Effects of Temperature and Volume Fractions on the Thermophysical properties of Periwinkle Shell Nanofluid.

Okafor A. A[1]., Nwadike E.C[2]., Ekengwu I.E[3] and Abonyi S.E[4].

[1,2,3,]Department of Mechanical Engineering, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria

[4]Department of Electrical Engineering, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria

Corresponding Author's e - mail: aa.okafor@unizik.edu.ng

Abstract

In this study, the top-down approach was used to synthesize nanoparticles from periwinkle shell nanoparticles using a ball-milling machine and universal sieving machine. The thermophysical properties investigated in this study are Ph and electrical conductivity. Two step method was used to produce the periwinkle shell bio material nanofluid. The Periwinkle shell nanoparticles with an average size of 100 nm were dispersed in an ethylene glycol (EG)/deionized water (50:50) base fluid up to 1.5% of the volume fraction. The Ph and electrical conductivity of Periwinkle shell nanoparticle–deionised water and EG (50:50) were investigated for temperature ranging from 20 to 70^{0}C. The results showed that the pH and the electrical conductivity increased as the volume fraction of the Periwinkle shell nanoparticle was increased from 0.3 to 1.5%. However, the pH decreased with an increase in the temperature while the electrical conductivity increased with an increase in the volume fraction

Key words: Nanofluids, Periwinkle Shell nanoparticles, ethylene glycol, Ph and Electrical Conductivity

1. Introduction

Nanofluids are engineered colloidal suspensions consisting of nanoparticles dispersed in a base fluid, such as water, oil, or ethylene glycol. These nanoparticles are typically on the nanometer scale (1-100nm) and can be metallic, ceramic, carbon-based or polymetric in nature. The addition of nanoparticles to the base fluid alters its thermophysical propertries, including thermal conductivity, viscosity and heat capacity.

Nanofluids have garnered significant interest due to their potential for enhancing heat transfer and fluid properties in various applications [1,2] including cooling systems, heat exchangers, solar collectors and microfluidic devices. The unique properties of nanoparticles, such as their high surface area-to-volume ratio and surface chemistry, contributes to the improved performance of nanofluids compared to conventional heat transfer fluids. Literature has revealed that so many works have been carried out on nanofluid using metallic, non meatallic and their various oxides. However, little work has been carried out on nanofluid using natural fiber or bio materials. From the survey of literature we made, these are the only people that have worked on nanofluids using natural fibre or bio-materials.[3, 4, 5, 6, 7, 8, 9].

However, due to high cost, availability and their toxic effect of metallic, non metallic and their various oxides during preparation and usage of nanofluids, it becomes imperative to explore the use of a bio-friendly and low-cost agricultural material such as periwinkle shell nanoparticles. The use of this material will solve the problem of toxicity and also, will reduce environmental hazard which this agricultural waste constitute in our environment.
In this paper, pH and electrical conductivity of nanofluid prepared from Periwinkle shell nanoparticles using a mixture of deionised water and EG as the base fluid are investigated so as to study these thermophysical properties for industrial applications. We also experimentally investigated the effects of temperature and volume fraction on the Ph and electrical conductivity of the developed periwinkle shell bio nanofluid

2. Experiment/Materials

The materials used for the laboratory experiment are Periwinkle shell nanoparticles, Powdered Sodium Hydroxide (NaOH), Ethylene Glycol and Deionized water , RADWAG AS 220-R2 Sensitive weighing scale(10mg – 500g, with a precision of 0.01g), ball mill, Universal sieving machine. GAUTRACK POTCH Oven, GAUSTING GT225 Impact Grinder (ball miller), a programmable constant temperature thermal bath (LAUDA ECO RE1225). 24 kHz Hielscher ultrasonic processor (UP200S).

