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A Theoretical Model Of Health Implications Due To Potasium-40 Prevalence In Sokoto Basin: A Case Study Of Dange-Shuni

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***Abstract*—Potasium-40 is very prominent within the Sokoto Basin due to its occurrence in Phosphate compounds that have a traceable antecedent in the Basin. Its hazard is a formidable threat to life forms as a result of potential radioactivity that it emits. A sizable portion of Dange-Shuni has long been found as a regional land mass known for Phosphate mining. The entire location of Phosphate prevalence was spotted out and equally sampled for its potential health effect on the inhabitants and theoretically examined. Though the radiological impact within the region is significant due to mining activities and relative cultural practices by the inhabitants, undermining the future occurrence due to further potential exposure without acknowledging the radiological data could be detrimental to the lives of the inhabitant. Hence this paper delves into theoretical modeling of the health implication of the Potasium-40 occurrence in the study locality by developing a virtual laboratory using MATHLAB to analyze the implications.**

Keywords—Potasium-40, Health, Radioactivity, MATHLAB, Sokoto-Basin.

I. INTRODUCTION

Potasium-40 is one of the heaviest radioactive element that can be naturally present in some compounds and ground-water [1][2][3]. In a study reported by Taylor, (1964) it was said that Potassium is one of the major rock-forming elements in the Earth's crust. Its concentration varies from less than 1% in limestone to several percent in granite. The average concentration in the upper crust was estimated to be around 2.1% [4][5]. Potassium-40 is a long-lived radioactive isotope (T1⁄2 = 1.25 × 109 years) with a natural abundance of 0.0117%. It has two decay modes: (i) beta decay to ^{40}Ca (89.3%) and (ii) electron captures (EC) transition to ^{40}Ar (10.7%) with emission of gamma radiation (E = 1.46 MeV) [6][7][8].

Radiation exposures arise in the mining and mineral processing industries through three principal pathways. These are external gamma radiation from ores, inhalation of dusts containing long-lived alpha-emitting radionuclides and inhalation of the short-lived decay products of radon. Inhalation of radon decay products in poorly ventilated underground mines can lead to exposures in excess of current radiation exposure limits, and this could cause high incidence of lung cancer in the mine workers or farmers who engage in tilling of soil for cultivation of crops [9][10]. There is consequently a need to adopt careful radiological control measures in mining and mineral processing operations involving radioactive ores, in order to protect those involved and to meet dose limits [11]. The need to enhance environmental as well as health safety of inhabitants must be put into consideration before unprecedented radiation exposure is ascertained. In this paper, we considered the vital need to extrapolate the available experimental result to determine the futuristic danger in order to support the model for this study's validity. This work stresses on the need to ascertain any if environmental factors could enable us to conclude on healthy status of inhabitations in the study area.

II. MODEL

A. *Model's Background*

Let us defined the soil-accumulation index of Pottasium-40 in this study, following the adoption of the theoretical validity of Sapana Guta et al., (2014) [12].

$$I_{Sacc} = \log 2\left[\frac{C_n}{iB_n}\right] \quad (1)$$

Where C_n is the concentration of the radioactive element n in fine grained fraction of the sediments; B_n is the soilaccumulative background concentration in the fraction of sediments (average soil-type value); x is the adjustment factor which provides for local lithological background values [13]. The total dose from internal intake of Pottasium-40 and other radioactive elements as summarized by World Health Organization is represented mathematically as [14].

$$D_K = \sum_i \left(\frac{C_i}{GL_i}\right) \leq 1 \quad (2)$$

where C_i is the measured activity concentration of radionuclide i, and GL_i is the guidance of radionuclide i, that, at an intake of 2 L/day1 for 1 year, will result in an effective dose of 0.1 mSv/year. The specific activity (in Bq kg^{-1}), A_{E_i}, of a nuclide and for a peak at energy E, is given by

$$A_{E_i} = \frac{N_{E_i}}{s_E \times t \times \gamma_d \times M_s} \quad (3)$$

Where N_{E_i} is the Net Peak Area of a peak at energy E, ε_E is the detection efficiency at energy E, t is the counting live-time, γ_d is the number of gammas per disintegration of this nuclide for a transition at energy E, and M_s is the mass in kg of the measured sample. The annual dose equivalent is given by [15] [16].

$$D = \sigma \mu t \quad (4)$$

Where D is the annual absorbed dose rate in micro sievert per year, σ is the absorbed dose rate in micro sievert per hour. μ is the occupancy factor which is given as 0.2 and t is the time in hour. Equation[1-4] gave rise to three basic equations [5-8]

$$D_u = \exp(I_{Sacc}) \sum_i \left(\frac{i}{2}\right) \quad (5)$$

Where $i < 2$

$$\sigma = \frac{\exp(I_{Sacc}) \sum_i \left(\frac{i}{2}\right)}{\mu t} \quad (6)$$

$$\gamma_d = \frac{N_{E_i} \sigma \mu \exp(I_{Sacc})}{A_{Ei} \varepsilon_E M_s \sum_i \left(\frac{i}{2}\right)} \quad (7)$$

