeria.climatemps.com
8. IEC 60296 (2003). Intenational Standard for mineral insulating oils. Third edition. Reference number IEC 60296:2003(E). available online at www.iec.ch.
9. Lance R. L. (2002). The role of corrosive sulfur in transformers and transformer oil. An online paper from Doble Engineering Company, *USA.*www.doble.com
10. *Luffa aegyptica*: Floridata Luffa aegyptiaca. Htm (2009)
11. Luffa.info-luffa sponge gourd information. Htm (2009)
12. Mankilik M, Mikailu A., Mhya DH., (2014). Phytochemical Content and Antimicrobial Activities of Luffa Aegyptiaca (Sponge Gourd) Leaves Extracts International Journal of Research in Pharmacy and Biosciences. 1 (1), 1-4.
13. Martin, D., Wang, Z.D., Dyer, P., Darwin, A.W., James, I.R., (2007) "A Comparative Study of the Dielectric Strength of Ester Impregnated Cellulose for Use in Large Power Transformers", ICSD Winchester, UK.
14. Mustapha AB, Ekanem EO, Kolo AM, Boryo DEA, John DS, lawan NM, Barambu AU (2017). Physiochemical and Electrical Properties of Pre-Processed Ester Oils. *Chemistry Research Journal*, 2(6): 267-272.
15. NoHwa Lee, Gary Amy, Jean Philippe Croue and Herbe Buisson (2204). Identification and understanding of fouling in low-pressure membrane (mf/uf) filtration by natural organic matter (nom). *Science direct*. 38 (20) 4511-4523.
16. Qi Wang, Muhammad Rafiq, Yuzhen Lv, Chengrong Li, and Kai Yi (2016). Preparation of Three Types of Transformer Oil-Based Nanofluids and Comparative Study on the Effect of Nanoparticle Concentrations on Insulating Property of Transformer Oil. *Journal of Nanotechnology*. 2016; Article ID 5802753; 6.
17. Thien Yee Von, NorhafizAzis, JasronitaJasni, Mohd Zainal Abidin Ab Kadir, RobiahYunus, MohdTaufiqIshak and ZainiYaakub, (2015). Evaluation on the Lightning Breakdown Voltages of Palm Oil and Coconut Oil under Non-Uniform Field at Small Gap Distances. *J ElectrEng Technol.* 11(1): 1921-718.

18. United Nations Environment Programme [UNEP] (2002). *PCB Transformers and Capacitors from Management to Reclassification and Disposal.* UNEP publication on transformer oil.
19. Lance R. L. (2002). The role of corrosive sulfur in transformers and transformer oil. An online paper from Doble Engineering Company, *USA*.www.doble.com.
20. Claiborne C. C., Walsh E. J., Oommen T. V., (1999). An Agriculturally Based Biodegradable Dielectric Fluid. *IEEE Electrical Insulation Magazine*. 0-7803-5515-6/99.