2.1. Preparation of Nanoparticles from Periwinkle shells

A big quantity of periwinkle shell (about 50 kg) waste was collected from our local market. The periwinkle shells were soaked in a bucket of water for 14 days with diluted sodium hydroxide (NaOH) to remove the impurities from the periwinkle shells bio materials. After the 14 days, it was rinsed thoroughly with water and sun-dried. The sun-dried Periwinkle shells were then oven-dried in a temperature range of 50^0C for 24 h to ensure that the residual moisture was completely renoved. This was achieved by steadily measuring the weight of the Periwinkle shells and oven drying was stopped when the weight of the Periwinkle shells became 1constant. The dried Periwinkle shells were fed into a ball-milling machine and allowed to run steady for 48 hours(2 days). The obtained periwinkle shells particles after 48 h was reduced to ultrafine particles in the nanometre range as shown with scanning electron microscope (SEM) image in figure. 500g of the crushed periwinkle shell particles was measured and passed through a 0.38mm thick cotton fabric of a universal sieving machine[10] with a pore size of about 100 nm for sieving, of which the nanoparticle was separated from other particles of periwinkle shell larger than 100nm. During the separation process, the nanoparticles flow into a container while particles larger than the cotton fabric's pore size are trapped on the fabric. The separation process was carefully done to ensure that particles obtained after separation are within the size range (<100nm). The X-ray diffraction pattern of the Periwinkle shell nanoparticles is shown in figure 2.