From the dispersion of contaminants discussed by [17][18], equation [7] can be written as

$$\gamma_d = \frac{V \cos(\beta) V_y}{V_z} e^{\left(\frac{4x}{k_z + k_{z2}}\right)} \quad (8)$$

Here we will then transform Equation [3] to

$$A_{Ei} = \frac{N_{E_i} \sigma \mu}{V \cos(\beta) \varepsilon_E \sum_i \left(\frac{i}{2}\right) M_s} \quad (9)$$

III. METODOLOGY

To test the theoretical validity of the equations above we created a virtual laboratory using MATHLAB to analyze the mathematical implications of the mathematical expression given in equation (5-9). The assumption is that potassium-40 concentration in the ground water, soil and rocks decays under the catalyst of natural factors which leads to a partial emission of gamma radiations into the atmosphere. Equation [8&9] is the rate of dispersion of gamma radiation into the atmosphere which is expressed as the 'soilaccumulation index'. Theoretically, we narrow the work to Dange as illustrated by the maps in figure 1 & 2.

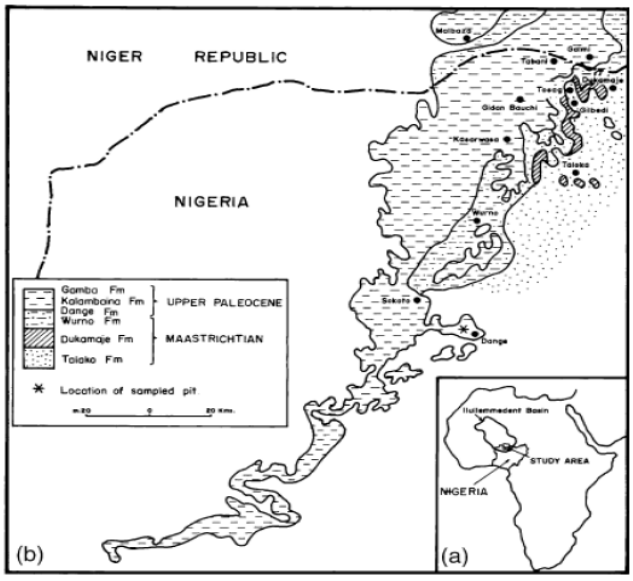


Figure 1. Map of Prominent Phosphate rock formation across two countries: Nigeria and Niger Republic. Extending into three states of Sokoto, Kebbi and Zamfara States in Nigeria.

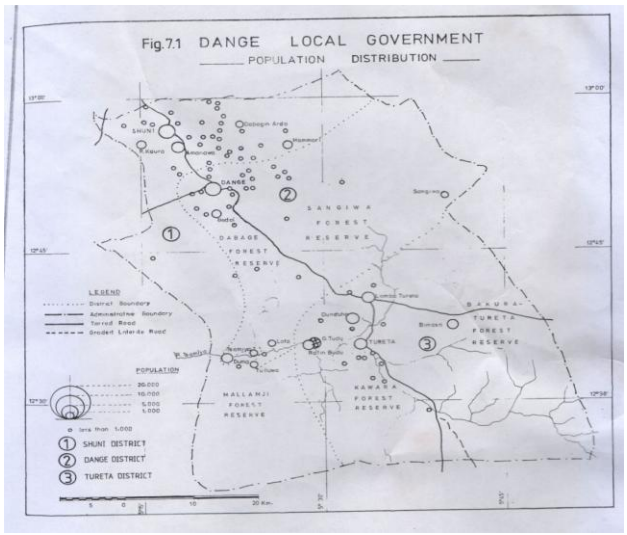


Figure 2: Map of Dange-Shuni Local government, Sokoto State.

