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DETERMINATION OF RADIONUCLIDE CONCENTRATION OF LANDFILL AT ELIOZU, PORT HARCOURT, RIVERS STATE

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ABSTRACT

A survey of the radionuclide concentration from landfill around Eliozu in Port- Harcourt Area of River State was carried out. This study assessed the level of terrestrial gamma radiation and associated dose rates from the naturally occurring radionuclides; ^{232}Th, ^{238}U and ^{40}K. 10 soil and 10 water samples collected from the respective reclaimed part of the Eliozu landfill were analyzed using the gamma-ray spectrometry NaI (Tl) detector system. The mean activity concentration for soil was found to be 27.41 ± 9.97 Bq/kg for ^{238}U, 19.27 ± 8.14 Bq/Kg for ^{232}Th and 326.08 ± 66.74 Bq/Kg for ^{40}K.The average specific activity concentration obtained for ^{238}U, ^{232}Th, ^{40}K for the water samples were 7.92 ± 2.69 Bq/l, 6.96 ± 2.37 Bq/l and 24.77 ± 8.33 Bq/l. Absorbed dose rates in air outdoors were calculated to be between the range of 23.53 nGy.h^{-1} and 50.39 nGy.h^{-1} with a mean of 38.17 ±12.45 nGy.h^{-1} for soil and between the range of 6.62 nGy.h^{-1} and 10.71 nGy.h^{-1} with a mean9.03±3.07 nGy.h^{-1} for water. This value is lesser than the world-averaged of 55 nGy.h^{-1}for soil. Inhabitants around the landfill are subjected to equivalent radiation exposure (effective dose rate) ranging between 0.2061 and 0.4414 m*Sv.y*$^{-1}$ *with a mean of 0.3344±0.1091* m*Sv.y*$^{-1}$ *and ranging between 0.0580 and 0.0938* m*Sv.y*$^{-1}$ *with a mean of 0.0791±0.0269* m*Sv.y*$^{-1}$ *for soil and water. The results comparable to those reported for environment in Nigeria and the World is relatively high due to the presence of medical wastes co-disposed with other wastes in these areas. The results indicated that the observed radiation dose of the terrestrial soils and water from Eliozu reclaimed landfill is minimal and seem to have no high exposure for either inhabitant in and around the landfills.*

Keywords: Absorbed dose, effective dose, natural radioactivity, medical waste, landfill, γ-ray spectrometry

INTRODUCTION

Wastes and the crude disposal techniques have created subtle and yet serious environmental pollution havoc in many developing countries. This has lead to the degradation of abiotic and biotic components of these nations' ecological systems. The dumping of large amount of waste materials in sites without adequate soil protection measures results in soil surface and groundwater pollution (Eikelboom et. al., 2001; Namasivayam et. al., 2001). The indiscriminate waste dumps cause soil pollution which can lead to unsustainable and wasteful utilization of resources giving rise to land degradation and threat to human health. (Odunaike et al, 2008).

Jibiri et al., (2007) revealed that staple food stuffs consumed in Nigeria contain traces of radionuclide. As a result of this, the refuse dumpsites or landfills are liable recipient of any such failure in containment of radioactive materials (Farai et al., 2007). It has also been established that vegetation and environmental fields in Nigeria contain traces of radionuclides (Akinloye and Olomo, 2005). The deleterious

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radiological health hazards posed by human activities, especially in the production of energy, research, medical application of nuclear facilities as well as oil and gas extraction and production have attracted great concern and tremendous interest over the years in the field of radiation protection (Arogunjo et. al., 2004). The Eliozu medical landfill contains mixed waste of different sorts. Ranging from chemical toxic wastes, hazardous industrial waste, medical waste, metal scraps and other debris.

