RADIOACTIVITY IN SOME FOODS AND SOILS FROM JOS TIN MINES, JOS, NIGERIA

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ABSTRACT

The commercial deposit of casseterite (as well as some monazite and zircon) in the Jos Plateau of Nigeria has led to extensive tin-mining activity in that region, for well over a century. However the peculiar temperate climate and arable soil associated with the plateau has also made it one of the major food baskets for the whole country. Such extensive farming on mineral-rich soil could result in the transfer of radionuclides into the food chain, in excess of safe limits. Employing low level gamma spectrometry, this paper assesed the radioactivity levels in six common food samples - Cowpea, Millet, Karakachi, Groundnut, Fresh Maize and Dried Maize obtained at different locations on the Jos Plateau. Radioactivity levels were also assesed in soil samples associated with the food samples, together with ash and slag samples from the Jos Lead Smelter. Soil samples were counted for 10 hours each on a Na-I (Tl) detector, while the food samples were counted for the same length of time using a high purity Ge detector. Camberra S100 software was used for data analyses. Specific activities of the naturally-occurring radioactive series U-238, Th-232 and K-40 were determined, after the achievement of secular equilibrium, using gamma lines from Ra-226, Ra-228 and K-40 respectively. In foods, activity levels for ^{40}K ranged from below detection limit in Dried Maize to 226.40 ± 24.34 Bq/kg in Cowpea. For the ^{238}U series, the activity levels ranged from below detection limit in Groundnut to 12.56 ± 3.56 Bq/kg in Dried Maize, while radioactivity associated with the ^{222}Th series ranged from 0.46 ± 0.24 Bq/kg in Cowpea to 15.54 ± 8.51 Bq/kg in Dried Maize. The effective dose equivalent due to each radioactive series in the food samples was estimated using effective dose conversion factors, and food consumption rates suggested by the International Atomic Energy Agency as well as those obtained from questionnaires locally-administered by us, for comparison. For all but one sample, these levels were well within the maximum permissible level of 1 mSv/yr limit. The exception was dried maize for which an effective dose equivalent of 1.29 mSv/yr was recorded.

Keywords: Natural Radioactivity. Food, Soil, Jos Tin Mines.

INTRODUCTION

The Jos Plateau in Central Nigeria, at an altitude of about 4,200 ft (1,280 m) covers some 7,770 sq km of good agricultural land, matched with a unique temperate climate. According to Encarta Encyclopeadia, "temperatures on the plateau tend to be 4C° cooler than those on the coast, and the average annual rainfall of about 1,300 mm is considerably higher than that in the surrounding lowland" (Roder, 2008). It is also acclaimed to be freer from disease than the surrounding lowlands. All these favour extensive farming on the plateau, and there are indeed many agricultural products which thrive (in Nigeria), only on the Jos Plateau with its unique climate.

However, the plateau was also the site of a century-long extensive tin mining due to the abundance of casseterites, monazites, and other radioactive minerals in the region. With the depletion of the easier-to-exploit surface deposits, together with the discovery of oil, attention has shifted away from tin mining, leaving behind an estimated 1,100 abandoned tin and columbite mines, occupying some 320 km^2 of arable farmland (Drillbits and Tailings, 1999). Thanks to innovative application of indigenous technology, the land is being reclaimed and restored back to agricultural productivity (Alexander and Kidd, 2000). However, serious concerns are being expressed whether or not the conversion of highly polluted land into agricultural land might not lead to a contamination of the food chain via transfer of toxic elements and radionuclides from soil.

Apart from the millions of Nigerians from far and near who directly consume food crops produced on the Jos Plateau, the plateau also impacts other regions of Nigeria via rivers emerging therefrom. For instance, the Jos Plateau is the source of the expansive Gongola River. Furthermore, according to Encarta, (Roder, 2008), headwaters of rivers feeding the Niger River, the Benue River, and Lake Chad radiate from the Jos Plateau.

In a previous work (Ojo, 2006), the possible transfer of toxic chemical elements into the food chain on the Jos plateau was examined. In this companion study, the levels of naturally-occuring radionuclides in some staple foods (and associated soils) grown on the Jos plateau were determined. The dietary pattern for these foods among local people was also determined and the resulting dose equivalents to adult members of the population computed.

