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Estimating radioactivity flux in tropical soils: a strategy for plant survival policy, environmental balance and human – animal - ecosystem nexus wellbeing

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Abstract
The experiment investigated the vertical distributions of natural radionuclides ^{232}Th, ^{226}Ra and ^{40}K as well as anthropogenic radionuclide ^{137}Cs in soil samples and analyze the correlation among the radioactivity of these radionuclides in relation to the geo-properties (elevation, longitude and latitude of the area). The radioactivity flux of the area indicated that there exist variation in the intensity of the radionuclides in the area with all sites of investigation having different variability status that falls in threat potential for human-animal-environmental sustainability. The Gamma ray energy (KeV) of the area varied between 192.21 KeV – 1100.29 KeV indicating a view that the area holds a concern status of been problematic to the sustainable development of human-animal-ecosystem wellbeing. Policy recommendations from field observation include that the area should be place under reserved forestry system as a green approach for the reclamation of the area, including reduction in the negative human attitude toward indiscriminate mineral exploitation including mining and quarrying.

Keywords
Radioactivity; Radioactive flux; Strategy; Survival Policy; Environmental balance

Introduction

Humanity has faced series of problems including environmental degradation and various flux of pollution including CO_2 pollution increase (Adiaha et. al., 2020; Adiaha et. al., 2022b). Increased human-animal ill-health, death, mutation and environmental contamination with radioactivity has been huge over this present century. The influence of radioactivity has a wide implication in all aspect of humanity, has it has been widely recognized especially in the food, climate, environmental and in the health sectors (Szerbin et. al., 1999). Natural and artificial radioactive isotopes are host in the environment and it is capable and has transmitted radioactivity into the earth-system properties (Navas et. al., 2011), among other natural systems, thereby increasing environmental degradation and impact on human and animal health (UNSCEAR, United Nations Scientific Committee on the Effects of Atomic Radiation, 2008; Michalik et al., 2013; Sandeep et al., 2009; Shomar et al., 2013; Adiaha et al., 2022).

Radionuclides with different biogeochemical processes and important movability can influence the environment through bioaccumulation and are hazardous for the environment, human-animal health sustainability nexus and beyond (Hannan et. al., 2015). The radioactive isotopes in the environment causes the external radiation dose to human organisms, while the isotopes integrated by inhalation and ingestion

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are the origin of the internal radiation dose which has for long debase and still playing a detrimental role in human- animal environment-nutrition deterioration nexus (Velzen, 2015). Dosage effect relationships of radioactive materials in environmental biology and in human biological system have helped to increase knowledge about the risks associated with radiations and have played an important role in developing radiation protection regulations across the globe (Guagliardi et al. 2016; Bryan, 2009; Walther and Gupta, 2015; Mesrar et al., 2017; Al-Sulaiti et al., 2016)

Soil radioactivity impede crop production and also act as a threat to human health and sustainability. Most soils including limestones may have relatively little to high radioactive content concentration which may affects the soil functionality. Soils might fluctuate in its radioactive content as the influence of its physiochemical characteristic fluctuates (Szerbin et. al., 1999). Earth-system properties like soil characteristics plays a critical role in life substantiating activities including playing a crucial role in radioactivity regulation in soils (Baskaran, 2011; Velzen, 2015). For example the risk from Cs-137 varies with its diffusion rates in soil. If Cs-137 migrate slowly in soil, the internal irradiation will be higher due to higher absorption by plants roots especially from the top surface of 5 cm depth (Baskaran, 2011). However, if Cs-137 diffuse rapidly, the external radiation will be less as in this case. The uppermost soil surface acts as a shield against radioactivity found in deeper soil layers (Belivermis, 2012), in-line with this understanding the need for effective soil management becomes imperative and holds high value for sustainable management of environmental radioactivity. Against the many problems debasing humanity that relate with radioactivity flux in soil, this experiment addressed the following objectives:

1. Estimate Radioactivity Flux in Tropical Soils of Abuja
2.X-ray the distribution of radioactive nucleus in soils of the study area
3.Present Policy guides for Radioactivity monitoring as a Strategy for Plant Survival Policy and Environmental Balance.

Materials and methods

The Study Area: Geography of Abuja, the Federal Capital Territory (FCT)

The Federal Capital Territory (FCT) is a relatively new creation of the Federal Government of Nigeria sequel to a decision in 1975 to relocate the seat of the central government to Abuja, a city within the FCT, from the former capital city of Lagos. The seat of government formally moved to the area in the December of 1991 (James et. al., 2013). In-between when the idea was born until the first phased movement, the FCT much like other modern new cities was elaborately planned to house and host all expected paraphernalia of the Federal Government and supporting infrastructure including industrial development (James et. al., 2013). The Territory is still in its formative stage as infrastructural development is carried out through a planned and step wise implementation of approved master plan. So, area layouts mapped for hosting industrial infrastructure are also being gradually inhabited. With a land area of 8,000 square kilometres and located within latitude 7º25' N and 9º20' North of the Equator and longitude 5º45' and 7º39' (James et. al., 2013), there are two main types of soils in FCT; the sedimentary belt in the southern and south-western extremities of the territory and the pre-Cambrian Basement complex rock country which accounts for more than 80 percent of the territory (James et. al., 2013). The specific location of the experiment (the University of Abuja) is as presented in Figure 1.