Medical waste, even though has attracted a high level of segregation in most hospitals,is generally co-disposed with the municipal solid waste stream by waste handlers (Longe et al., 2005). This waste constitutes a small fraction of the municipal solid waste (MSW), the potential environmental and health hazards could be deleterious if not properly handled (WHO, 1999).The disposal of the waste without adequate management, particularly the radioactive contaminants expose the populace to radiation hazard.

Landfills are holes in the ground where the waste is placed, perhaps the site of a disused quarry or pit, or they may be purposefully excavated. Landfills contain a mixture of wastes, some of which may be soluble, toxic and reactive during decomposition. Landfill is therefore likely to remain a relevant source of groundwater contamination for the foreseeable future. Waste disposal by landfill has led to the pollution of resource thus; landfills are liable recipients of any such failure in containment of radioactive materials (Farai et al., 2007). In the landfill, sources of radionuclides come from both land and air in the landfill area. Surface, subsurface soil samples can reveal various levels of radionuclides contamination as well as surface and underground water samples (Entry et al, 1997). Accurate survey of the occurrence of radionuclides in some environmental matrix such as drinking water, soils, some foodstuffs, air, etc will provide information from which estimates of average radiation exposures of the public from these sources(mixed waste- medical wastes and other wastes) in the landfill areas of Eliozu, Obio-Akpor Local Government Area of Rivers State can be made.

The aim of this study is to determine the specific activity and radionuclide doses of the naturally occurring radionuclides (^{238}U, ^{232}Th and ^{40}K) in soils and water from the landfill (Eliozu area, Port-Harcourt) using γ- ray spectrometry. Absorbed dose rates and equivalent human dose rates in the landfill area were also determined.

MATERIALS AND METHODS

Study Area

Rivers state covers a land area of 10,387 square kilometres with a population of about 5 million people settled in over 250 communities as mainland and islands with 23 local government areas. The resources in the state range from human, natural to social resources. The Eliozu landfill reclamation (through spread and compaction) process is being carried out to convert the landfill to a purposeful use. The study area is located along Eliozu-Rukpoku road and lies between latitudes $7^0$00' to $7^0$02'N and longitude $4^0$50' to $4^0$53'E within Port Harcourt Metropolis in Obio/ Akpor Local Government Area of Rivers State in Nigeria (Figure1). The survey area is accessible through networks of tarred roads. The site is traversed by a set of high-voltage power transmission line owned by the Power Holding Company of Nigeria (PHCN) and two swamps, one adjacent to and the other opposite the landfill. The area is characterized by alternate seasons of wet and dry (Ileoje, 1972), with total annual rainfall of about 240 cm, relative humidity of over 90% and mean annual temperature of 27^0C (Udon et al,2004)

