



Physicochemical Properties, Radioactivity Measurement and Determination of Thorium Level in Monazite Ore Obtained from Parts of Plateau State, Nigeria

*¹OKOH, S; ²OMONIYI, KI; ²PAUL, ED; ²AJIBOLA, VO

¹Centre for Energy Research and Training, Ahmadu Bello University, Zaria, Nigeria

²Department of Chemistry, Ahmadu Bello University, Zaria, Nigeria

*Corresponding author: sunnyo_eve2@yahoo.co.uk

*ORCID: <https://orcid.org/0009-0003-3448-3696>

*Tel: +2348034533203

Co-authors email addresses: israeliflourish@yahoo.com, elaoyi@gmail.com, tunjajibola2003@yahoo.com

ABSTRACT: Monazite ore is a source of thorium and can be used as an alternative source of nuclear fuel in place of depleting uranium which has been popular over decades. Therefore, the objective of this paper was to evaluate some physicochemical properties, radioactivity measurement and determination of thorium level in Monazite Ore obtained from parts of Plateau State, Nigeria using appropriate standard methods. Results of physicochemical parameters analyzed such as pH (5.48 ± 0.05), moisture content ($0.123 \pm 0.01\%$) and loss of mass on ignition (LOI) ($0.67 \pm 0.01\%$) were to ascertain the ore quality preparatory to extraction. Additionally, the radioactivity of the ore was measured as $3.65 \mu\text{S/hr}$. The Scanning Electron Microscopy provided data on the presence of thorium and the concentration of thorium was determined as $4.68 \pm 0.05\%$. The results showed the monazite ore as being of high quality and are indicative of the fact that the sample is a potential source of thorium that can be further processed for nuclear applications.

DOI: <https://dx.doi.org/10.4314/jasem.v29i7.14>

License: CC-BY-4.0

Open Access Policy: All articles published by JASEM are open-access and free for anyone to download, copy, redistribute, repost, translate and read.

Copyright Policy: © 2025. Authors retain the copyright and grant JASEM the right of first publication. Any part of the article may be reused without permission, provided that the original article is cited

Cite this Article as: OKOH, S; OMONIYI, K. I; PAUL, E. D; AJIBOLA, V. O (2025) Physicochemical properties, radioactivity measurement and determination of thorium level in Monazite Ore Obtained from Parts of Plateau State, Nigeria. *J. Appl. Sci. Environ. Manage.* 29 (7) 2167-2170

Dates: Received: 29 May 2025; Revised: 28 June 2025; Accepted: 13 July 2025; Published: 30 July 2025

Keywords: Monazite ore; physicochemical parameters; radioactivity; thorium; concentration

Thorium is a naturally occurring radioactive material (NORM), which exists as a mono isotope and denoted as ^{232}Th with a half-life of 14.05 billion years (Al-Areqi *et al*, 2015). Thorium can be utilized as an alternative nuclear fuel to replace uranium (Lainetti, 2015). There are several types of reactors where ThO_2 can be used as a nuclear fuel such as heavy water reactors, high temperature gas cooled reactors, boiling water reactors, pressurized water reactors, fast neutron reactors and molten salt reactors (Park, 2018). Monazite is a phosphate

mineral and occurs most abundantly in Brazil, India, Australia and the United States. These ores develop when rocks containing monazite are eroded by moving water such as rivers and deposited as the characteristic black monazite sands (Habashi, 2013). Also, Nigeria has deposits of monazite ores in States like Plateau, Nasarawa and Cross River. Often, thorium and uranium are present in monazite in significant amounts. Depending on the quantity of these radioactive elements, it may be desirable to extract them with other rare earth elements (REEs) as

*Corresponding author: sunnyo_eve2@yahoo.co.uk

*ORCID: <https://orcid.org/0009-0003-3448-3696>

*Tel: **+2348034533203

co-products, or separation may be preferred (Galvin, 2018). Therefore, the objective of this paper is to evaluate the physicochemical properties, Radioactivity Measurement and Determination of Thorium Level in Monazite Ore obtained from Parts of Plateau State, Nigeria.

MATERIALS AND METHODS

Sample preparation: Monazite ore which is a major source of thorium was collected from Plateau state, Nigeria. The collected monazite sample was ground using Yam 1100 Q 4 model pulverizing machine and sieving was carried out using American Society for Testing and Materials (ASTM) standard sieve to produce a mass fraction of 125 μ m.

Identification of Thorium in the ore: The collected sample was identified with the use of a radioactivity meter (NORM identifier AT 6102A) to detect the presence of thorium as a Naturally Occurring Radioactive Material (NORM) and the dose rate of the sample was measured with same meter.

