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Radiogenic Heat Production of Rock from Three Rivers in Osun State of Nigeria

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Abstract: Ten fresh rock samples were collected from three rivers in Osun State, namely Erin-Ijesha (EI), Osun-Osogbo river (OS) and Ishasha river in Edunabon near Ile-Ife (IS). The study area is underlain by the Precambrian Basement Complex of southwestern Nigeria. This is to determine their radioactive heat production and the contribution of each radionuclide content. The radiogenic heat production was determined by spectrometer which gives the area photopeak of the radionuclides contribution. These photo peaks were later converted to Bq Kg^{-1} and part per million (ppm) for radiogenic heat computation. The result shows that concentration and rate of heat production of ^{40}K, ^{238}U and ^{232}Th in the samples varies significantly with geological location. The total heat production ranges from 8.21 to 235.82 pW kg^{-1}. The highest concentration and heat production is recorded in Quatz of Osun-Osogbo rivers and the heat produced by ^{40}k is highest in six samples. It is also noted that rock samples from Erin-Ijesha river are associated with high heat production of ^{232}U.

Key words: Radiogenic, heat production, radionuclide, gamma-ray spectrometer, photo peaks

INTRODUCTION

There are two main sources of heat in the earth interior, namely: slow cooling of the earth from an earlier hotter state and radioactive heat production (Strivastava and Singh, 1998). The radiogenic heat production is also referred to as radiogenic heat production which is generated mainly from the decay of long-lived radioactive isotopes (Louden and Marechal, 1996; Sigvalderson, 1973; Tripp and Ross, 1997). These Isotopes are known as primordial (existing since the formation of the earth) radioactive elements with heir half-life compared to the age of the earth and are in abundance.

Surveying for radiometric minerals has become important over the last few decades because of the demand for nuclear fuels (Keller, 1981; Ehinola *et al*., 2005). Radiometric surveying is employed in the search for deposits necessary for this application (Kintzinger, 1956; Philip, 2001). Radiometric surveys are of use in geological mapping as different rock types can be recognized from their distinctive radioactive signature.

The economy of Nigeria is heavily dependent on oil and gas and other hydrocarbon products and it is a known fact that the content of radionuclides elements in rocks, soil and water affect hydrocarbon reservoir.

MATERIALS AND METHODS

Ten fresh rock samples were collected from three rivers in different geological location in Osun State. The rivers are: Erin-Ijesha river, Close to Erin-Ijesha water fall (EI), Osun-Osogbo river (OS) and Ishasha river in Edunabon near Ile-Ife (IS).

The rock samples were crushed to fine grains to minimize self-absorption and to have geometry and matrix. Each sample was carefully packed in a 39.1 g Plastic Container, sealed with paper cellotape and weighed. They were then left for thirty days in order for gaseous members of Uranium and Thorium series to reach secular equilibrium before counting.

Natural radionuclide of relevance for the radiogenic heat production are mainly ^{40}K and gamma-ray emitting nuclei in decay series of ^{238}U and ^{232}Th. Gamma radiation analysis allows various gamma emitter to be distinguished and the quantitative content of potassium, uranium and thorium to be calculated. Concentration of ^{40}K, ^{238}U and ^{232}Th are determined in the laboratory through spectrometry of emitted gamma rays using a cylindrical

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NaI (Tl) scintillator. The detector used is 7.6 by 7.6 cm NaI (Tl) detector (model No. 802 series) by canberra Inc. The gamma rays, which interact with the scintillator are converted into quanta of visible light, which can be detected with a photomultiplier. The photomultiplier produces voltages pulses with height proportional to the energy of the gamma rays. These pulses are amplified and fed to a multichannel analyzer (canberra series 10 multichannel analyzer-model No. 1104). All the samples were counted for 18000 sec, as this was considered adequate for measurement of the low activity of the samples. The efficiency and quantitative calibration of the apparatus was determined using a standard material prepared from Rocketdyne laboratories, California, USA. The photopeak area values were converted into concentration in Bq kg^{-1} and then later to part per million (ppm). These concentrations in ppm were used for determination of the radiogenic heat production rate for each sample. Radiogenic heat production was calculated using Rybach equation:

$$Q = 95.2\ C_u + 25.6C_{Th} + 0.00348C_K$$ (Rybach, 1988)

where C_u, C_{Th} and C_k are concentration in ppm of uranium, thorium and potassium, respectively.