MATERIALS AND METHODS

The major food types produced and consumed on the plateau were identified via a Food Basket Analysis conducted by a qualified local dietician. Details have been previously reported by Ojo (2006). Food samples were collected from 6 farms and homes located on reclaimed mining sites at Barkin Ladi, Wereh, and Jos, all on the Plateau. The food items collected were cowpea, millet, karakachi, groundnut, fresh maize, and dried maize. All the food samples, except dried maize, were obtained directly from the farm and root-level soils (0 – 7 cm) associated with them were also collected. The dried maize sample was collected from the storage barn and had been in storage for several months. Apart from these soil and food samples, ashes and slags were also collected for analyses from the only major Pb-Sn smelter situated at Jos. For comparison, soil and bitumen samples were also collected from Ile-Ife for co-evaluation with the samples from the Jos plateau.

To quantitatively evaluate dietary intakes in the study population, a carefully designed questionnaire, adapted by a trained dietician from one designed by the US Department of Agriculture (USDoA) (www.barc.usda.gov/bhnrc/foodserver), was administered on 50 adult residents at the villages of Tenti and Wereh in Barkin Ladi Local Government Area on the Jos Plateau. Dose equivalents H were calculated as H = (Activity) x (Effective Dose Conversion Factor by ingestion of radionuclide "i" C_i) x (Consumption rate of food "f", U_f)

Values for C_i were: For ^{40}K, 6.2 x 10^{-9} Sv/Bq; For ^{226}Ra, 2.8 x 10^{-7} Sv/Bq; For ^{228}Ra, 6.9 10^{-7} Sv/Bq

Figure 1 shows the location of Jos on the map of Nigeria, while Figure 2 shows the picture of a reclaimed mine being converted for agricultural use. The mound now being farmed at the background was actually mines tailings, from the mine pit now filled with water, forming the small lake at the foreground.