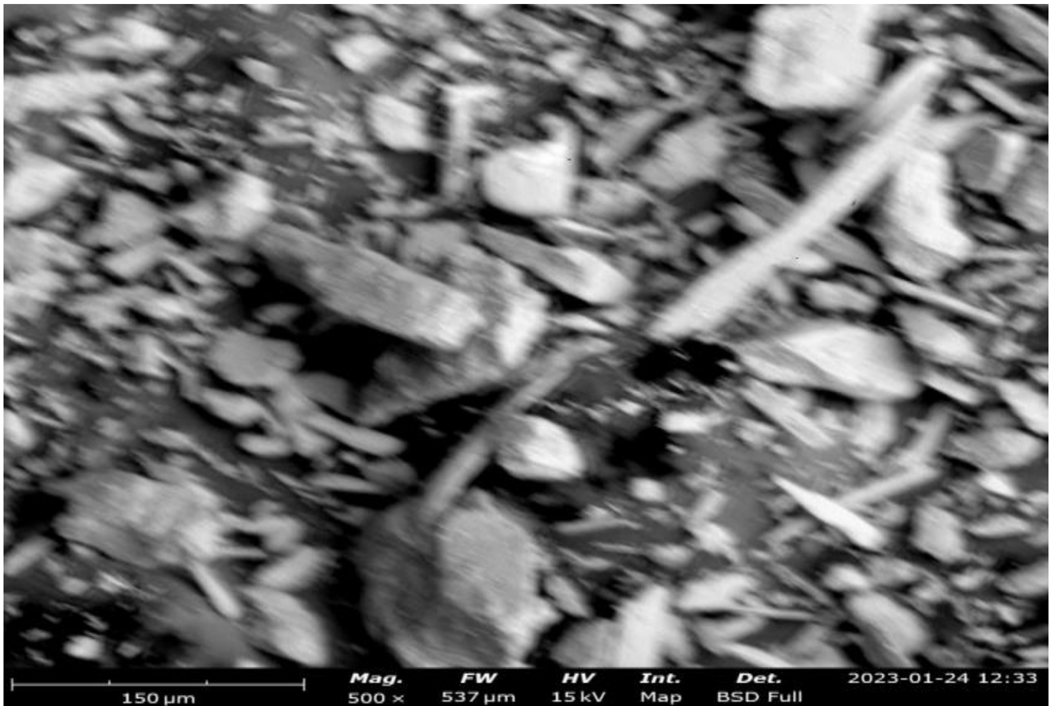

Figure 1: SEM image of periwinkle shell nanoparticles

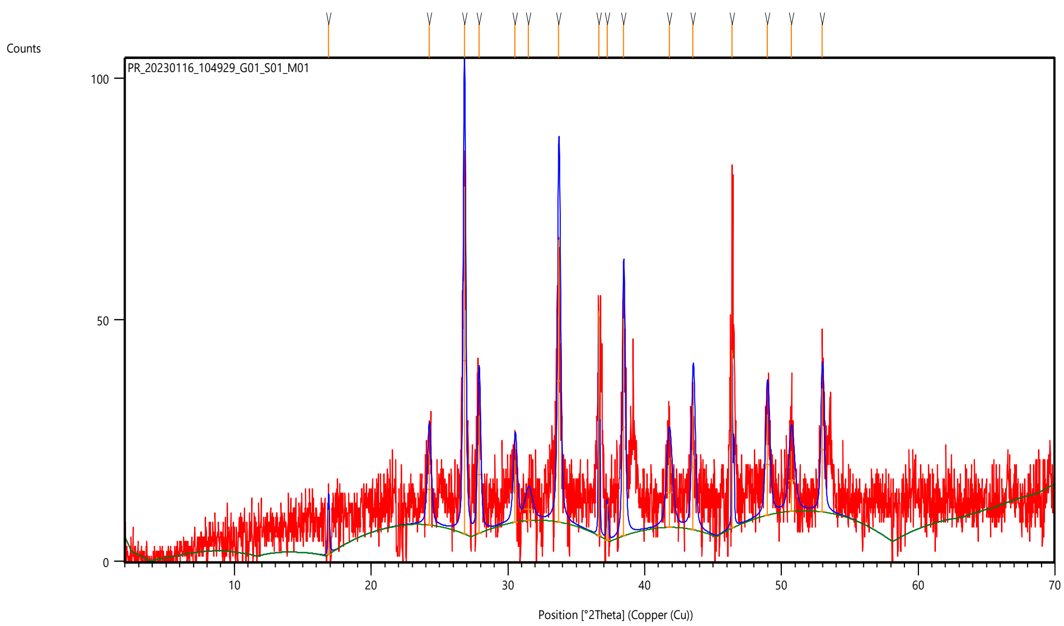

Figure 2: X-Ray diffraction pattern of Periwinkle Shell nanoparticles

2.1.1Preparation of various volume fractions of nanofluids

A ‘two-step’ method was used in the preparation of nanofluid from the fabricated bio-material nanoparticles since it is better method out of the two common methods in use [11], [12], [13]. In this method, nanoparticles are initially produced in the form of dry powder and then dispersed in the basefluid. The commonly employed equipments for dispersing nanoparticles in the basefluid are magnetic stirrers, ultrasonic bath, homogenizers, high-shear mixers, and bead mills. Unlike the one-step approach, the two-step approach is more commonly used to fabricate nanofluids due to its lower processing cost. A known mass of the periwinkle shell nanoparticles corresponding to a predetermined volume concentration were measured and mixed with a binary mixture of Ethylene Glycol (EG) and deionised water(base fluid) in a ratio of 50:50 .Volume fractions of nanofluid obtained ranged from 0.3%-1.5%, with five (5) samples of nanofluid formed for each bio materual nanoparticle. This was achieved using a mathematical model equation to calculate the weight of base fluid (ethylene glycol/ de-ionized water) and nanoparticles required to achieve various volume fractions

$$Volumetric\ fraction, \varphi \times 100 = \frac{\frac{M_P}{\rho_P}}{\frac{M_P}{\rho_P}+\frac{M_{bf}}{\rho_{bf}}} \qquad 1$$

Where Mp is the mass of the nanoparticle, ρ is the density of the nanoparticle, M_{bf} is the mass of base fluid and ρ_{bf} is the density of the base fluid.

Therefore, $Volumetric\ fraction, \varphi \times 100 = \frac{V_P}{V_P+V_{bf}}$ 2

Where V_p is the volume of nanoparticle. V_{bf} is the volume of base fluid.

The density of the nanoparticles (ρ) was determined by measuring the mass of the nanoparticle for a given volume. 1.78 grams of the nanoparticle was determined using a weighing balance as the mass of the nanoparticle for 5 ml. of the nanoparticle, of which the density of the nanoparticle was calculated using equation 3

$$\rho_p = \frac{\text{mass}}{\text{volume}} \qquad 3$$

After mixing the various weighed samples of nanoparticles with a measured volume of base fluid to achieve different volume fractions from 0.3%-1.5%, magnetic stirrer containing a magnetic stirring bar is used to stabilize the nanofluid mixtures for about 120 minutes for each volume fraction. This is to ensure proper mixing of the two phases of the mixture. All samples of the nanofluid were stored in a test tube.