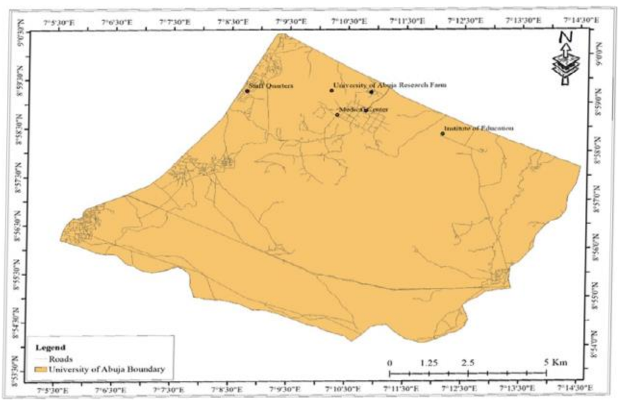

Figure 1. *Study area map.*

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Activities in the Study Area

The area is being exposed to various kind of local crude mining activities. This mining activities include stone quarrying, heavy engineering land excavation processes including areas where indiscriminate and unsorted waste is being deposited.

Experimental Design

The study took the form of exploratory field technique where the area was stratified into four (4) Strata and reconnaissance field survey done to map experimental positions and points of data collection

Modelling and Statistical Analysis

The area was modelled, interpolated to find spatial radioactivity distribution and for the production of analytical graphs and map. Descriptive and exploratory statistics was applied in the study

Laboratory Analysis and Soil Sample Processing

Soil sampling was at a depth of (0–16 cm) respectively for all the four (4) Strata. The collected sample were processed and used to x-ray the radioactivity levels.

Experiment: Radioactivity Concentration

Soil sample at depth of (0–16 cm) was collected, where the radioactivity levels of the radionuclide in the soil samples were determined by Geiger Muller Counter, the data obtained from the Muller Counter was transfer to computer Canberra Genie 2000 spectroscopy software. The weighted mean radioactivity level of 226Ra, 232Th, 40K and 137Cs in the soil depth levels (0–1 cm), (1–6 cm), (6–11 cm), and (11–16 cm) were determined. Radioactivity experimentation was done following the guides as expressed by UNSCEAR, United Nations Scientific Committee on the Effects of Atomic Radiation (2008).

<u>Results and Discussion</u>

Soil Radioactivity Flux

The levels of Radionuclide, Half-life, Gamma ray energy (KeV) and Progeny Radionuclide of the experimental site as presented in Table 1 indicated that the area holds threat for sustainable environmental sustainability and human-animal health sustainability. It was observed that at strata 1in Station 1 a Gamma ray energy (KeV) value of 192.21t KeV was recorded which indicated that the soils at that location holds a contributory factor to radioactivity threat in the area. Station two soils produced a KeV value at 151.31 which indicated that the soils of the area also holds a radioactive potential for the threat observed in the area. The KeV value observed for Station 3 of Strata 1 indicated that the site holds a value at 309.31 for Gamma ray energy (KeV) in the soils. The behaviour of the soils at Strata 2 Station 1 indicated that the soils of the area holds great threat for human-environmental sustainability with a Gamma ray energy (KeV) value observed at 1100.29. The Gamma ray energy (KeV) value for Station 2 of Strata 2 produced a radioactive Gamma ray energy (KeV) at 1038.11, while Station 3 of the same Strata produced soils with Gamma ray energy at 678.36. Field observation and radioactivity analysis revealed that Strata three produced a radioactive value of 221.32 Gamma ray energy at Station 1 while 311.6 KeV and 461.6 KeV was produced for Station 2 and 3 respectively. Strata 4 produced a Gamma ray energy value at 331.23 KeV including 128.61 respectively. Outcome of this findings agrees with the research of (UNSCEAR, United Nations Scientific Committee on the Effects of Atomic Radiation (2008); Pumpanen et al. (2016) which indicated flux of radioactivity in soils and environment as a natural system.

Spatial distribution of radioactivity of the study area

The spatial distribution of the radioactivity in the area presented in Figure 2 indicated that area with high evaluation varied widely in their radioactivity flux, with the highest radioactivity flux been observed in Experimental station one as presented in Figure 2 . Findings of this study agrees with the research of Michalik et. al. (2013); Walther and Gupta (2015); Velzen (2015); Szerbin et. al. (1999); Navas, et. al. (2011) where they stated radioactive variability in in soils as natural mediums.