IV. Result and Discussion

The parameter for the dispersion of gamma-rays was analyzed at various hazard levels. This was only possible by comparing equations [7] & [8] as given below,

$$\frac{4x}{k_z + k_{z2}} = I_{Sacc} \tag{10}$$

$$\sigma = \frac{V_z N_{E_i \mu}}{A_{E_i} \varepsilon_E M_s \cos(\beta) V_y \sum_i (\frac{i}{2})} \tag{11}$$

In order to solve for the Klein–Nishina formula, we multiply both sides by the acceleration due to gravity (g). But here (g) is a function of Soil accumulation in consideration of the radionuclide Potassium-40. Therefore,

$$\sigma = \frac{V_z N_{E_i \mu}}{{}_g \Omega A_{E_i} \varepsilon_E M_s \cos(\beta) \sum_i (\frac{i}{2})} \tag{12}$$

Where Ω is the volume of the dispersed gamma radiation. We therefore differentiate both sides with respect to Ω

$$\frac{d\sigma}{d\Omega} = -\frac{V_z N_{E_i \mu}}{{}_g \Omega^2 A_{E_i} \varepsilon_E M_s \cos(\beta) \sum_i (\frac{i}{2})} \tag{13}$$

From the Klein–Nishina, it is evident that equation (12) reduces to

$$V_z N_{E_i \mu} = {}_g \Omega^2 A_{E_i} \varepsilon_E M_s \cos(\beta) \sum_i (\frac{i}{2}) \tag{14}$$

The gamma radiation dispersion analysis was carried out under five conditions i.e. $I_{Sacc} = 0.1, I_{Sacc} = 0.2$, $I_{Sacc} = 0.3$, $I_{Sacc} = 0.4$, $I_{Sacc} = 0.5$, as shown in figure [3] below. The dispersion analytical model was in true agreement with experimental results. Line 'a' represents the soilaccumulation index at 0.1. Line 'b' represents the soilaccumulation index at 0.2, presently no region of the country falls within the group a & b. Line 'c' represents the soilaccumulation index at 0.3, the experimental field work of Ahijjo et al., (2014) shows that Dange-Shuni North-west Nigeria belongs to group 'c'. This was compered to the study carried out by Avwiri et al., (2012) [19], within south-south of Nigeria which belongs to the group 'c'. Line 'd' and represents the soilaccumulation index at 0.4, the experimental field work of Arabi *et al.* (2013) [20] shows that Kundiga and Yimirdallang, North east Nigeria belongs to group 'd' . Line 'e' represents the soilaccumulation index at 0.5, the experimental field work of and Lar (2013) [21] shows that Barkin Ladi, Jos Plateau, north central Nigeria belong to group 'e'. Low soilaccumulation index was chosen because it is assumed that the gamma dispersion is not from the uranium mill but from the rocks, soil and ground water within as could be thought of in Dange-Shuni area. The result below shows that the increase of the soilaccumulation index beyond 0.5 is eminent. This may be detrimental to the health of the people in such area. Also, the higher the volume of radiation, the intense it is for life forms. At this low geothermal index, cases of kidney malfunction alongside cancer in both adult and children have increased in hospitals [22][23][24]. The good thing is that the higher volume of gamma dispersion do not travel very far (as shown in figure. 3) unlike pollution from anthropogenic sources.

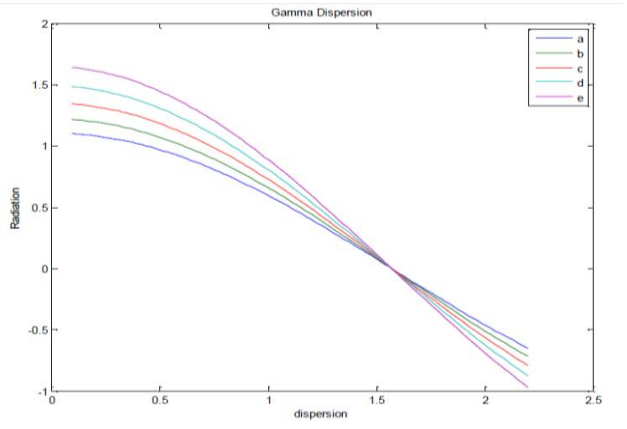
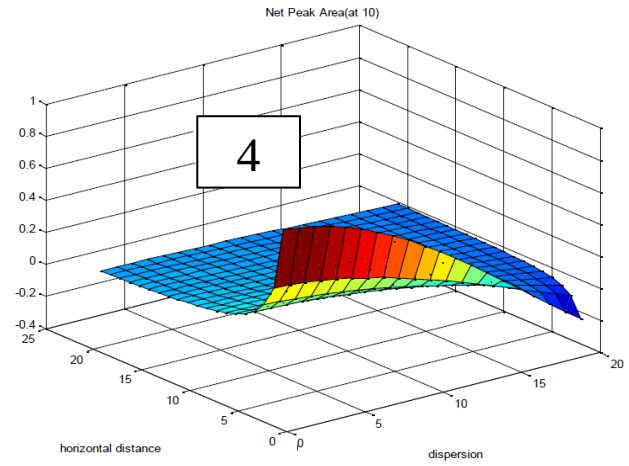
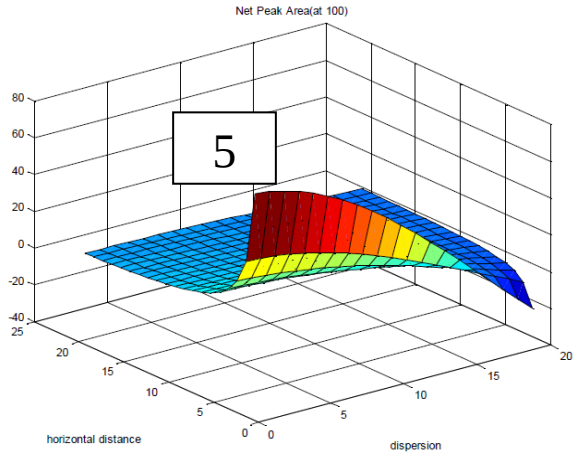