Determination of moisture content: This is aimed at estimating the level of wetness or dryness of the monazite sample. This was carried out by weighing 5.0g of the sample into a crucible and placed in an oven at 105°C for 5 hours. The sample was then removed and transferred into a desiccator to cool (this is to prevent atmospheric moisture interference). The monazite ore was reweighed and the difference in weight was recorded as the moisture content (Baldan *et al*, 2020).

Loss of mass on Ignition (LOI): LOI is the amount of weight lost in a sample having gone through the heating process. It is used as a quality test and ensures volatile organic matter is removed from a sample. The oven dried sample from the moisture content determination was transferred to a muffle furnace at 550°C for 2 hours. After the heating period the sample was cooled in a desiccator and reweighed with the difference recorded as LOI (Li *et al*, 2020)

pH Measurement: This measurement which is required so as to determine the acidity or otherwise, of the monazite ore sample, was carried out over a three days period using a pH meter. 5g of the monazite ore was weighed into a beaker, followed by the addition of distilled water. This was left covered with aluminum foil for 3 days and pH measurements of the supernatant solution were taken daily for those number of days with the average pH taken at the end of the period (Ghadri, 2020).

Elemental Analysis using NAA: Neutron Activation Analysis for determination of elemental thorium was carried out using Am-Be neutron source. In order to validate the method and its effectiveness for the analysis, analytical grade Thorium Oxide (ThO₂) from Fluka was purchased and used as a standard, with known concentration of Th as 87.88%, the neutron flux was measured after exposing the sample for 72 hours. Analytical grade Thorium Nitrate (Th (NO₃)₄.5H₂O) from British Drug House (BDH) chemicals Ltd was used as an unknown sample to validate the analytical method. After validation, 2g of the sample was then transferred into a sample vial and exposed to neutrons in the Am-Be (Americium-Beryllium) neutron source for 72 hours. Radioactivity measurement of the induced Thorium as a radionuclide was performed by the PC-based gamma-ray spectrometry set up. The associated facility for the radiation measurements is a gamma-ray acquisition system (Jonah *et al*, 2006).

Scanning Electron Microscopy (SEM) Analysis: SEM was used to investigate the morphology and surface features of the ore sample. A small amount of the sample was sprinkled onto a stub with adhesive carbon tape. The particles were gently pressed onto the tape to enhance adhesion. The prepared stubs were mounted on the SEM sample holder and inserted into the microscope chamber and imaging conducted with a secondary electron (SE) detector at an accelerating voltage of 15kV and a working distance of approximately 10 mm. Observations were centred on identifying the morphological characteristics typical of monazite minerals.

RESULTS AND DISCUSSIONS

Table 1: physicochemical properties of the monazite ore

S/N	Parameter	Value
1	Moisture Content (%)	0.123 $\pm$ 0.01
2	LOI (%)	0.67 $\pm$ 0.01
3	pH	5.48 $\pm$ 0.05

The physicochemical parameters of the ore are displayed in table 1. The moisture content is 0.123 $\pm$ 0.01%, meaning that the ore is very dry. A wet ore is generally undesirable because it may dilute the concentration of the elements present and drying the ore prior to analysis is both energy and time consuming. The loss of mass on ignition (LOI) as indicated is 0.67 $\pm$ 0.01%. LOI measures the volatile components in the ore and the lower the value, the higher the quality of the ore. Typically, some ores have exhibited up to 2-5% LOI especially in wet

seasons. Understanding the LOI value is crucial in ore processing and beneficiation, as it provides information about the potential for loss during heating or roasting operations. This knowledge can be used to optimize processing methods and reduce potential losses of valuable elements. The LOI for this ore appears good in comparison with a reference value of up to 2-5% in some cases. Looking at the pH of 5.48 ± 0.01 as indicated on table 1, the ore is slightly acidic as expected of monazite ores generally. Typically, the pH of monazite ores range from 7 to 5 i.e. from neutral to being slightly acidic. This is so because monazite is a relatively stable phosphate mineral and its composition is not significantly altered by the surrounding pH in most cases.