Variation influence between elevation, experimental stations and Gamma ray energy emanating from the area

Analysis output presented in Figure 3 indicated that the area varied greatly in the flux of it radioactivity due to the earth-system properties that exist in the area. The output of the experiment indicated the area holds threat points which was observed as red spot in the analysis output as indicated in Figure 4, 5 and 6 below. The variability outcome reported in this finding is in-line with the research findings of UNSCEAR, United Nations Scientific Committee on the Effects of Atomic Radiation (2008) which stated variation in radioactivity rate in soils and environment.

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Table 1. *Soil radioactivity flux*

Latitude	Longitude	Elevation (m)	Experimental station	Strata	Radionuclide	Half-life (yr.)	Gamma ray energy (KeV)	Progeny Radionuclide
8.983139	7.180917	284	1	1	226Ra	1650	192.21	214Pb
8.981389	7.177806	264	2				151.31	214Pb
8.979833	7.176528	261	3				309.31	214Bi
8.975778	7.168500	252	4	2			1100.29	214Bi
8.976694	7.169278	269	5				1038.11	214Bi
8.971639	7.174667	275	6				678.36	214Bi
8.972861	7.188944	293	7	3	^{232}Th	$1.405*10^{10}$	221.32	^{228}Ac
8.976917	183000	283	8				311.6	228Ac
8.976972	7.181639	275	9				461.6	^{228}Ac
8.981639	7.193583	284	10	4			331.23	^{228}Ac
8.983722	7.177444	272	11				128.61	^{212}Pb
8.985222	7.175778	277	12		^{40}K	$1.278*10^{9}$	1230.81	40Ar
8.987972	7.175778	272	13		^{137}Cs	30.1	211.66	^{137}Ba