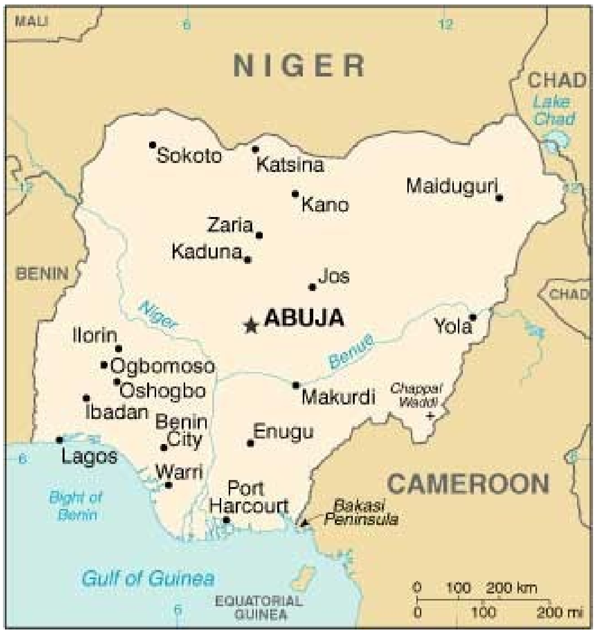

Figure 1: Map of Nigeria Showing Jos, North East of Abuja the Federal Capital

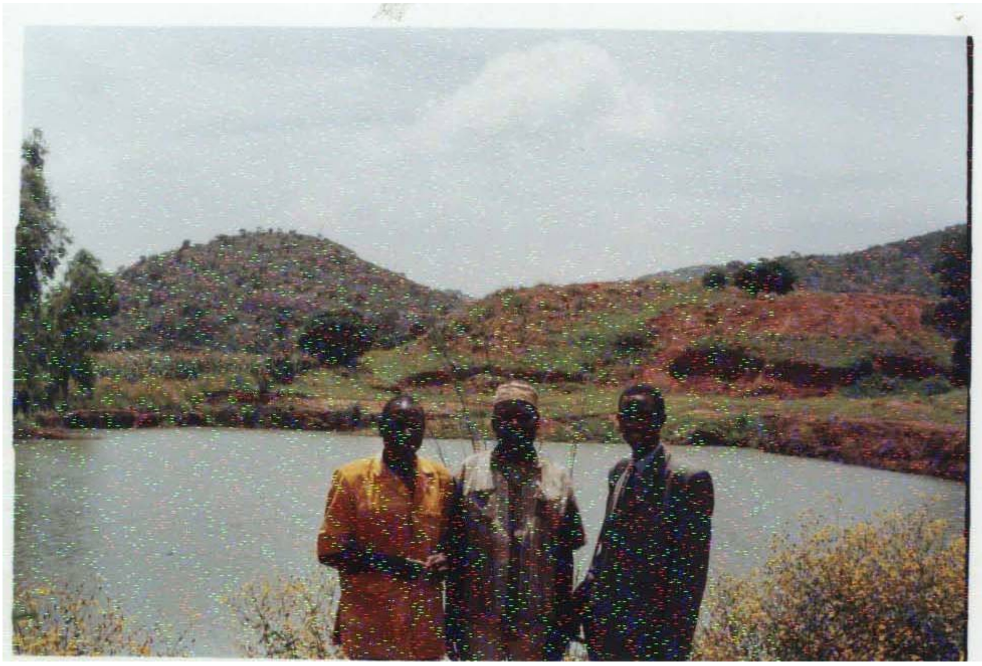

Figure 2: Showing Farming on Mines Tailing on the Jos plateau.

Sample Preparation

Soil Samples were air-dried in the laboratory, and thereafter milled and thoroughly pulverized. They were subsequently homogenized and sieved before being packaged in the standard container used for gamma spectrometry at the laboratory of the Department of Physics and Engineering Physics, Obafemi Awolowo University (OAU), Ile-Ife. The samples were sealed and left for at least 4 weeks to allow the attainment of secular equilibrium among the daughter nuclides in the three natural radioactive series. Radioactivity in the soil samples were evaluated via gamma spectrometry using the NaI (Tl) detector at the Centre for Energy Research and Development at the OAU. Each sample was counted for 10 hours and spectra obtained compared with the spectrum of IAEA Soil S6 obtained under same counting geometry.

A similar process of drying, homogenizing, sieving and packaging was carried out for the food samples, but the evaluation of radioactivity was carried out on a hyperpure Ge detector in the Department of Physics and Engineering Physics at OAU, Ile-Ife. Each sample was also counted for 10 hours each and evaluated as for the soil samples. In both cases, Spectra Peak Heights analyses were done using CAMBERRA S100 software. Blank Background was first determined and subtracted from each spectrum. Typical spectra for food (dried maize) and soil samples are shown in Figure 3.

