# Radiological effects of some industrial wastes and by-products generated in Lagos, Nigeria

I. P. Farai[a], O. O. Adewole[a], M. O. Isinkaye[b] and N. N. Jibiri[a]
[a]*Radiation and Health Research Laboratory, Department of Physics, University of Ibadan, Nigeria*
[b]*Department of Physics, University of Ado-Ekiti, Nigeria*

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The activity concentrations of $^{40}$K, $^{238}$U and $^{232}$Th have been measured in industrial wastes and by-products collected from different industries in Lagos, Nigeria by gamma-ray spectroscopy. The mean concentrations of $^{40}$K, $^{238}$U and $^{232}$Th were 943.0±22.7, 100.0±3.7 and 31.2±2.5 Bqkg$^{-1}$ respectively. The radiation hazards to the public due to the specified radionuclides were estimated using the radium equivalent activity and the representative level index. The average radium equivalent obtained in this study is below the internationally accepted value of 370 Bqkg$^{-1}$ while the representative index value is above the 1.0 Bqkg$^{-1}$ recommended by United Nation Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).

## I. INTRODUCTION

It is well known, that a larger percentage of human exposure to ionizing radiation comes from natural origin, the major contributors being the naturally occurring radioactive elements of the uranium and thorium series and the non-series radioactive potassium [1]. Natural radiation exposure in the environment can either be external or internal. External exposure is cause primarily by direct gamma radiations from primordial radionuclides while internal exposure is caused by the inhalation of radioactive gases such as radon. Knowledge of the level of radioactivity of waste materials is important in order to assess the possible radiological hazards to human health and to develop standards and guidelines for the management and use these waste materials.

The city of Lagos (6.45°N, 3.47°E) is located in southwestern region of Nigeria and until 1985, was the federal capital city of Nigeria, with a population of over 5 million people [2]. Lagos is one of the most populous cities in Africa. It is a coastal city with one of the biggest sea ports in the continent, a situation which has aided its development as the most industrialized and commercial nerve centre of Nigeria. Many of the industries, such as paper mills, breweries, petrochemicals etc. employ radioactive materials in their process flow. Until the year 2001 when the Nigeria Nuclear Regulatory Authority came into being following the enactment of Act 19 of 1995, there was virtually no control of nuclear materials and wastes in Lagos ant the country as a whole. Prior to this development radioactive waste could have been disposed of in an unsafe manner into the environment. The extent of subsequent dispersal would obviously not be known.

The effect of a failure in containment of radioactive waste from the industries will be most undesirable for a densely populated city like Lagos. The coastal plain of Lagos is characterized by numerous creeks, rivulets and stagnant seasonal swamps [3]. The aquatic environment of the city, with its many creeks and lagoons, will aid dispersal and endanger both human and animal lives. The primary aim of this present work was to acquire data on radioactive level of $^{40}$K, $^{238}$U and $^{232}$Th in wastes and by-products from the major industries in Lagos and its environs against which pollution might be assessed in future. The second objective is to determine the concentration of these radionuclides in the waste materials and thereafter assess their radiation hazard indices. This will assist in beefing up data on radioactivity in the country which presently is still very scanty [4].

## II. MATERIALS AND METHODS

A total of sixteen major industrial premises were visited and between one and three samples (as illustrated in Table I) of industrial wastes and by-products were collected from each at the point of disposal. Disposal mechanisms include; stockpiling and disposal into designated refuse dumps around the city and incineration, while the bye-products undergo recycling. The map of Lagos showing the sampling areas is shown in Fig. 1. Only solid wastes were collected in this pioneering survey and this included aluminum cast, aluminum dust, aluminum scraps, paper mesh, broken bottles, spent grains, paints (resin), dolomite chips, asbestos, broken bricks etc. They were dried, pulverized and packed in 200 g by mass in cylindrical plastic container of diameter 6.0 cm and height 6.5 cm which sits on the 7.6 cm × 7.6 cm NaI(Tl) detector with high geometry. The containers were sealed for about four weeks to ensure radioactive equilibrium between the parent radionuclides and their gaseous daughter products in the uranium and thorium series [5,6]. Each of the samples was then counted for 10 hrs in a low level gamma–counting spectrometer comprising of a 7.6 cm × 7.6 cm NaI(Tl) scintillation detector which is coupled to a Canberra series 10 plus multi channel analyzer (model No.1102) through a pre-amplifier base. The detector has a resolution of about 8% at 0.662 Mev of $^{137}$Cs, which is capable of distinguishing the gamma-ray energies of the natural radionuclides measured in the study.