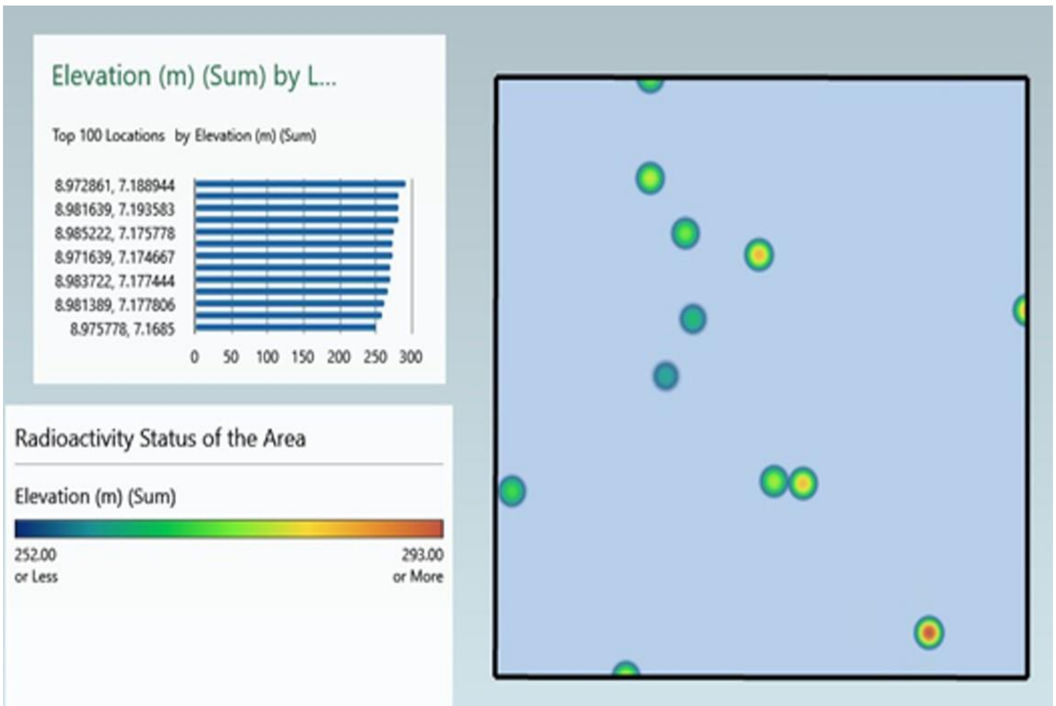

Figure 2
Spatial distribution of radioactivity of the study area

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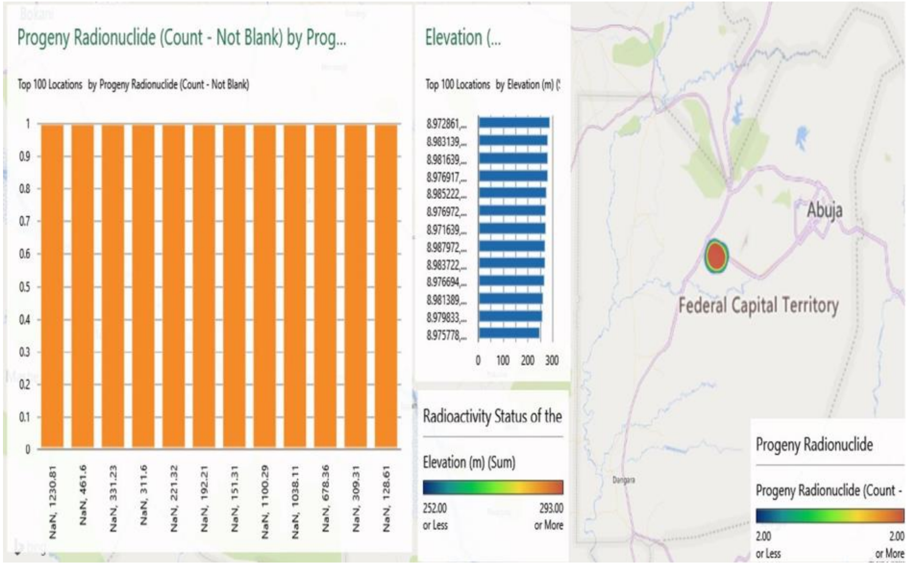

Figure 3: *The impact and radioactivity influence in the study area*

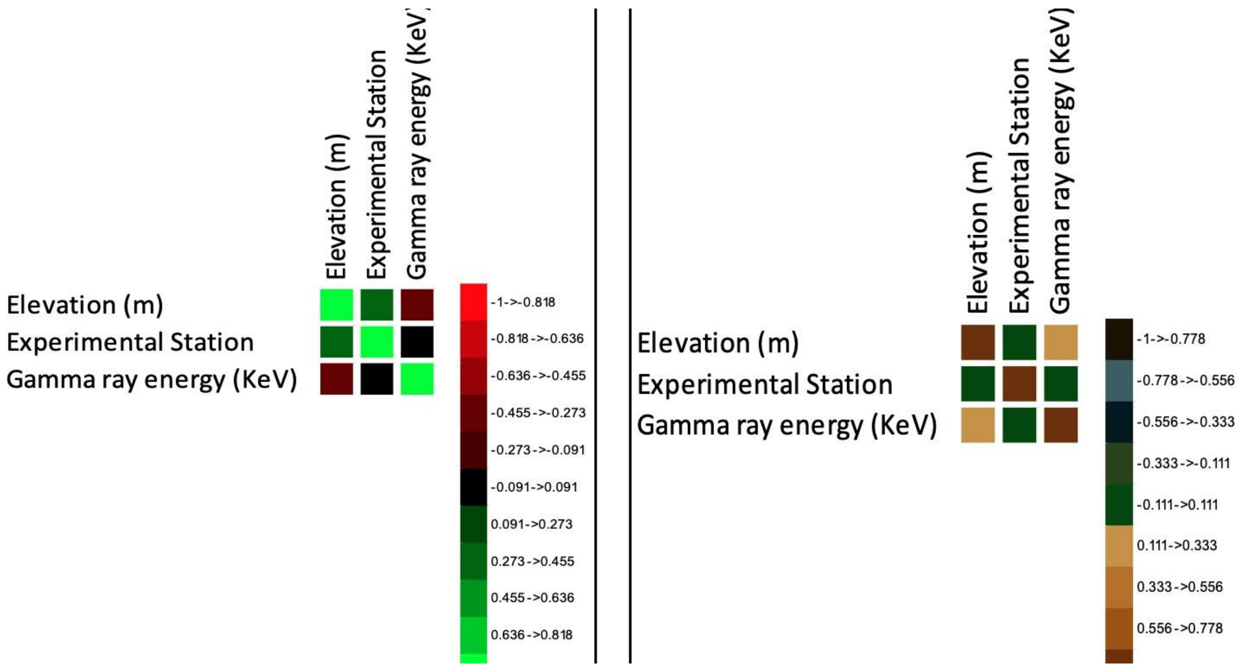

Figure 4. *Variation influence between elevation, experimental stations and Gamma ray energy emanating from the area*

Projection on the trend of Gamma ray energy (KeV) in 3 years interval

The behavior of the radioactivity of the area as presented in Figure 7, 8, and 9 indicated that increase is expected in the area as the years goes by, where significant increase at 95.0 % of probability level indicated rapid increase in the radioactivity of the area across the sites of investigation.