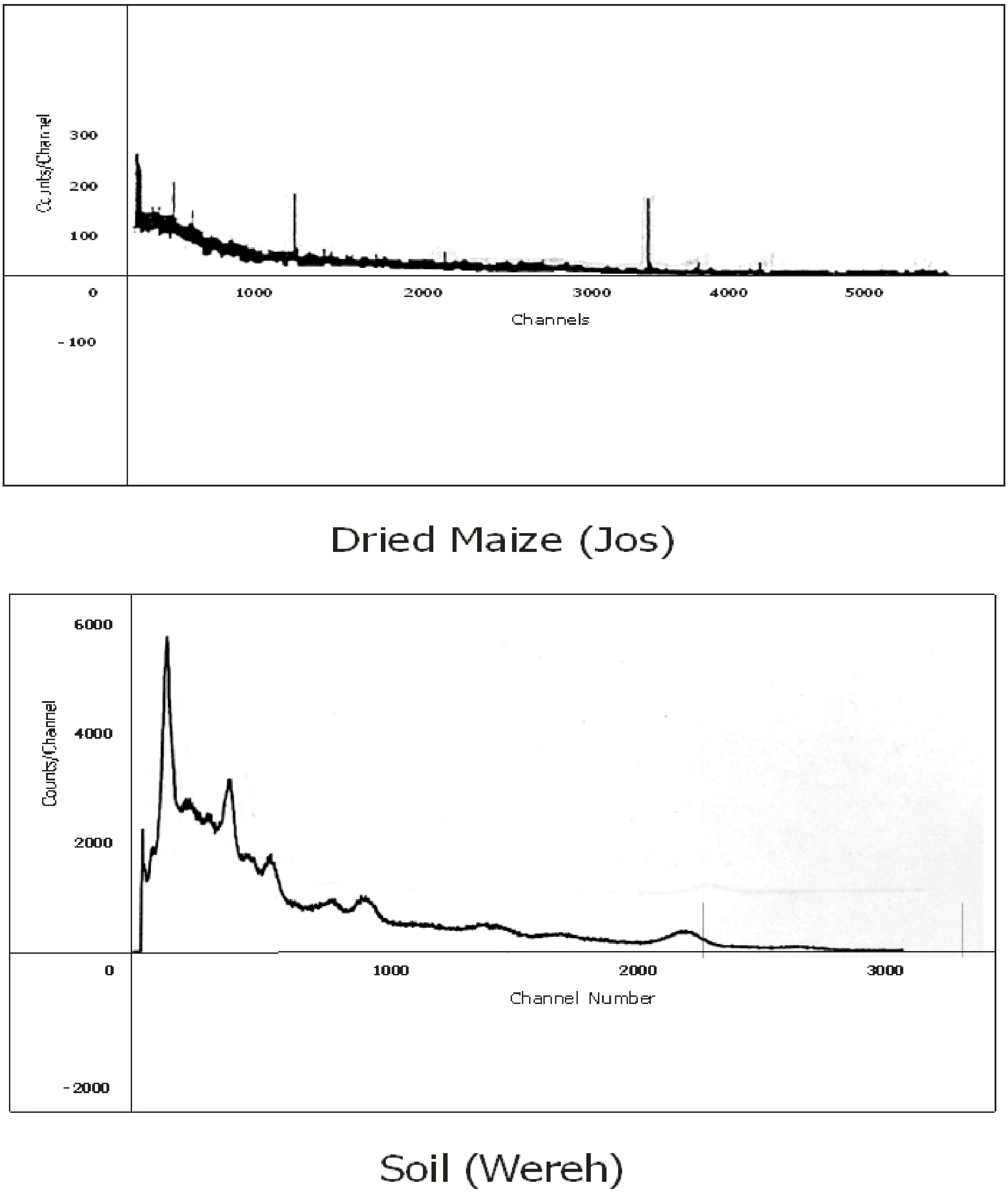

Figure 3: Typical Spectra for Food (on HP-Ge detector) and Soil (on NaI detector)

RESULTS AND DISCUSSION

The activity concentrations for soil samples and other non-food samples from the various locations are shown in Table 1, while those for the food samples are shown in Table 2. No man-made radioactivity was detected in both soil and food samples. There are no clear correlation between activities in soil and food or between the various radionuclides. Their migration and distribution probably being controlled by complex, external environmental processes including leaching, erosion, etc. Most of the activities in soil are due to K-40, reflecting the fact that the Jos Plateau is largely granitic. Th-232 series elevated in soil around the Pb smelter. These levels are comparable to levels previously reported for soil and food from the Jos plateau by Jibiri (Jibiri and Agomuo, 2007,; Jibiri *et al.,* 2007). No ^{40}K was detected in the dried maize, which happens to have the highest values of ^{226}Ra and ^{228}Ra. However, in a study of tailings from the Jos mine, Ademola (2008) also using a hyper pure Ge detector, reported not detecting ^{40}K in tailings from the Jos Plateau with remarkably high Th and U.

The computed dose equivalent for the characteristic six food samples from the Jos Plateau are shown in Table 3. The values were calculated using both the default values for Food Consumption Rate in Africa as suplied by the IAEA, and values obtained from our locally administered dietary recall questionnaire. The IAEA values are: 1.20 x 10^5 kg/yr for the Cereals and 7.9 x 10^4 kg/yr for Karakachi whereas our locally-derived values are 8.1 x 10^4 kg/yr for the cereals, and 8.8 x 10^4 kg/yr for Karakachi. Using the IAEA figures for maize consumed, the dose equivalent for dried maize would be 1.29 mSv per annum (Table 3), which is in excess of the recommended safe limit of 1.00 mSv/annum (IAEA, 2002). However, using the figures for maize consumption determined by us, the dose equivalent for dried maize would be 0.97 mSv per annum.

