Advances in Life Science and Technology
ISSN 2224-7181 (Paper) ISSN 2225-062X (Online)
Vol 6, 2012

Gamma Ray Assessment of Subsurface water-Rock interaction in Abuja from Geologic Background and Its Effect in Groundwater, Nigeria (Review Article)

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Abstract: The radiometric interpretation of geologic data is aimed at mapping the concentration of Uranium, Thorium and Potassium and its effect in groundwater in subsurface rock formations. The water has been consumed without treatment and during drilling, the process cut across so many rock formations. The Uranium and Thorium exist in this rock formation like granite to some extent which could contaminate the groundwater system through leaching and weathering process. This study is to address the issue by determining the concentration of uranium, Thorium and potassium in the water-rock interface. The mean dose equivalent for rock samples will be obtained and determine the health implications or adverse effect on the populace and the environment. The methodology will include drilling of boreholes measuring 40m, 50m, 60m and 70m in depth using 30ton capacity Rig machine. Samples obtained during cutting and coring will be analyzed using High Resolution Gamma Spectroscopy. From the 3D model, it indicates the linear relationship in water-rock lithologic structure. The linear relationship between unit volume of granite, hydraulic gradient and hydraulic conductivity is inferred to be the effect of tectonic activity during Pan African Orogeny in Nigeria.

Keywords: Geologic Map of Abuja, 3D Model of (hydraulic conductivity; Unit Volume of Granite and hydraulic gradient)

1.0 Introduction

The main objective of radiometric interpretation of geologic data and its effect in groundwater is to map the radioelemental concentrations of uranium, Thorium and potassium in the subsurface rock formation. The total activity is not only used for geological mapping but also by health physicist for acquiring on the distribution of radiation exposure rates and risk in groundwater consumption

Generally, the underlying bed-rocks and minerals of the earth crust constitute the geology of a location are known to contain natural radioactive elements at varying concentrations and depends on lithology, geomorphology and other geological conditions of the region. (Mahesh, 2001). The concentration also varies seasonally with the nature of the geological formation (Moel et al., 1972).The presence of ionizing radiation in the natural environment was noted in 1899 and was assumed to originate from radioactivity in environmental materials like rivers, groundwaters, soils and rocks (Lowder,1990). The radionuclides are present in earth's crust (Evans, 1969) and are distributed everywhere in all soil and rock in different concentration. Phosphate rock contains uranium and its daughter isotopes in concentrations far exceeding the average abundance in the earth's crust and also concentrations of Thorium and its daughter products (Jaworowski,1982). Regional and local variations in the distribution and availability of natural radioactive materials for ingestion and inhalation are related to ancient geological processes and a combination of contemporary geological stresses, atmospheric condition and anthropogenic activities.(Triumble, 1968; Redinger et al., 1974; Delune et al., 1986). Exposure of humans to nuclear radiations gives rise to absorbtion of energy by bodily organs which in turn may result in damage of critical and/or radio sensitivity organs .This study will be undertaking to measure the activity level of radionuclide in water-rock interaction in Abuja, Nigeria.

Water Problem in Nigeria

In Nigeria, the case for conjunctive use of surface and underground water supply, where available, to meet the ever increasing demand cannot be over-emphasized. In the same vein, relating the available resources to demand, the population becomes a sinequanon. The average daily, domestic water demand is estimated to range from about 70lit/person/day in the rural areas to 150lit/person/day in the urban areas and semi urban towns. Typical household water consumption in the United Kingdom quoted from 'Mordern Housing' by Tebbutt (1973)

Nigeria has obtained third position as one of the world's poorest countries in gaining access to water and sanitation. The world Health organization and UNICEF report for 2012 ranked Nigeria third behind China and India, as countries with largest population without adequate water and sanitation. "The challenge is critical as women and children trek long distance to fetch water from stream, and ponds which are most times contaminated. Also, sourcing for alternative water pushed alot in drilling of shallow wells and boreholes.