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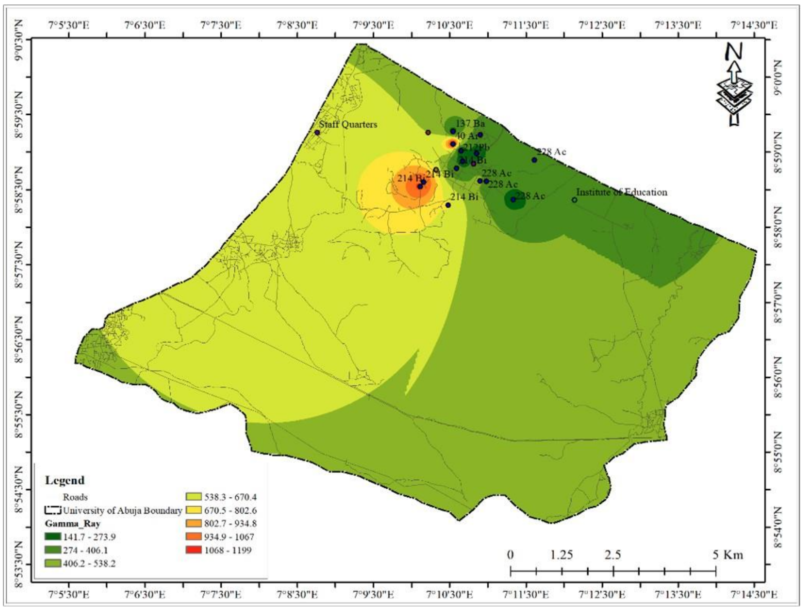

Figure 5. *The radioactivity flux in tropical soils*

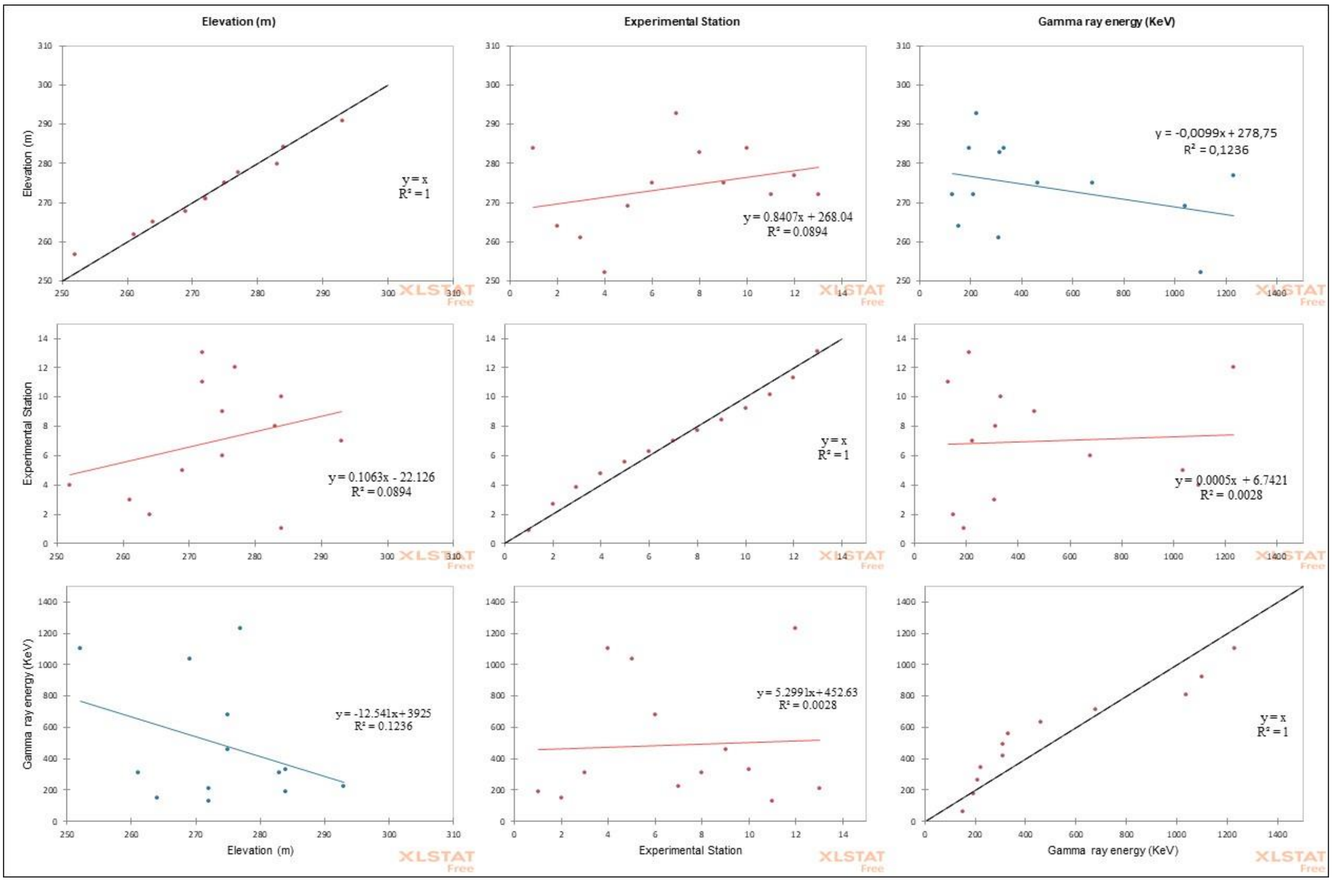

Figure 6. Variation influence between elevation, experimental stations and Gamma ray energy emanating from the area.