The detector was calibrated for energy and efficiency using certified standard calibration radioactive solution of $^{137}$Cs (Ref No: Ro1319/7), $^{238}$U(IAEA/RGU-1), $^{232}$Th(IAEA/RGTh-1), $^{40}$K(IAEA/RGK-1) and $^{152}$Eu (Ref. No: EA3/1496/20866) supplied by the Radiochemical Centre Amersham, England through the technical aid of International Atomic Energy Agency (IAEA), Vienna, Austria. The transition gamma energies of the certified samples ranged from 0.344 MeV to 2.615 MeV.

The photopeak efficiencies were determined by relating each photopeak efficiency $\varepsilon_p$ to the net count $A$ under the photopeak. The detection efficiency $\varepsilon_p$ of the counting system is given as:

$$\varepsilon_p = \frac{A}{tA_r Ym} \quad (1)$$

where, $A$ is the net count above the background, $t$ is counting time in seconds, $A_r$ is current total activity of the reference samples, $Y$ is gamma yield (i.e. the fraction of the γ-rays of the particular energy per distingration) and $m$ is mass of sample in kg.

The activity concentration of the radionuclides in each sample was calculated using:

$$C = \frac{A}{t\varepsilon_p Ym} \quad (2)$$

where $C$ is the specific activity of the radionuclides in Bqkg$^{-1}$

These standard sources were counted at the same geometry as the solid waste and bye-product samples for 10 hrs. The concentration of $^{238}$U was estimated from 1.76 MeV transition line of $^{214}$Bi while that of $^{232}$Th was estimated from 2.615 MeV of $^{208}$Tl and gamma energy value of 1.465 MeV was used to determine the concentration of $^{40}$K in all the samples [7-9]. In order to determine the background radiation distribution in the environment around the detector, an empty sealed container was counted for 10 hrs [10]. The background count was subtracted from the count for each sample before concentration calculations were carried out [11].

## III. RESULT AND DISCUSSIONS

The concentrations of $^{40}$K, $^{238}$U and $^{232}$Th together with their corresponding radium equivalents ($Ra_{eq}$) and representative level index (Irγ) in various industrial waste and by-product investigated in this study are given in Table II. As can be observed from Table II the concentrations of the materials vary considerably depending on their type and the nature of industry generating them. For $^{40}$K, the activity concentrations ranged between 26.71±15.42 Bqkg$^{-1}$ in dolomite chips from building materials and 2298.22±30.99 Bqkg$^{-1}$ in sample from Aluminum industry with a total average of 943.0±22.7 Bqkg$^{-1}$. For $^{238}$U the values of activity concentration ranged between 3.19±1.67 Bqkg$^{-1}$ in paper mesh and 188.18±4.82 Bqkg$^{-1}$ in spent grain from brewing industry with an average of 100.0±3.7 Bqkg$^{-1}$ while for $^{232}$Th, the values were between 0.72±2.2 Bqkg$^{-1}$ in Resin from a paint manufacturing industry and 227.6±2.4 Bqkg$^{-1}$ in dolomite chips with a total average of 31.2±2.5 Bqkg$^{-1}$. It is evident from the results that the highest mean value of $^{40}$K is found in samples from galvanizing industries while the lowest mean value is found in paper industries. The highest mean value of $^{238}$U is found in building material industries while the lowest mean value is found in paper industries. Paper industries have the highest average value of $^{232}$Th and the lowest value is obtained from galvanizing industries. The values of total mean activity concentrations of $^{40}$K and $^{238}$U obtained in this study are higher than the values reported for soil samples from the studied area, while the value of $^{232}$Th is lower than that of soil. In an earlier study carried out by Jibiri and Farai (1998) [12], the values of $^{40}$K, $^{238}$U and $^{232}$Th reported were 138±75 Bqkg$^{-1}$, 16±9 Bqkg$^{-1}$ and 43±17 Bqkg$^{-1}$ respectively.

**TABLE I.** Distribution of the industries visited and the number of samples collected.

| S/N | Type of Industry | No of Industry | No of Samples Collected |
|---|---|---|---|
| 1 | Building | 3 | 3 |
| 2 | Aluminum | 4 | 8 |
| 3 | Plastic | 3 | 4 |
| 4 | Paper | 1 | 2 |
| 5 | Galvanizing | 1 | 2 |
| 6 | Brewing | 3 | 3 |
| 7 | Paint | 1 | 1 |