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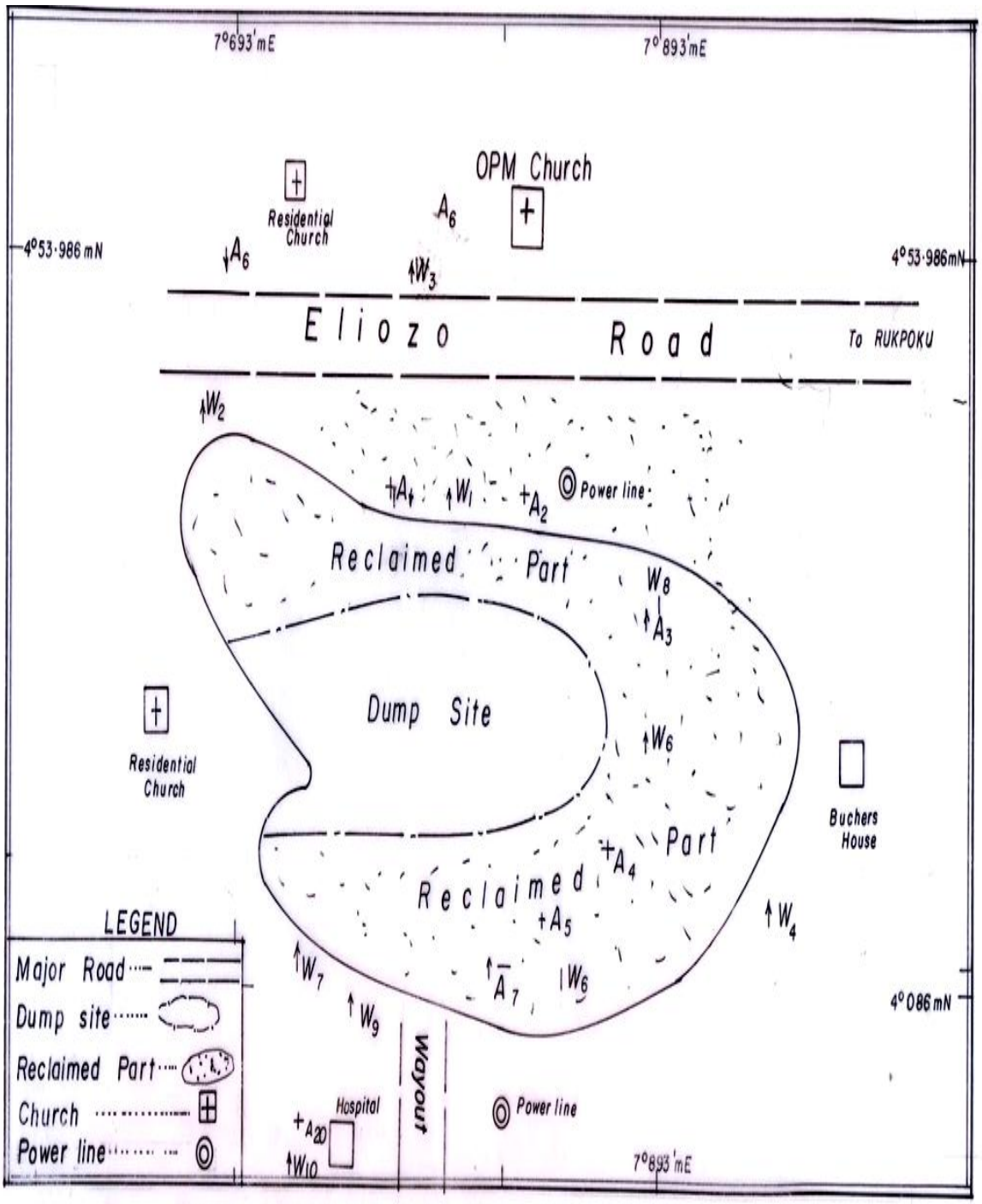
Fig 1: Map of Eliozu Landfills



Sketch Map of the study area (Eliozo dump site)

SAMPLE PREPARATION

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Ten samples of soil and water were each collected from different locations for the radiometric study using coring method as shown in Tables 1 and 2.

The bulk soil samples of about 800g were collected in waste covered level areas (reclaimed part) and in remote locations from man-made structures such as roads and buildings to prevent any external influence on the results. Each soil sample was collected sporadically from an area of approximately 100 m^2 and up to a depth of 0.25 to 0.50m. The samples were collected in polythene bags labelled to avoid cross contamination.

The soil samples were then oven dried at 60^0C for about 24 hours. The dried samples were ground with mortar and pestle and then allowed to pass through a 2mm-mesh sieve, the larger particles were discarded while the meshed soil was sealed for least 28 days in a 250ml air tight plastics containers previously washed and rinsed with diluted tetraoxosulphate (VI) acid before analysis with the gamma-spectrometer (IAEA, 1989) in order to maintain radioactive equilibrium between ^{226}Ra and its daughters.

Tap water, leachates and well water were collected from the landfill and other sources. The water samples were acidified with 11 MHCl at the rate of 10ml per litre of sample immediately after collection to avoid adsorption of radionuclide on the walls of the containers (IAEA, 1989).