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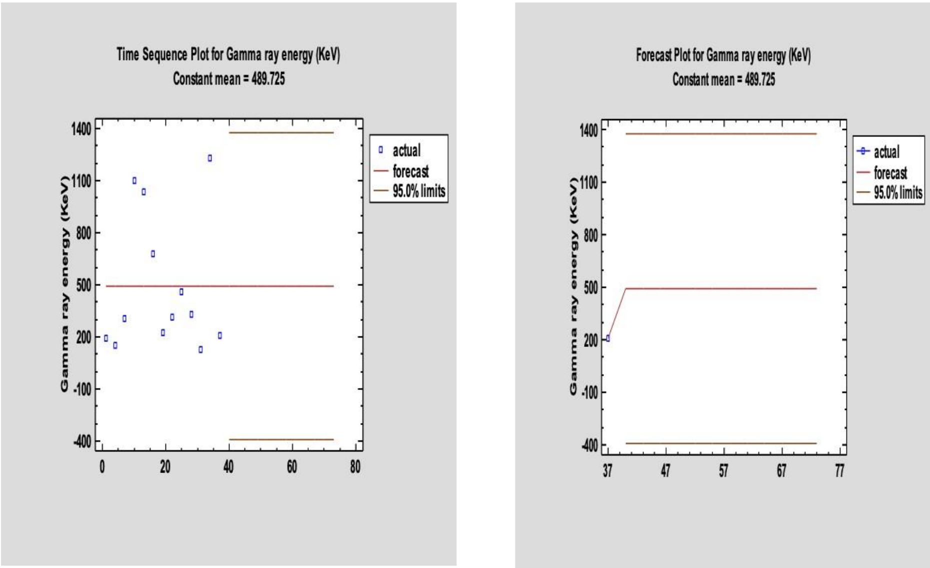

Figure 7. *Projection on the trend of Gamma ray energy (KeV) in 3 years interval.*

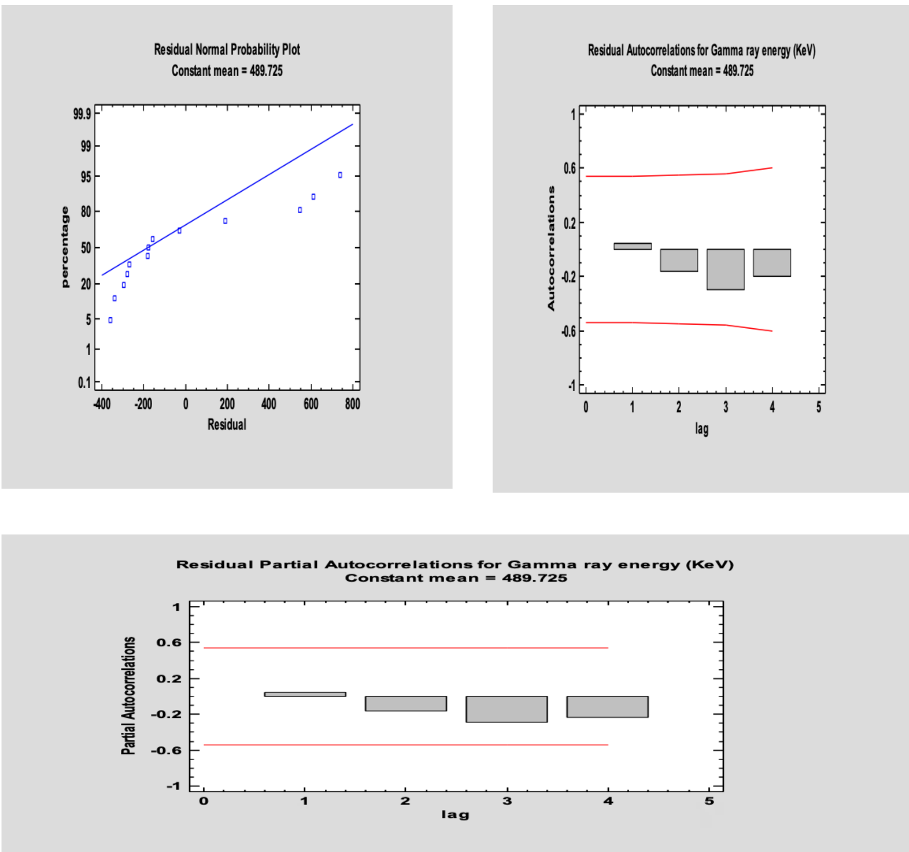

Figure 8. *Projection on the trend of Gamma ray energy (KeV) in 3 years interval.*