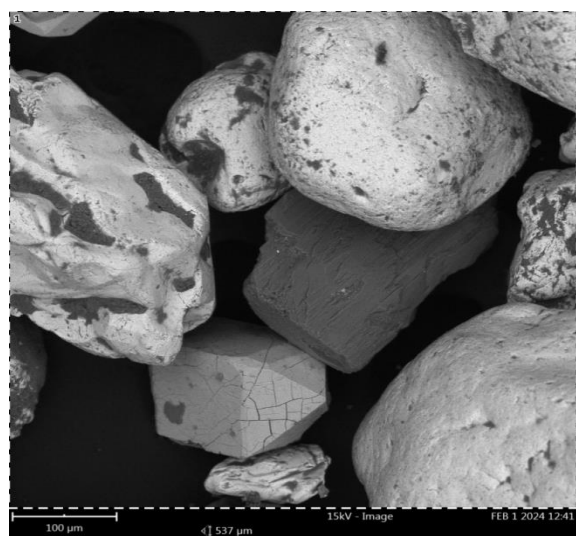


Fig. 1: SEM image of the monazite ore particles

The radioactivity measurement showed a dose rate of $3.65 \mu\text{S/hr}$. This dose rate is higher than the normal background radiation usually around $0.05\text{--}0.2 \mu\text{S/hr}$, depending on location. A dose rate of $3.65 \mu\text{S/hr}$ is not immediately dangerous, but prolonged exposure could lead to higher cumulative doses, which might warrant radiation protection measures.

The thorium concentration as determined by Isotopic (Am-Be) Neutron Activation Analysis is 4.68%. This is relatively high compared to the work reported by Wadeah *et al.*, (2017) for Malaysian monazite at 2.5% thorium. Galvin, (2018) also reported thorium concentration at 2.60% for monazite from South Dakota, U.S. The Nigerian ore investigated with $4.68 \pm 0.05\%$ is considered high- monazite ores typically contain 2-10%. This suggests that the ore is potentially rich and useful for nuclear energy applications in thorium-based nuclear reactors. Fig. 1 shows the SEM image of the monazite ore

confirming it as monazite – (Ce) and distinguishing it from similar looking minerals like zircon or xenotime. The image shows sub-angular to sub-rounded grains of monazite with varying sizes, ranging approximately from $100 \mu\text{m}$ to $300 \mu\text{m}$. The particles display relatively smooth surfaces with occasional fractures and pitting, indicative of natural weathering or mechanical processing. The morphology suggests a brittle mineral structure, consistent with monazite phosphate composition.

Conclusion: The characterization of the monazite sample indicates a low moisture content, which suggests that the sample is suitable for accurate analysis of its composition and further processing. The relatively low value of loss of mass on ignition is suggestive of low presence of volatile components, implying good thermal stability of the ore. With the mildly acidic nature of the ore, the leaching behavior of thorium may be impacted during hydrometallurgical treatment. The notable concentration of thorium confirms the ore as a rich source of thorium. This reinforces the ore's potential for nuclear fuel applications. Overall, the analysis provides a good foundation for developing efficient extraction and beneficiation strategies for thorium from the monazite ore.

Declaration of Conflict of Interest: The authors declare that no known conflict of interest or personal relationships that could have influence the work reported in this paper.

Data Availability Statement: Data are available upon request from the corresponding author

REFERENCES

- Al-reqi, WM; Majid, AA; Sarmani, S (2015). Thorium: issues and prospects in Malaysia, AIP conference proceedings 1659, 040005-1-040005-6
- Baldan, Y; Fernandez, A; Urrutia, AR; Fabani, MP; Rodriguez, R; Mazz, G (2020). Non-isothermal drying of bio-wastes: kinetic analysis and determination of effective moisture diffusivity. *J. Environ Manag.* 262, 110348.
- Galvin, J; Safarzadeh, MS (2018). Decomposition of Monazite Concentrate in Potassium Hydroxide Solution. *J. Environ. Chem. Eng.:* (6): 1353-1363
- Ghadri, M (2020). Investigating variables affecting hea (bio) leaching through determining access to sub-surface mineral grains by micro-scale X-ray tomography. *J. Fac. Eng* 84(3):253-266

- Habashi, F (2013). Extractive Metallurgy of rare earths. *Can metal*. Q52 (3) p224-233
- Jonah, SA; Umar, IM; Oladipo, MOA; Balogun, GA; Adeyemo, DJ (2006). Standardization of NIRR-1 irradiation and counting facilities for Instrumental Neutron Activation Analysis. *Appl. Rad, Ist*. 61. Pp818-822.
- Lainetti, PEO (2015). Thorium and its future importance for nuclear energy generation International Nuclear Atlantic Conference. 1-6
- Li, W; Okelly, BC; Yang, M; Fang, K; Li, X; Li, H. (2020). Briefing: specific gravity of solids relationship with ignition loss for peaty soils: *Geochem. Res.*7(3). 134-145
- Park, J; Farfan, EB; Enriquez, C (2018). Thermal Transport in Thorium Dioxide, *Nucl. Eng. and Technol.* 1-7, <https://10.1016/j.net.2018.02.002>
- Wadeeah, M; Al-Areqi; Che, NA; Che, ZB; Amran, AM; Suliman, S (2017). Extraction of Thorium from Rare Earth Elements in Monazite Thorium Concentrate. *Mal. J. Anal. Sci.* DOI:<https://doi.org/10.17576/mjas-2017-2106-06>