All the storing containers were previously washed with dilute tetraoxosulphate (VI) acid (H_2S0_4) and dried to avoid contamination and filled with about 1litre of water each. Two control samples were collected for soil and water from host community in course of the study. They were later firmly sealed for a period of one month to ensure that loss of radon does not occur and secular equilibrium is established before the γ-ray analysis. When this equilibrium state is attained the activity of each nuclide in a given series is equal to the activity of the parent nuclide. This is expressed mathematically as:

$\lambda_1N_1 = \lambda_2N_2 = \text{-------} = \lambda_nN_n$ ..... (1)

Where λ_1N_1 = the activity of the daughter and granddaughters respectively.

Table 1: Soil Samples descriptions

S/No	Sample Code	Location
1	A1	Few metres to the left of the landfill fence
2	A2	100 m from the entrance fence close to base of Power line pole
3	A3	200 m from the entrance fence upstream of Power line pole
4	A4	300 m upstream from of the entrance fence close to the base of the landfill
5	A5	400 m away from the entrance fence just 50m to the residence fence
6	A6	600 m away from the entrance fence close to the uncompleted building
7	A7	100 m downstream from the entrance few metres away from Pentecostals church (right-way of the entrance point)
8	A8	5 m of outside the fence of residence-church near the landfill
9	A9	(Control source) Omega Power Ministry across the road to landfill
10	A10	(Control source) 500 m upstream out of landfill (near Hosp.)

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Table 2: Water Samples Descriptions

S/No	Sample Code	Location	Sample type
1	W1	100 m from the entrance fence few metres from Power line pole of landfill	Leachate
2	W2	Borehole from residence-church	Water
3	W3	Borehole water in Omega Power church	Water
4	W4	(Control source) Open well 200m from the landfill	Water
5	W5	100 m danger pole upstream base	Leachate
6	W6	700 m reverse side of landfill deep slope	Leachate
7	W7	900 m upstream from entrance fence at the landfill base	Leachate
8	W8	100 m downstream inward of landfill base	Leachate
9	W9	Temporary open well 20 m from 2nd Power line pole	Water
10	W10	(Control source) Borehole in the hospital at the downstream of landfill	Water

Gamma-ray Detection System and Calculation of Activity

The gamma spectrometric measurement was carried out using Gamma ray spectrometric system at the at the centre for Energy Research and Development (CERD), Obafemi Awolowo University, Ile-Ife using well calibrated NaI (Tl) detector system. The detector is mounted vertically coupled with 8K PC based multi channel analyzer (MCA) and the detector is enclosed in a massive lead shield to reduce background of the system. IAEA standard reference materials, Uranium ore (RGU-1) Thorium ore (RG Th-1) and KCl powder of known activity, were used for calibration of the system. The spectrometer was calibrated for energy and efficiency over the energy range 60keV to 3MeV. Each sample was counted for 36,000 seconds to reduce the statistical uncertainty. Minimum measurable activity was determined from the background radiation spectrum

The specific activity concentrations A_{ck}, A_{cu} and A_{cTh} for ^{40}K, ^{238}U and ^{232}Th respectively were computed using the relation (Beck, et. al, 1972).

$$A_c = \frac{AA^s_c m^s}{A^s m} \qquad (2)$$

where A_c =activity of sample, A =full peak area of samples, A^s_c =activity concentration of standard sample, m^s = mass of standard sample, A^s = full peak of the standard sample and m = mass of sample.

The absorbed dose rate, D (nGy h^{-1}), at a height of 1 m above the ground surface due to the concentrations of ^{238}U, ^{232}Th and ^{40}K in the soil in all sampling locations was calculated using the Beck et al (1972) relation,

$$D = 0.042Ac_k + 0.429Ac_u + 0.666Ac_{Th} \qquad (3)$$

where 0.042 = Dose constant of K-40, 0.429 = Dose constant of U-238,0.666 = Dose constant of Th-232

Ac_k = Activity concentration of K-40, Ac_u = Activity concentration of U-238, Ac_{Th} = Activity concentration of Th-232

Also the dose equivalent rate of each sample was calculated using the relation (Shapiro, 1981)

1 Sievert = Gray X Q.F. (4)

where QF is the quality factor, simply the measure of the relative hazard of an energy transfer by an emitted radiation of interest which for gamma radiation equals unity.