Abuja was initially developed according to a Master Plan devised in 1979. This apportioned 2.0% area for government Activity /usage, 49.0% for residential development, and 32.5% as open/green/recreational areas to add to the aesthetics of the city, with the remaining land (16.5%) being used for ancillary services, light industries, other infrastructure and commercial activities. This rapid expansion far exceeded what had been anticipated in the Master Plan, and the population of Abuja now exceeds the original design capacity for water board. In 1991 the population of the Federal capital (Abuja) was 378,671, and this had increased to 1,724,205 by 2001. Projected population figures for the Abuja region predict massive growth with 5.8 million people expected by 2026 (Federal Ministry of Environment Report, 2004). Unfortunately, the opportunity to develop Water Board in phase with city growth and in line with a pre-agreed Master Plan, was lost, and Abuja now shares many of the same problems as other Nigerian cities. From the water demand and supply situation, it is clear that another source of water is needed to defray the deficit. With this supply status quo, the continual increase in population and the building of more industries; the deficit continues to increase, as the water supply problem gets more acute, which has led to the drilling of boreholes in several residential areas as a complementary source. In this regard, people are exposed to so many water contaminants. This study will focus on detection of radioelement concentration in underlying geological formation and its risk in groundwater consumption. The detail of the study will rely on water-rock interaction.

Location/Geology of the Study Area

The study area, Abuja the federal capital territory of Nigeria is situated within the geographic coordinates of Latitude: 09 10' 00" N and Longitude: 007 11' 00" E. It is located in the centre of Nigeria. Abuja was built mainly in the 1980s and officially became Nigeria's capital on 12 December 1991. It has an area coverage of 713 km2 (275.3 sq mi) and density of 1,091.9/km2 (2,828/sq mi). As at the 2006 census, the city is said to have a population of 778,567.

The area of investigation falls within the basement complex rocks of Northern Nigeria. The assemblage of rocks consists of gneisses, granite-gneiss, migmatite, schist bed and their modification. The main source of water in the basement complex is the weathered zone or in the joints and fractured system in the unweathered rock.

The study area is underlain by crystalline basement complex rocks, where the occurrence of ground water is due to development of secondary porosity and permeability by weathering and / or fracturing of basement rocks. However, by providing an overburden of relatively more porous and more permeable materials from the rocks, deep weathering has proved to be important factor for groundwater hydrology of such geologic environment. The highest ground water yield in basement terrains is found in areas where thick overburden overlies fractured zones. These zones are often characterized by relatively low resistivity values.

Experience has shown that the rate of failure of borehole is usually highest in basement complex terrain. This is due to an inadequate knowledge of the basement aquifers, which results from in-situ weathering of basement rocks. Figure 1.0 shows the geologic map of the study area.

2.0 Theory of Water-Rock Interaction:

Mass Balance of Water-Rock Interaction

In order to evaluate whether it is necessary to suggest that the weathering process can affect the uranium signatures of the granitic rocks to some extent, a need to under look the calculation of mass balance for the water-rock interaction between the groundwater and the granitic rocks. Total uranium leached from granitic rock can be obtained by estimating the groundwater volume (Vgm) that has passed through a unit volume of granite using:

$$V_{gw} = n_p K R_g T A \qquad \ldots 1.0$$

Where K (cm/s) is the hydraulic conductivity, Rg is the hydraulic gradient; T(s) is circular time; A (cm^2) is the unit surface (i.e., A=1). For the purpose of the scoping calculations, it was assumed that hydraulic conditions have remained similar to the present. The K value ranges from $5.7x10^{-8}$ to $3.6 \, x10^{-5}$ cm/s (Yanagisewa et al., 1991) and Rg from 0.2 to 0.5 (Japan Nuclear Cycle Development Institute,2000) in the present water-rock system. For T, the age of the Toki granite (68 Ma, Suzuki and Adachi, 1998) is employed. The np value is fixed at 29% (porosity). From the Vgw and uranium abundance in the ground water, we can estimate uranium leach, the total amount of uranium leached from a unit volume of granite. Since uranium can be transported, not only as dissolved species but also as sorbed species on particulate matter. The uranium leach will be divided by the density of granite in order to compare the uranium leach directly with uranium abundance in the granite. In the same way, uranium and its daughter elements can equally determined or estimate the total leach from the host rock (granite) to the ground water.

3.0 Material and Methods

The method will involve three sections:

- Drilling of four borehole of varying depths (40m, 50m, 60m and 70m) with the help of 30 tone capacity Rig machine
- Samples will be collected by cutting and coring through the top soil to the deep subsurface layers.
- The samples will be analyzed for three different results
  1) Geochemical-PH, TDS, TOC, ORP and ALKANILITY
  2) Petrophysical- Porosity, conductivity, Porosity factor, Cementation etc
  3) The rock samples will be air dried, crushed and pass through a mesh. The powdered rock will be stored in plastic container to the laboratory for radioelement determination using high resolution gamma spectroscopy.