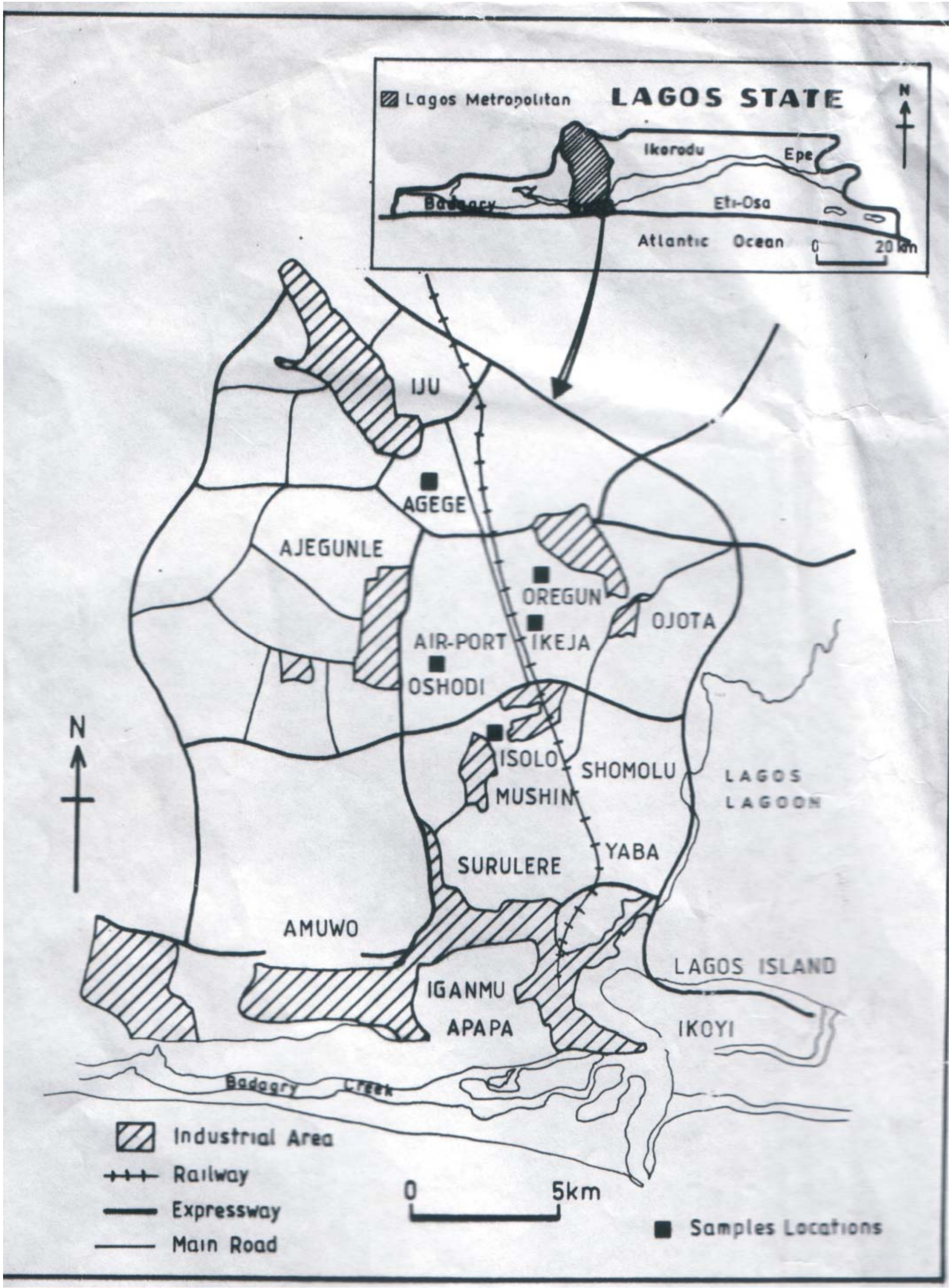


**FIG. 1.** Map of industrial area of metropolitan Lagos showing the areas where samples were collected.

**TABLE II.** Mean concentrations of $^{40}K$ $^{238}U$ and $^{232}Th$ with radium equivalent ($Ra_{eq}$) and representative level index (Iγr) in the industrial wastes and by-products.