The total heat production represents the summation of the three isotopes for each sample and is a comprehensive parameter to reflect the race of radiogenic heat rock samples.

RESULTS AND DISCUSSION

The concentration of the isotopes ranges from 611.55 to 60154.42 ppm for ^{40}K, 0.10 to 0.59 ppm for ^{232}Th and 0.06 to 0.81 ppm for ^{232}U (Table 1). Highest concentration as well as radiogenic heat production is noted in the OS 4 (Quartz) and closely followed by IS 2 (schist). Figure 1 is the plot of the rate of heat production against the different geological location in pw kg^{-1}. The radiogenic heat production ranges from 8.21 to 235.82 pw kg^{-1}. General heat produced by potassium is highest in all except in EI 1, EI 2, EI 3 and IS 3 (Fig. 1).

The radiogenic heat production from the three samples from Erin-Ijesha river (EI1, EI 2 and EI 3) are highly associated with uranium isotope (Fig. 1).

It can be seen from these results that samples from Erin-Ijesha have a unique characteristic of radiogenic heat production form than other samples because of the highest contribution of uranium radionuclides to heat production compared to other two radionuclides. This may be as a result of its in situ geology. It is also noted that EI 3 (mica) is associated with high heat production of uranium.

Generally, the Uranium and thorium contents in most of the rock samples analysed in they study are very unusually low.

Table 1: Concentration and radiogenic heat production by three isotopes for simple collected from Osun tate river, Nigeria

		Concentration			Heat production (pW kg^{-1})			
Sample code	Lithology	^{40}k (ppm)	^{238}U (ppm)	^{232}Th (ppm)	Potassium	Uranium	Thorium	Total
EI 1	Quartz	719.09	0.13	0.06	2.50	12.16	1.51	16.17
EI 2	Quartz vein	611.55	0.06	0.01	2.13	5.87	0.21	8.21
EI 3	Mica	8504.87	0.81	0.24	29.60	77.03	6.02	112.65
OS 1	Pegmatite	24764.86	0.50	0.15	86.18	47.85	3.80	137.83
OS 2	Gneiss	16973.65	0.04	0.52	59.07	4.10	13.30	76.47
OS 3	Schist	31529.80	0.22	0.10	109.72	21.30	2.65	133.67
OS 4	Quartz	60154.42	0.15	0.50	209.34	13.83	12.65	235.67
IS 1	Gneiss	18485..37	0.08	0.59	64.33	7.85	14.98	87.16
IS 2	Schist	35102.65	0.30	0.05	122.16	28.40	1.30	151.86
IS 3	Quartz	1208.74	0.20	0.05	4.21	19.31	1.21	24.73

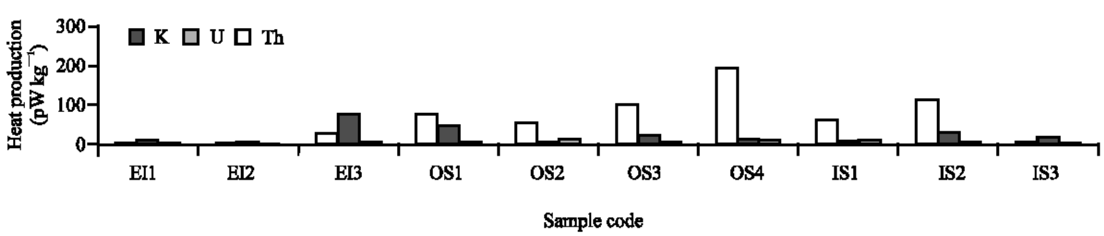

Fig. 1: Radiogenic heat production histogram from the study section

CONCLUSIONS

The concentration and radiogenic heat production by the three isotopes for each sample vary significantly. Highest concentration and heat production is recorded in OS 4 (Quartz) and the heat produced by potassium is highest in all the rock samples except EI1, EI 2, EI3 and IS3. The rock samples from Erin-Ijesha river are associated with high heat production of uranium.

Thus there is a need for further research on rocks from Erin-Ijesha river in order in order to know if the content of uranium radionuclide available there is economical viable for geothermal energy production.

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