3.1 Theoretical Evaluation of Water-Rock Interaction after Y. Takahashi et al ;(2002)

However, Y. Takahashi et al.;(2002), estimated the Rare Earth Elements (REE) that could have been leached from granite by water-rock interaction by calculating the total volume of groundwater that could have been interacted with the granite under the following conditions in 2D: Hydraulic conductivity: $5.7x10^{-8}$ to $3.6 \, x10^{-5}$ cm/s; hydraulic gradient: 0.02 to 0.05; reaction duration:6.8 $x10^{7}$ years; Porosity (n_p):29%. The result of Y. Takahasha (2002) summarized as:

1) Most of the uranium deposits in Tono, Central Japan were transported
by groundwater from whole-rock analysis.

(2) U^{234} dissolves in aqueous phase than U^{238}, which could be the damage of the crystal lattice by Alpha-recoil energy in vicinity of Tono.

From the above conditions, this work focuses on modifying the 2D after Y. Takahashi et al; 2002, to 3D modeling of the vicinity of Tono, Central Japan, to understand the detail geological attributes to the water-rock interaction. This will help to determine the degree of the radioelement from geological background. Figure 2 shows the 3D model to optimize the subsurface information of the relationship between hydraulic conductivity; hydraulic gradient and unit volume of granitic rock in water-rock interaction. The modification of the previous work of Y. Takahashi, 2002, will enable this research work to infer the nature of the uranium behavior in the subsurface bedrock in Abuja. However, the interrelationship between the hydraulic conductivity, hydraulic gradient and unit volume of granite from this modification will improve the understanding of the flow of underground water in Abuja. Furthermore, it will identify the lithological control of water bearing rock (aquifer) and uranium bearing rocks (granite)

3.2 Interpretation of 3D Model

In Figure1.2 shows 3D model. Theoretically, the model shows linear relationship between hydraulic gradient, hydraulic conductivity and unit volume of granitic rock. It indicates that geological background has attributes to uranium concentration in the water-rock interface. The tectonic activity or physical weathering could constitute to uranium mobility in the subsurface rock formation within the study area. Furthermore, the 3D indicates the interconnectivity in the weathered mantle in overburden (sedimentary terrain) and joints in the fractured basement. In the study area, Abuja, which is basement complex, could experience more leaching of radioelement due to Pan-African Orogeny that caused the deformation of subsurface structures.

Result

The 3D model after modifying the result of (Yoshio Takahashi et al.; 2002) indicates that the unit volume of granite has linear relationship with the hydraulic conductivity and hydraulic gradient. It is observed that the volume of granitic rock formation in a certain region will determine the concentration of uranium which is associated with the dispersion of chemical constituents as a result of hydraulic conductivity and hydraulic gradient of water-rock interaction. Geologically, the 3D model which will play role during the experimental analysis of the study area could have a spatial attribute as a result of interconnectivity of the overburden terrain, joints, fissures and fractures in the weathered basement. These features can stimulate uranium mobility in the leachate form that constitutes serious threat to the groundwater consumption and human health.

Conclusion

In conclusion, the assessment of radionuclide concentration and their possible health effect on the people of Abuja will be carried out. The possibility of radioelement in the groundwater is there from the modification of 3D model of water-rock interaction. This will be aimed at improving occupational and public awareness of the presence of radioactive elements in borehole groundwater and their possible health hazards. The correlation of the theoretical and experimental model will be determined and the background geological conditions with the water-rock interaction. The mean dose equivalent for rock samples will be obtained and determine the health implications or adverse effect on the populace and the environment. However, this work will determine the hydrological cycle if their maybe increase in the value obtained with longer period of operation. It recommends occupational and public awareness on the presence of natural radiation especially in borehole groundwater consumption and their possible health hazard. Background radiation and proper health monitoring should be part of the environmental assessment for both shallow well and borehole of reasonable depth.