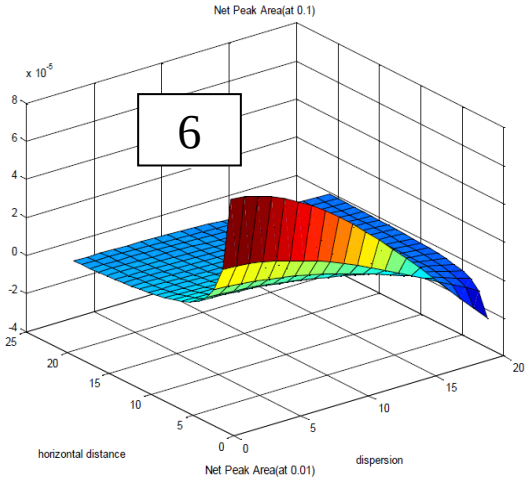
Figure 3: Gamma radiation dispersion within an energy range of 0 - 2.5KeV

To confirm the results in figure [4], we investigate the Net Peak Area at a distance range 0- 25km. We then adopted the Adewole *et al.* (2011) distances to see the variation difference between a theoretical and experimental data in order to know the accuracy of our model. We assumed a detection efficiency of 20%

and acceleration due to gravity in Dange to be 9.81m/s^2. The volume was tested at 0.01m^3, 0.1m^3, 10m^3 and 100m^3 yielding the dispersions of the three dimensional models as shown below;







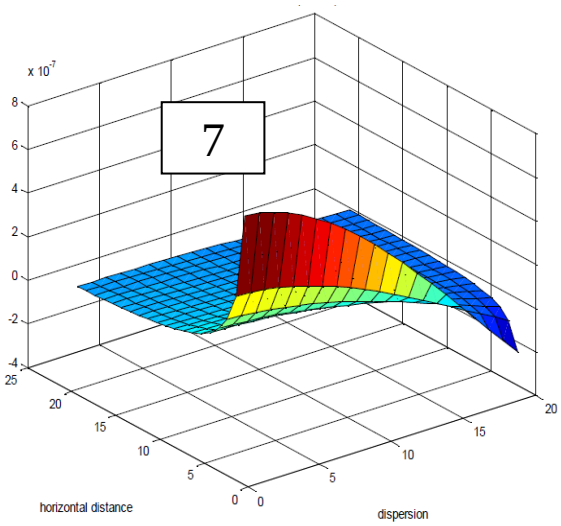


Figure (4-7): Net Peak Area analysis at varying distances

The general feature of figures [4-7] seems alike. The detail analysis of each figures corroborate with the findings in figure [3]. Firstly, figures [4-7] shows that the dispersion of gamma radiation is dependent on the net peak area. Secondly, it also shows that gamma pollution is localized. This means that far neighboring communities from affected zone may not be excluded from unsafe contamination. Thirdly, a two way directional movement of dispersion is notices which might as a result of the atmospheric deflection force known as the Coriolis force lead to significant health risk. The distinct difference in the features of figure [4-7] is the decrease in the Net peak area as the volume of gamma dispersion decreases.

A. CONCLUSSION

The dispersion of the bye-products of Potassium-40 (gamma and radon gas) is directly proportional to the Net Peak Area and inversely proportional to the propagating distance. The spread of both the radon gas and gamma ray seem to be localized. The investigation into spot deposition of Potassium-40 in parts of Nigeria and its effect has shown that governments in developing countries may not be aware of the need to control future radiological ambient pollution from anthropogenic radioactivity. Already, through illegal mining, some parts of the country like Zamfara and Niger states are already suffering. The first step towards achieving health safety of ambient air has long been neglected holistically analyzing the safety parameters in air, water, vegetation and land of all the regions of the country. Hence, we conclude that further study need to be encouraged to unveil other stones untouched in regards to health implication of relative environmental radioactivity exposure.

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