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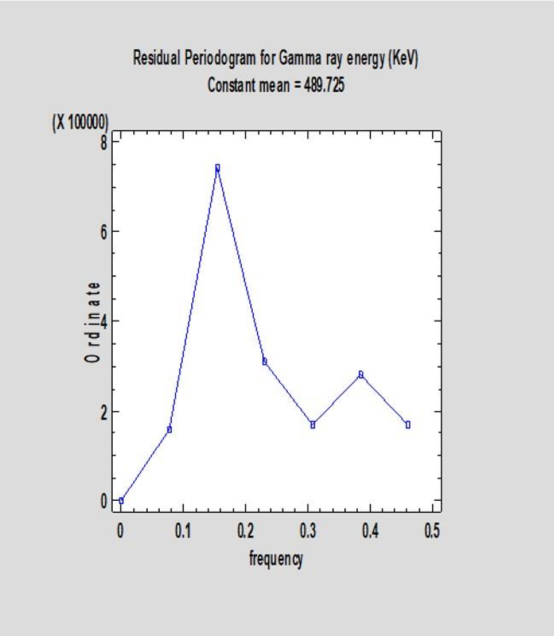
Outcome of this study agrees with the research of Wang et. al. (2016); UNSCEAR, United Nations Scientific Committee on the Effects of Atomic Radiation (2008) where their studies indicated anticipated increase in the trend of radioactivity in the environment with the increase in natural and anthropogenic phenomena in the earth planet.



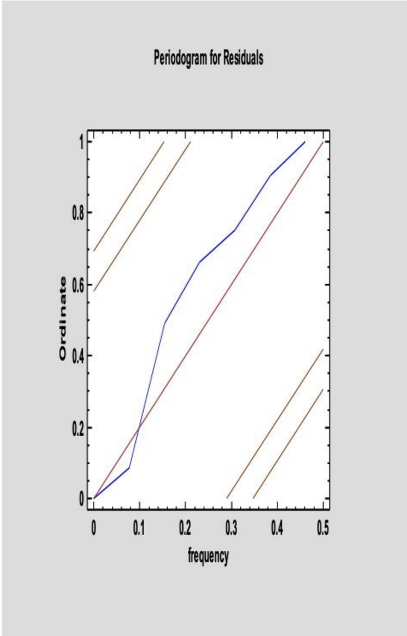


Figure 9. *Projection on the trend of Gamma ray energy (KeV) in 3 years interval*

Implication of the observed radioactivity trend for policy development for plant survival strategy and environmental balance

1.The area and its environs have been shown to be of a toxic nature for sustainable plant survival and Environmental Balance, hence the need for sustainable remediation strategy

2.Human settlement found in the area could be advised to be relocated especially in place with high radioactive wave flux.

3.Ecosystem regeneration in the area could be play a mitigative role in cutting down the radioactive frequency of the area.

4.The human attitude toward indiscriminate mineral exploitation mining and environmental pollution with the release of waste in the area could be reduced

5.The area should be place under reserved forestry system as a green approach for the reclamation of the area

Conclusions

Result of this findings concludes that the radioactivity concentration levels of the natural radionuclides ^{226}Ra, ^{232}Th and ^{40}K vary substantially in each location site depending primarily on the concentration of radionuclides in bedrocks from which the soil originates.

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Author's Contribution

M. S. Adiaha designed, conducted experiment, analyzed data and wrote the research paper.

References

ADIAHA M.S., BUBA A.H., TANGBAN E.E, OKPOHO A.N. (2020) Mitigating Global Greenhouse Gas Emission: The Role of Trees as a Clean Mechanism For CO2 Sequestration, The Journal of Agricultural Sciences, 15(1):101-115. http://doi.org/10.4038/jas.v15i1.8675

DOI: 10.6092/issn.2281-4485/15681

ADIAHA M.S., CHUDE V.O., NWAKA G.I.C., OKU E.E. (2022a) Carbon auditing in tree-soil nexus: a sustainable approach towards CO_2 sequestration and environmental transformation. EQA - International Journal of Environmental Quality, 48(1):1–9. https://doi.org/10.6092/issn.2281-4485/13838

ADIAHA, M. S, CHUDE, V. O., AGBA, O. A., NWAKA, G. I. C., and OKU, E. E. (2022 b). Mapping soil organic carbon-soil biodiversity variability in the ecosystem-nexus of tropical soils. EQA - International Journal of Environmental Quality, 50, 1–19. (ISSN2281-4485) https://doi.org/10.6092/issn.2281-4485/14617

AL-SULAITI, H., TABASSUM NASIR, K.S. AL MUGREN, N. ALKHOMASHI, N. AL-DAHAN, M. AL-DOSARI, D.A. BRADLEY, S. BUKHARI, M. MATTHEWS, P.H. REGAN, T. SANTAWAMAITRE, D. MALAIN, A. HABIB, HANAN AL-DOSARI, IBRAHIM AL SADIG, EMAN DAAR, (2016). Determination of 137Cs activity in soil from Qatar using high-resolution gamma-ray spectrometry. Radiation Physics and Chemistry, 127: 222-235. https://doi.org/10.1016/j.radphyschem.2016.07.003