Reference

1 Jaworowski, Z. 1982. Natural and Man-made Radiationuclides in the Global Atmosphere. IAEA Bulletin 24 (2) p.35

2 Lowder, V. M. 1990. Natural environmental radioactivity and radon gas. Proc. Of Int. Workshop on radon monitoring in radioprotection, environmental radioactivity and earth sciences. World scientific. Singarpore. P.1-17

3 Japan Nuclear Cycle Development Institute, 2000. H12: Project to establish the Scientific and Technical Basis for HLW Disposal in Japan. JNC TN1400 99-020

4 Moe, H.J.,Lasuk, S. R., Schumacher, M.C., Hunt, H. M., 1972. Radiation safety Technician Training Course. Illinois, Argonne National Laboratory ANL-7291

5 Suzuki, K, Adachi, M., 1998. Denudation history of the high T/P Ryoke metamorphic belt, southwest Japan: Constraints from CHIME monazite ages of gneisses and granitoids. J. Metamorphic Geol.16,23-3

6 Tebbut, T.H.Y. (1973) *Water Science and Technology* (John Murray) [UGH]

7 Takahashietal., 2002 Y. Takahashi, H. Yoshida, N. Sato, K. Hama, Y. Yusa, H. Shimizu W-and M-type tetrad effects in REE patterns for water–rock systems in the Tono uranium deposit, central Japan Chem. Geol., 184 (2002), pp. 311–335

8 Yanagisawa, K., Imai, H., Saito, A., Ohsawa, H., Nakajima, M., 1991. Analytical prediction of groundwater flow in the shaft excavation effect experiment. PNC Technical Report, GE 90-04.