In estimating the effective dose in any environment, the two factors of importance are the conversion coefficient from Gy h^{-1} to Sv h^{-1} and the occupancy factor. The former gives the equivalent human dose in Sv y^{-1} from the absorbed dose rate in air (Gy h^{-1}) while the latter gives the fraction of the time an individual is exposed to outdoor radiation.

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RESULTS AND DISCUSSION

Table 3: Radionuclides Concentration of Soil Sample ($BqKg^{-1}$)

		Soil (Bq/kg)				
S/No	**Sample**	**K-40**	**U-238 (Ra-226)**	**Th-232 (Ra-228)**	**Absorbed dose rates (nGy/hr)**	**Equivalent dose rate (mSv/yr)**
1	**A1**	570.08 ± 87.6	20.52 ± 5.2	18.95 ± 9.9	45.25 ± 12.5	0.3964 ± 0.1
2	**A2**	105.57 ± 24.9	18.94 ± 8.4	16.62 ± 6.7	23.53 ± 9.1	0.2061 ± 0.1
3	**A3**	404.95 ± 99.8	34.81 ± 13.6	19.33 ± 6.5	44.68 ± 14.3	0.3914 ± 0.1
4	**A4**	140.49 ± 35.8	23.87 ± 9.7	17.84 ± 6.5	27.92 ± 10.0	0.2446 ± 0.1
5	**A5**	254.55 ± 79.5	38.28 ± 11.4	29.54 ± 11.5	46.60 ± 15.8	0.4082 ± 0.1
6	**A6**	256.22 ± 68.6	26.54 ± 9.7	22.46 ± 8.7	36.97 ± 12.8	0.3239 ± 0.1
7	**A7**	527.91 ± 89.5	35.91 ± 11.4	19.41 ± 9.9	50.39 ± 15.2	0.4414 ± 0.1
8	**A8**	545.13 ± 87.5	26.41 ± 11.1	18.63 ± 7.8	46.52 ± 13.6	0.4075 ± 0.1
9	**A9**	323.64 ± 75.9	29.36 ± 9.3	13.43 ± 7.3	35.05 ± 12.0	0.3070 ± 0.1
10	**A10**	132.23 ± 18.7	19.44 ± 9.9	16.52 ± 6.5	24.80 ± 9.3	0.2173 ± 0.1
Mean Values		326 ± 66.7	27.41 ± 10.0	19.27 ± 8.1	38.17 ± 12.5	0.3344 ±0.1

Table 4. Radionuclide Concentrations of Water Samples (Bql^{-1}).