| S/N | Type of Industry | Mean activity concentrations (ranges), radium equivalent activity and representative level index, all in $Bqkg^{-1}$ | | | | |
|---|---|---|---|---|---|---|
| | | $^{40}K$ | $^{238}U$ | $^{232}Th$ | $Ra_{eq}$ | Iγr |
| 1 | Building | 723.3±21.0 (26.7 - 1202.0) | 131.6±4.1 (122.5 - 146.6) | 45.9±2.7 (6.4 - 120.7) | 253 (244 - 300) | 1.8 (1.7 - 2.1) |
| 2 | Aluminum | 1069.1±21.4 (323.1 - 2298.2) | 111.7±3.8 (25.4 - 153.2) | 15.7±3.5 (4.1 - 64.2) | 219 (66 - 312) | 1.6 (0.5 - 2.4) |
| 3 | Plastic | 839.6±22.7 (245.5 - 1504.2) | 78.9±3.2 (8.8 - 185.2) | 15.1±2.3 (1.9 - 27.8) | 168 (92 - 301) | 1.3 (0.7 - 2.2) |
| 4 | Paper | 275.9±19.5 (138.9 - 413.0) | 4.1±3.0 (3.2 - 5.0) | 116.8±2.2 (5.9 - 227.6) | 192 (239 - 341) | 1.4 (1.8 - 2.4) |
| 5 | Galvanizing | 1482.2±26.5 (1447.2 -1517.2) | 127.3±4.1 (123.1 - 131.5) | 4.3±2.2 (2.9 - 5.7) | 248 (239 - 257) | 1.9 (1.8 - 2.0) |
| 6 | Brewing | 1041.1±23.2 (323.9 - 2036.5) | 116.6±3.7 (16.1 - 188.2) | 19.9±2.3 (8.5 - 25.2) | 225 (183 - 283) | 1.7 (1.3 - 2.0) |
| 7 | Paint | 1169.9±24.5 | 129.6±4.1 | 0.72±2.2 | 221 | 1.7 |
| Total Average | | 943.0±22.7 | 100.0±3.7 | 31.2±2.5 | 218 | 1.6 |

The gamma ray radiation hazards due to the specified radianuclides Ra (U), Th and K can be assessed by two different indices; the radium equivalent activity $Ra_{eq}$ and the representative level index Irγ [13]. The radium equivalent activity is defined as the weighted sum of activities of these radionuclides and it was calculated based on the assumption that 370 $Bqkg^{-1}$ of radium, 259 $Bqkg^{-1}$ of thorium and 4810 $Bqkg^{-1}$ of potassium produce the same γ-ray dose rates [14].

The radium equivalent activity ($Ra_{eq}$) is given as;

$$Ra_{eq} = C_{Ra} + 1.43C_{Th} + 0.077C_K \quad (3)$$

where, $C_{Ra}$, $C_{Th}$ and $C_K$ are the activity concentrations of $^{226}Ra$, $^{232}Th$ and $^{40}K$, respectively in $Bqkg^{-1}$.
The representative level index Iγr is defined as [15,16]:

$$I\gamma r = \frac{1}{150}C_{Ra} + \frac{1}{100}C_{Th} + \frac{1}{1500}C_K \quad (4)$$

where, $C_{Ra}$, $C_{Th}$ and $C_K$ are the activity concentrations of $^{226}Ra$, $^{232}Th$ and $^{40}K$, respectively in $Bqkg^{-1}$. This radiation index is used to estimate the level of gamma-radiation hazard associated with different concentration of natural radionuclides in materials.

The radium equivalents and the representative index of the samples, calculated on the basis of Eqs. (1) and (2) respectively are shown in Table I. The radium equivalents obtained in this study ranged from 66 $Bqkg^{-1}$ to 341 $Bqkg^{-1}$ with a total mean radium equivalent activity of 218 $Bqkg^{-1}$ while the representative index Irγ is highest in Aluminum with a value of 2.43 $Bqkg^{-1}$ and lowest in paper mesh with a value of 0.36 $Bqkg^{-1}$ with an average value of 1.6 $Bqkg^{-1}$. The average $Ra_{eq}$ from different wastes and by-products obtained in this study were below the internationally accepted value of 370 $Bqkg^{-1}$ while the Iγr values were all higher than the internationally accepted lower limit of 1.0 $Bqkg^{-1}$ [17,13].

## IV. CONCLUSION

The naturally occurring radionuclides ($^{40}K$, $^{238}U$ and $^{232}Th$) in industrial wastes and by-products generated in Lagos, Nigeria have been measured using gamma-ray spectrometer. Potassium-40 is observed to have the highest activity concentration values in all the investigated samples, this is followed by Uranium-238. The concentrations of the materials varied considerably depending on their types and the nature of the industry generating them. The average radium equivalent activity ($Ra_{eq}$) values for the different industrial types obtained in this study are below the internationally accepted value of 370 $Bqkg^{-1}$ for save use (recycling) of the materials. The mean Iγr values are all higher than the lower limit of 1.0 $Bqkg^{-1}$. The values obtained in this study are low enough to expect no significant increase in health risk to the population. It suffices to say however, that the data represent baseline values for the city upon which future reference will be based.

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