ISSN 2224-7181 (Paper) ISSN 2225-062X (Online)
Vol 6, 2012

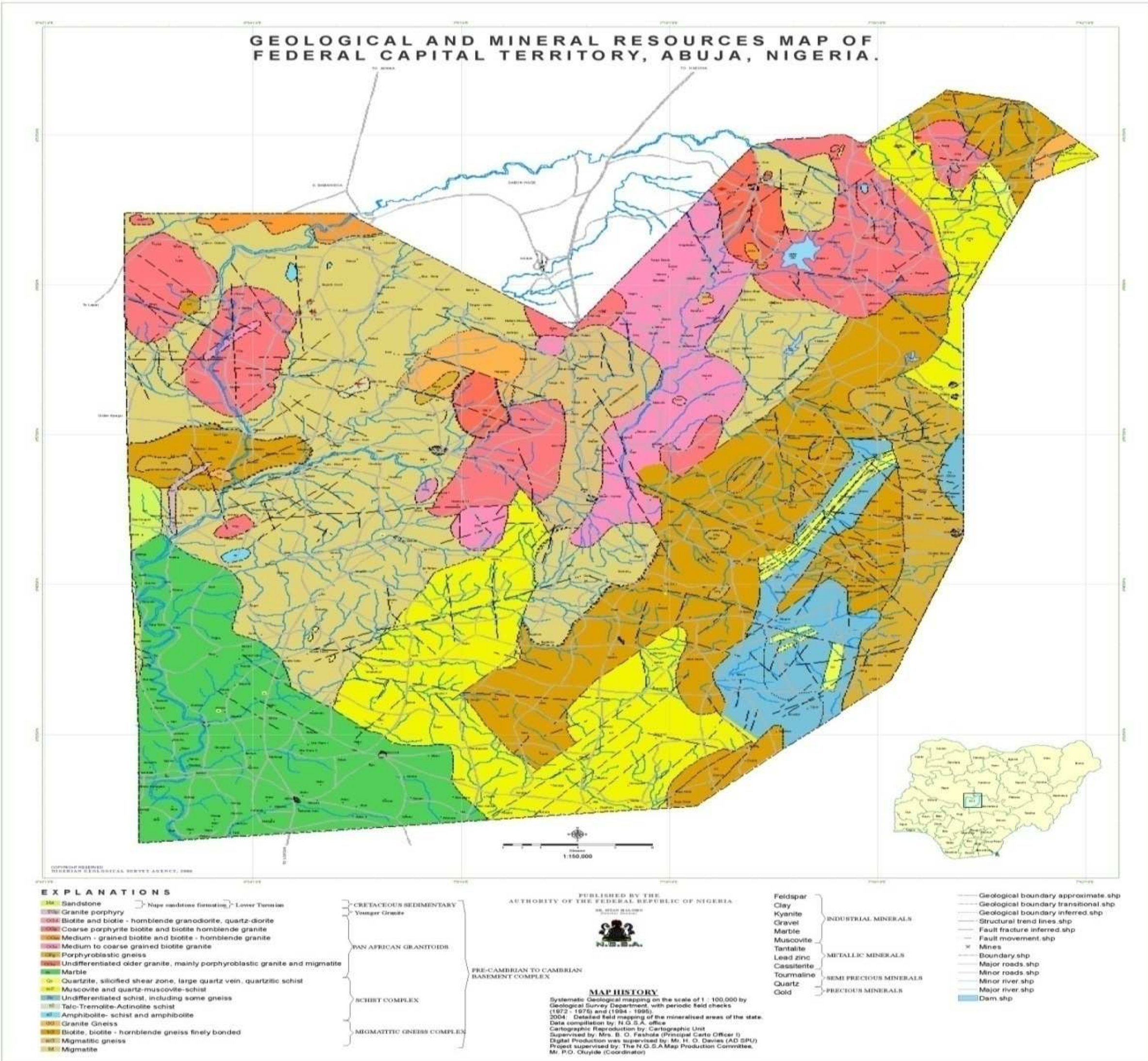

Figure1.0 Geologic Map of the study Area after Nigeria Geological Survey Agency 2004.

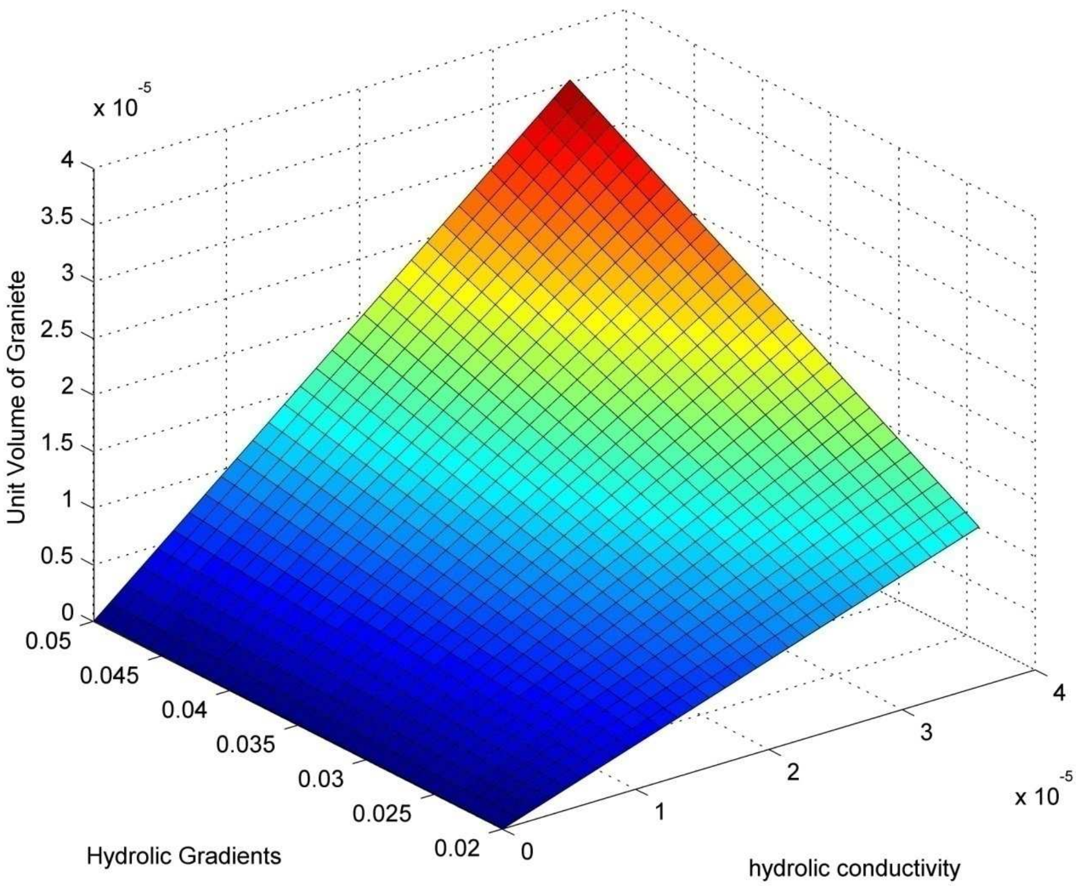

Figure2: 3D model showing the relationship of unit volume of granite; hydraulic gradient and hydraulic conductivity.