BASKARAN M. (2011) Handbook of environmental isotope geochemistry. Heidelberg: Springer

BELIVERMIS M. (2012) Vertical distributions of 137Cs, 40K, 232Th and 226Ra in soil samples from Istanbul and its environs, Turkey. Radiation Protection Dosimetry. 151(3):511–521. https://doi.org/10.1093/rpd/ncs023

BRYAN J.C. (2009) Introduction to nuclear science. Boca Raton , CRC Press.

GUAGLIARDI I., ROVELLA N., APOLLARO C., BLOISE A., DE ROSA R., SCARCIGLIA F., BUTTAFUOCO G. (2016) Effects of source rocks, soil features and climate on natural gamma radioactivity in the Crati valley (Calabria, Southern Italy). Chemosphere, 150:97-108. https://doi.org/10.1016/j.chemosphere.2016.02.011

HANNAN M., WAHID K., NGUYEN N. (2015) Assessment of natural and artificial radionuclides in Mission (Texas) surface soils. Journal of Radioanalytical and Nuclear Chemistry, 305(2):573–582. https://doi.org/10.1007/s10967-015-4018-4

JAMES I. U., MOSES I. F., VANDI, J. N. (2013). Assessment of Gamma Dose Rate within Idu Industrial Area of the Federal Capital Territory (FCT) Abuja, Nigeria. The International Journal of Engineering and Science (IJES), 2(11):52-55. ISSN (e): 2319 – 1813

MESRAR H., SADIKI A., FALEH A, QUIJANO L., GASPAR L., NAVAS A. (2017) Vertical and lateral distribution of fallout 137Cs and soil properties along representative toposequences of central Rif, Morocco. Journal of Environmental Radioactivity. 169-170:27-39. https://doi.org/10.1016/j.jenvrad.2016.12.012 .

MICHALIK, B., BROWN, J. & KRAJEWSKI, P. (2013). The fate and behaviour of enhanced natural radioactivity with respect to environmental protection. Environmental Impact Assessment Review. 38:163–171. https://doi.org/10.1016/j.eiar.2012.09.001

NAVAS A., GASPAR L., LÓPEZ-VICENTE M., MACHÍN J. (2011) Spatial distribution of natural and artificial radionuclides at the catchment scale (South Central Pyrenees). Radiat. Meas., 46(2):261–269.

PUMPANEN J., OHASHI M., ENDO I., HARI P., BÄCK J., KULMALA M., OHTE N. (2016). 137Cs distributions in soil and trees in forest ecosystems after the radioactive fallout – Comparison study between southern Finland and Fukushima, Japan. Journal of Environmental Radioactivity, 161:73-81. https://doi.org/10.1016/j.jenvrad.2016.04.024 .

SANDEEP S., MANJAIAH K. M., SACHDEV P., SACHDEV M.S. (2009) Effect of nitrogen, potassium and humic acid on 134Cs transfer factors to wheat from tropical soils in Neubauer growth units. Environmental Monitoring and Assessment, 149(1-4):43–52. https://doi.org/10.1007/s10661-008-0181-1

SHOMARB.,AMRM.,AL-SAADK.,MOHIELDEEN Y. (2013) Natural and depleted uranium in the topsoil of Qatar: Is it something to worry about? Applied Geochemistry, 37:203–211. https://doi.org/10.1016/j.apgeochem.2013.08.001

SZERBIN P., KOBLINGER-BOKORI E., KOBLINGER L., VÉGVÁRI I., UGRON A. (1999) Caesium-137 migration in Hungarian soils. Science of The Total Environment, 227(2-3):215-227. https://doi.org/10.1016/S0048-9697(99)00017-0

DOI: 10.6092/issn.2281-4485/15681

UNSCEAR - United Nations Scientific Committee on the Effects of Atomic Radiation (2008). Report to the General Assembly United Nations, New York. Annex B. 1:223–439.

VELZEN L.V. (2015) Environmental Remediation and Restoration of Contaminated Nuclear and Norm Sites. Elsevier Science, 5–276.. https://doi.org/10.1016/C2013-0-16493-8

WALTHER C., GUPTA D. (2015) Radionuclides in the Environment, Springer Cham. 61–80. https://doi.org/10.1007/978-3-319-22171-7

WANG Q., SONG J., LI X., YUAN H., LI N., CAO L. (2016) Environmental evolution records reflected by radionuclides in the sediment of coastal wetlands: A case study in the Yellow River Estuary wetland. Journal of Environmental Radioactivity. 162–163:87-96. https://doi.org/10.1016/j.jenvrad.2016.05.015