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Investigation of foundation bed's characteristics and environmental safety assessment in some parts of Bayelsa State, south–south Nigeria

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Abstract: The application of appropriate geophysical survey is very pertinent in planning for a successful development of civil engineering structures. In this study, an uphole seismic refraction survey and borehole logs were used to determine the foundation bed's characteristics for civil engineering development, while a portable gamma spectrometer was used to assess the environmental safety worthiness in some parts of Bayelsa State, Nigeria. The seismic refraction revealed a two-layer model, composing of an unconsolidated layer and a consolidated layer. The overburden thickness of the unconsolidated stratum varied from 2.2 to 7.5 m. The borehole logs showed alternating sequence of clay and sand up to a depth of 60 m. The radiometric survey revealed that thorium and the average radioactivity ratios of U/K, Th/K and U/Th are above the global standards by factors of 1.4, 6.4, 11.0 and 2.3 in sequence. Though the overburden in the study area is thin, it is advisable to excavate some aerated soil materials within the unconsolidated layer to minimize the effects of clay on the structure's foundation. Furthermore, periodic environmental safety monitoring and assessment is recommended in the study area.

Theophilus Aanuoluwa Adagunodo

ABOUT THE AUTHOR

Theophilus Aanuoluwa Adagunodo is the current Postgraduate Coordinator at the Department of Physics, Covenant University, Ota, Nigeria. He has contributed to several publications both as a lead-author and a co-author. He has served as Managing Editor, Associate Editor, Guest Editor and Reviewer to many high-profile journals. As part of the reward for diligence in his career, he has been listed twice as one of the Chancellor's Exceptional Researchers at Covenant University in the 2018/2019 and 2019/2020 academic sessions. His research interests include Environmental Geophysics, Engineering Geophysics, Groundwater Exploration, Structural Analysis, Seismology, Seal Integrity/Fault Seal Analysis, Reservoir Characterization, Mining, Geodesy, Medieval Climate Anomaly, and Radiometrics. He is a member of the Nigerian Institute of Physics.

PUBLIC INTEREST STATEMENT

This study integrates an uphole seismic refraction and in-situ radiometric methods to determine the foundation bed characteristics and environmental safety of inhabitants in part of Bayelsa state against radiation exposure for an enhanced subsurface integrity check. The overburden in the study area is composed of two-layered earth model heterogenous materials with varying depths. Despite the thin overburden, it is advisable to excavate the weathered layer in order to minimize the effect of clay on the structure's foundations. The radiometric geospatial maps revealed that thorium and uranium contents are higher than the global limits. The risk assessment revealed that the annual gonadal equivalent dose is slightly higher than the global average. The risk being exposed to in the study area could lead to gradual depletion in the amount of the total red blood cells produced by the bone marrow of the inhabitants.

Subjects: Earth Sciences; Natural Hazards & Risk; Geology - Earth Sciences; Engineering Geology; Geophysics; Environment& Health; Environment & the City; Applied Physics; Environmental Physics

Keywords: engineering geophysics; environmental safety assessment; foundation bed's integrity; radiometric survey; uphole seismic refraction

1. Introduction

The rate at which structural failures occur recently in Nigeria is terrifying (Akintorinwa & Adelusi, 2009; Awoyera et al., 2021; Ede, 2010; Hammed et al., 2017). Its occurrence has led to the loss of lives and invaluable properties in Nigeria and some other developing countries (Dimuna, 2010). Some of the contributing factors to incessant structural failures in these developing nations include inadequate experience about the nature of the near-surface structures, usage of substandard materials for constructions, extraordinary loads, unprofessional/bad designs, foundation failure and natural disasters (such as earthquake, fire, flood, among others) (Dimuna, 2010; Oyeyemi et al., 2020). Reports had shown that most of the failures in Nigeria (when classified in terms of geological settings) occurred in sedimentary environments (Awoyera et al., 2021; Ede, 2010; Odeyemi et al., 2019; Okagbue et al., 2018; Oseghale et al., 2015). To properly understand the nature of the near-surface structures before the construction of any civil engineering structure, it is imperative to carry out a geophysical survey at the subsurface to determine its competence or suitability (Hammed et al., 2018).

The two major subsurface investigations before construction activities are conceptual and detailed subsurface investigations (Hammed et al., 2017). The former entails checking some surficial features (such as sinkholes, cavities, old fill, or slopes) before construction activities. However, the latter entails thorough checking of near-surface features, which could be achieved by conducting a geophysical survey and geotechnical test in such an environment (Mayne et al., 2001). Geotechnical investigations have been proved to be acceptable in that information such as soil structures, soil compositions, lithologic profiles and the soil bearing capacity could be determined by using geotechnical tests (Oyeyemi et al., 2020). However, these methods of investigation are not without their shortcomings in that they are cumbersome, very invasive and non-environmental friendly (Mohd et al., 2012). In recent times, geophysical techniques have been used to investigate the condition of the subsurface for construction purposes (Adegbola et al., 2012; Azahar et al., 2018; Obare et al., 2020; Rasul et al., 2015; Soupios et al., 2007). These methods have proven to be very reliable, non-destructive, environmentally friendly and less expensive. This approach can also give information on the lateral variation in the geologic condition of the subsurface with depth (Adewoyin et al., 2021). Bacic et al. (2020) opined that the adoption of a geotechnical test is limited by the cost and time required to carry out a significant subsurface investigation in comparison to a geophysical survey. Furthermore, the information provided by vertically drilled boreholes for the geotechnical survey is solely restricted to the point of investigation as the sub-vertical features that are parallel to the axes of drilled boreholes are undiscovered (Balia & Manca, 2019). In contrast, geophysical techniques have revealed the properties of the subsurface rock mass in non-invasive and non-devastating ways (Bacic et al., 2020). George et al. (2015) demonstrated that aquifer's hydraulic parameters could be estimated from geophysical methods. Also, the effectiveness of the seismic refraction method for geotechnical investigations had been demonstrated by some authors both in soft terrain and in hard terrain (Aka et al., 2018; Bacic et al., 2020; Bawuah et al., 2018). Due to these qualities, geophysical techniques possess a favourable information-to-cost ratio (Adewoyin et al., 2019; Balia & Manca, 2019). However, geophysical surveys are not to replace geotechnical investigations, when the latter is not available geophysical methods could be effectively used for subsurface characterisation (Tezcan et al., 2009).

Several geophysical methods (such as electrical resistivity, seismic refraction, magnetics, gravity and electromagnetics) have been adopted for geostructural surveys (Adegbola et al., 2012;