The bio-materials nanofluids were prepared by dispersing or pouring different volume fractions (0.3%, 0.6 %, 0.9 % 1.2 % and 1.5%) of periwinkle shell nanoparticles into the base fluid. The nanofluids samples were homogenized by using an ultrasonic sonicator continuously for 40 minutes and the samples were observed for dispersion and stability

3. Experimental measurement

3.1. Measurement of PH

PH (potential of hydrogen) is a measure of the acidity or alkalinity of a solution. It is determined by the concentration of hydrogen ions in the solution. PH is typically measured on a scale from 0 to 14, where 0 represents strong acidity, 7 is neutral, and 14 indicates strong alkalinity. In this work, the pH was measured using a Jenway pH meter (model 3510). The pH meter consists of of a pH probe or electrode, which is dipped into the solution being texted, and a meter that displays the pH value

3.2. Measurement of electrical conductivity

Electrical conductivity, also known as specific conductance, is a measure of a materials ability to conduct an electrical current. The measurement of electrical conductivity can be done using various methods, depending on the sample type and the required precision. In this work, the electrical conductivity was measured using a EUTECHCON700 conductivity meter. A conductivity meter, also known as a conductance meter, is an electronic device designed for precise electrical conductivity measurements. A pair of conductivity electrodes was immersed in the sample solutions, and the meter measures the electrical conductance between the electrodes. The meter provides a direct reading of electrical conductivity in S/m.

4.0 Results and Discussions

4.1.Effect of temperature and volume fraction on PH of Periwinkle shell nanofluid with \ deionize water/EG (50:50) Base Fluid.

Figure 3 is the graph of PH versus temperature for base fluid and periwinkle shell bio materials nanofluids. It could be seen from the plot that the addition of periwinkle shell nanoparticles to the base fluid gave a higher pH value compared to the base fluid, increasing the temperature from 20 to 70◦C showed a continual decrease in the pH value. The pH of the base fluid reduced with an increase in temperature in a similar manner reported by Konakanchi *et al* [14] on the pH of PG–water, 60:40 base fluid .The temperature increase influences the pH of any solution due to the dissociation of the weak acids' and bases' groups and splitting of water component into H+ and OH− ions.

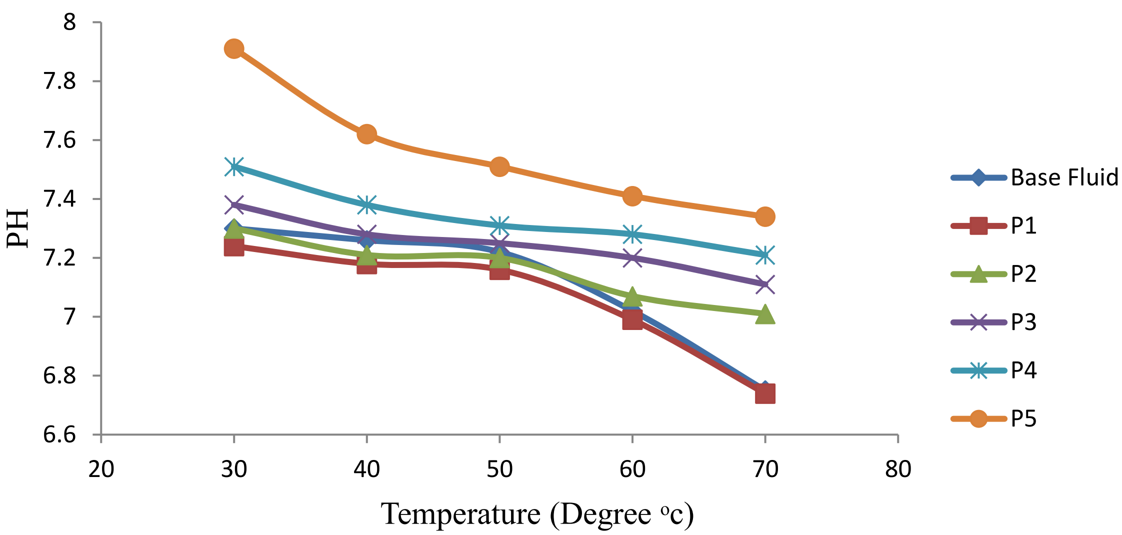

Figure 3: Effects of Temperature and volume fraction on pH of 0.3 - 1.5 % volume concentrations of periwinkle shell nanofluid with Di ionize water/EG (50:50) Base Fluid.