Table 1: Activity Concentrations in Soils (Bq/kg)

Reclaimed site, Plateau state	^{40}K	^{238}U (via ^{226}Ra)	^{222}Th (via ^{228}Ra)
Site 1 (Farm, B/Ladi)	645.99 ± 56.46	57.72 ± 5.11	3.50 ± 0.12
Site 2 (Farm, B/Ladi)	130.54 ±11.75	24.98 ± 2.13	2.22 ± 0.99
Site 3 (Farm, Wereh)	1057.92 ± 91.38	92.13 ± 3.37	2.93 ± 0.01
Pb-Sn Smelter, Plateau State			
Site 1 (Outside Pb smelter)	802.37 ± 70.01	22.01 ± 2.00	4.71 ± 0.16
Site 2 (Farm, Staff Qtrs at Smelter)	1012.65 ± 91.40	102.71 ± 9.39	5.47 ± 0.20
Site 3 (Farm, Jos)	158.80 ± 13.75	50.73 ± 6.81	11.02 ± 0.35
Non-mining Site, Ile-Ife			
Soil	506.13 ± 43.35	24.11 ± 2.11	3.22 ± 0.10
Bitumen	2450.06 ± 212.86	40.46 ± 5.71	6.11 ± 0.21
Slag (from Pb smelter)	1078.44 ± 93.48	43.23 ± 3.84	2.81 ± 0.12
Ash (from Pb smelter)	211.48 ± 18.88	10.22 ± 0.65	3.93 ± 0.14

Table 2: Activity Concentrations in Foods (Bq/kg)

SAMPLE	^{40}K	^{238}U (via ^{226}Ra)	^{222}Th (via ^{228}Ra)
Cowpea	226.40 ± 24.34	2.51 ± 0.36	0.46 ± 0.24
Maize (fresh)	13.55 ± 1.56	0.78 ± 0.24	4.93 ± 1.25
Millet	11.17 ± 1.36	10.30 ± 4.27	1.08 ± 0.08
Karakachi	25.73 ± 4.06	9.95 ± 2.89	3.78 ± 1.65
Groundnut (NYB)	45.40 ± 5.65	ND	1.75 ± 0.51
Maize (Dried, Smelter Farm)	ND	12.56 ± 3.56	15.54 ± 8.51

Table 3: Computed Dose Equivalent [Using IAEA-default values for Food Consumption Rate in Africa (IAEA Factor) And Food Consumption Rate Obtained Locally Using Dietary-Recall Questionnaire (Local Factor)]

	^{40}K (mSv/yr)		^{226}Ra (mSv/yr)		^{228}Ra (mSv/yr)	
SAMPLE	IAEA FACTOR	LOCAL FACTOR	IAEA FACTOR	LOCAL FACTOR	IAEA FACTOR	LOCAL FACTOR
Soya beans (Wereh)	0.169	0.127	0.085	0.064	0.038	0.029
Maize (Jos)	0.010	0.008	0.026	0.020	0.410	0.309
Millet (Jos)	0.008	0.006	0.347	0.262	0.090	0.068
Karakachi(Wereh)	0.013	0.014	0.219	0.245	0.205	0.230
Groundnut (Wereh)	0.034	0.026	-	-	0.145	0.110
Maize (Dried, Smelter Farm)	-	-	0.424	0.319	1.292	0.973

CONCLUSION

With the exception of dried maize, the radioactivity levels in six common food samples (cowpea, millet, karakachi, groundnut, fresh maize and dried maize) are well below the maximum permissible level and hence not significant. While the general population in the study area could be declared relatively safe from dangerous levels of radioactivity through ingested food, individuals with particular dietary consumption patterns might be at risk.

ACKNOWLEDGEMENT

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