P_1 = 0.3% volume fraction of Periwinkle shell nanoparticles

P_2 = 0.6% volume fraction of periwinkle shell nanoparticles

P_3 = 0.9% volume fraction of Periwinkle shell nanoparticles

P_4 = 1.2% volume fraction of Periwinkle shell nanoparticles

P_5 = 1.5% volume fraction of Periwinkle shell nanoparticles

4.2. Effect of temperature and volume fraction on Electrical Conductivity of Periwinkle shell nanofluid with deionize water/EG (50:50) Base Fluid.

Figure 4 is the graph of electrical conductivity versus temperature for base fluid and periwinkle shell nanofluid. The addition of periwinkle shell nanoparticles into the base fluid showed an increment in the value of the electrical conductivity of the bio material (periwinkle shell) nanofluid and increasing the temperature also gave a corresponding increase in the electrical conductivity values. As the volume fraction was changed from 0.3 to 1.5%, there is an appreciable enhancement in the electrical conductivity as shown in the figure.

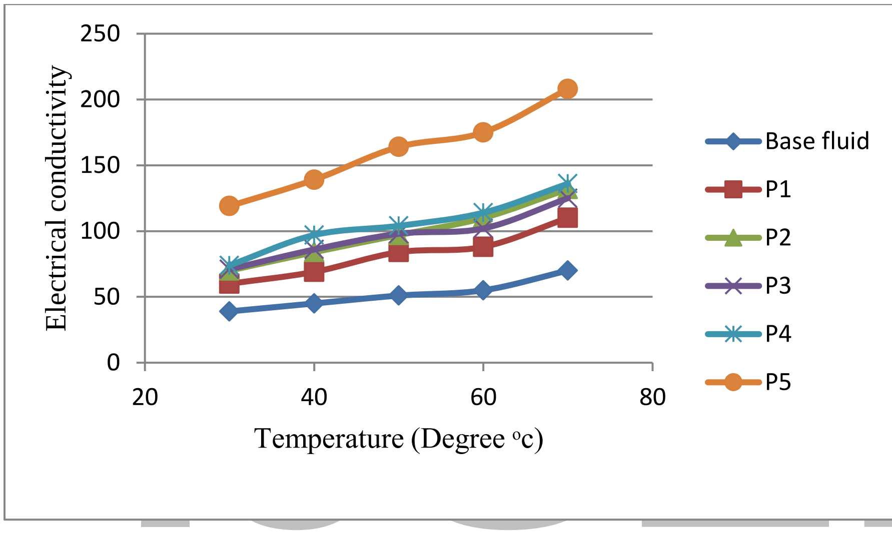

Figure 4: Effects of Temperature and volume fraction on electrical conductivity of 0.3 - 1.5 % volume concentrations of periwinkle shell nanofluid with Di ionize water/EG (50:50) Base Fluid

4.0 **Conclusion**

In this paper, a bio material nanoparticles was produced from periwinkle shell nanoparticles using a ball-milling machine and universal sieving machine at room temperature. The Periwinkle shell nanoparticles has an average size of 100 nm and were dispersed in an EG/water (50:50) mixture to produce a nanofluid with the volume fraction ranging from 0.3 to 1.5%. The thermophysical properties such as electrical conductivity and pH responses to volume fraction and temperature were studied for a temperature range of 20–70^{0}C. The pH and electrical conductivity increased with increasing volume fraction of the Periwinkle shell nanoparticles. The pH of nanofluid reduced with an increase in temperature while the electrical conductivity increased with temperature increase. This showed the effects of temperature and nanoparticles volume fraction concentration on the PH and electrical conductivity of periwinkle shell nanofluid. Some of the limitations of nanofluid which limits their practical applications which this present study has addressed are cost of production of nanofluid, stability of nanofluid, toxicity and homogeneity of nanofluid. This study has revealed the PH and electrical conductivity properties of nanofluid which can be utilized in various industrial applications such as heat transfer enhancement, sensing applications, energy storage and electro kinetic applications. The unique electrical conductivity and PH properties of bio nanofluids offer opportunities for innovation in various fields, ranging from thermal management to sensing and energy storage

References

1 Raud R, Hosterman B, Diana A, Steinberg T A and Will G 2017 *Appl. Therm. Eng.* **117** 164

2. Nieh H M, Teng T P and Yu C C 2014 *Int. J. Therm. Sci.* **77** 252

3. G A Adewumi, F L Inambao, M Sharifpur, J P Meyer, Thermal Conductivity of Nanofluids Prepared from Biobased Nanomaterials Dispersed in 60: 40 Ethylene Glycol/Water Base Fluid, International Journal of Mechanical Engineering and Technology, 2019, 10 (6), pp. 151-159.

4. Justin Awua, Jacob Ibrahim, SA Adio, M Mehrabi, M Sharifpur and JP Meyer, Experimental investigation into viscosity, pH and electrical conductivity of nanofluid prepared from palm kernel fibre and mixture of water and ethylene glycol, Bulletin of Materials Science, (2018) 41:156. (IF=1.783)

5. Gloria A Adewumi, Freddie Inambao, Mohsen Sharifpur, and Josua P Meyer, Investigation of the Viscosity and Stability of Green Nanofluids from Coconut Fibre Carbon Nanoparticles: Effect of Temperature and Mass Fraction, International Journal of Applied Engineering Research, Vol. 13, Number 10, 2018 pp. 8336-8342.

6. J.T. Awua, J.S. Ibrahim, M. Sharifpur and J.P.Meyer, Particle Characterization and Stability of Nanofluid Prepared from Palm Kernel Fibre with Mixture of Water and Ethylene

Glycol as Base Fluid, 14th International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics (HEFAT 2019), 22 -24 July 2019, Wicklow, Ireland.

7. U. Kallamu, J. Ibrahim, M. Sharifpur and J.P. Meyer, Experimental Investigation of the Viscosity of Nanofluid Prepared From Banana-fiber Nanoparticles, 12th International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics (HEFAT 2016), July 11-13, 2016, Costa del Sol, Malaga, Spain.

8. J.T. Awua, J.S. Ibrahim, A. Kwaghger, M. Sharifpur and J.P. Meyer, Investigation into Thermal Conductivity of Palm Kernel Fibre Nanofluids with Mixture of Ethylene Glycol/Water as Base Fluid. 12th International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics (HEFAT 2016), July 11-13, 2016, Costa del Sol, Malaga, Spain.

9. Ohimor, E. O. and NwaokoloP. V (2022), The Effects of Low Volume Fraction Palm Kernel Shell Nanoparticles on the Thermal Conductivity of Ethylene Glycol

10. A. A. Okafor , S. E. Abonyi , A. E. Ilechukwu , C. V. Obinani (2023) "Design of a Universal Sieving Machine" International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-7 | Issue-4.

11. Amaechi, Okafor Anthony , Ogonna, Mgbemena Chinedum (2022). Preparation of Hybrid Nanofluids, Their Thermophysical Properties, and Stability Parameters , Journal of Engineering Physics and Thermophysics, Volume 95, Issue 2, p.533-538

12. Anthony Amaechi Okafor, Chinedum Ogonna Mgbemena, Benjamin Ufuoma Oreko (2022). Preparation, Characterization, Stability and Thermophysical Properties of Bio, Non-Bio (Metallic and Non-Metallic) and Hybrids Nanofluids: A Review, *Journal of Nanofluids, volume 11, Issue 6, Pages 803-818*

13. Okafor A. A,, Dara J. E., Okafor L. U2Osazuwa O. K. and Agu P. T(2024), Experimental Investigation into Viscosity and Thermal Conductivity of bio nanofluid produced from Periwinkle shell nanoparticles. International Journal of Scientific and Engineering Research. Volume 15, Issue 3, March 2024

14. Konakanchi H, Vajjha R S, Chukwu G and Das D K (2014), *Heat Transfer Eng.* 36