		Water (Bq/l)				
S/No	**Sample**	**K-40**	**U-238 (Ra-226)**	**Th-232 (Ra-228)**	Absorbed dose rates(nGy/hr)	Equivalent dose rates (mSv/yr)
1	**W1**	16.40 ± 7.3	8.24 ± 2.8	5.87 ± 2.0	7.80 ± 2.8	0.0683 ± 0.03
2	**W2**	26.74 ± 7.7	7.48 ± 3.3	7.44 ± 2.2	9.24 ± 3.2	0.0809 ± 0.03
3	**W3**	24.98 ± 9.8	9.32 ± 2.3	8.32 ± 2.5	10.54 ± 3.0	0.0923 ± 0.03
4	**W4**	19.84 ± 7.0	7.89 ± 3.0	7.89 ± 2.1	9.43 ± 3.0	0.0826 ± 0.03
5	**W5**	23.51 ± 9.7	8.04 ± 2.1	6.78 ± 2.3	8.91 ± 2.9	0.0781 ± 0.03
6	**W6**	32.08 ± 8.2	9.06 ± 3.2	8.29 ± 3.1	10.71 ± 3.8	0.0938 ± 0.03
7	**W7**	16.12 ± 7.2	9.41 ± 2.7	7.89 ± 2.5	9.92 ± 3.1	0.0869 ± 0.03
8	**W8**	27.16 ± 9.0	6.94 ± 3.5	5.20 ± 2.0	7.55 ± 3.2	0.0661 ± 0.03
9	**W9**	21.67 ± 7.4	5.99 ± 2.1	4.76 ± 2.1	6.62 ± 2.6	0.0580 ± 0.02
10	**W10**	39.15 ± 10.0	6.85 ± 1.8	7.34 ± 2.9	9.68 ± 3.1	0.0848 ±0.03
Mean Values		24.77± 8.3	7.92±2.7	6.96±2.4	9.03 ± 3.1	0.0791 ± 0.03

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The results of the gamma-ray analysis of various samples are presented in Tables 3- 4 above. The radionuclides observed with reliable regularity belonged to the decay series chain headed by ^{238}U and ^{232}Th as well as the non-series ^{40}K. ^{238}U activity in the soil samples is distinctly higher than that of ^{232}Th and it ranges between 18.9Bq/kg and 35.9Bq/kg with a mean activity of 27.4± 10.0Bq/kg. This is because ^{238}U is moderately soluble in natural water (Ashraf et al., 2001). ^{232}Th concentration in the soil samples is found to be lower than those of both ^{238}U and ^{40}K and it ranges between 13.4Bq/kg and 29.5Bq/kg with a mean activity of 19.3± 8.1Bq/kg. The activity of ^{40}K is observed comparatively higher than ^{232}Th and ^{238}U in all sampling locations studied and it ranges between 105.6Bq/kg and 570.1Bq/kg with an average of 326± 66.7Bq/kg in soil and varies from 16.12Bq/l to 39.15Bq/l with an average of 24.77±8.3Bq/l in water samples. ^{232}Th concentration in the water samples is found to range from 4.76± 2.1Bq/l and 8.32± 2.5Bq/l with a mean activity of 6.96± 2.4Bq/l and ^{238}U activity in some water samples is higher than that of ^{232}Th and it ranges between 5.99Bq/l and 9.41Bq/l with a mean activity of 7.92± 2.7Bq/l. Soil samples (A1-A8) collected from the landfill have relative higher values of radionuclide concentrations compared with the control source samples (A9 and A10). This is due to the radionuclides concentration contributed by waste from medical sources co-disposed with other hazardous wastes in the landfill. A1 and A8 have relatively high concentration of K-40 compared to all other samples in the studied areas while sample A9 (control source) was observed to have relatively high U-238 content. The gamma absorbed dose rates of soil ranges between 23.53± 9.1nGy/hr and 50.39± 15.2nGy/hr with an average value of 38.17± 12.5 nGy/hr. These values also are comparable with Alatise et al.(2008) whose mean value in five Niger-Delta State was 33.655nGy/hr and Tchokossa (2006) whose mean value for soil was 36.90nGy/hr. The value also is comparable with Senthilkumar et al 2010) whose mean value is 43.30nGy/hr for soil samples around Thanjavur, India. The variations among the radiation levels in soil of different countries may be linked to the wide variations in geological formations of different types of soil. The absorbed dose rate due to ingestion of these sources of water ranged from 6.62 to 10.54nGy/hr with an average of 9.03± 3.1nGy/hr in landfill areas, Water sample W6 had the highest absorbed dose rate level. Water sample from W3 was next to W6 in dose content, followed by W7, W10, W4,W2, W5, W1, and W8 in that order. No significant difference in radionuclide concentration was shown by the water samples of the landfill area and the control sources (W4 and W10). This is due to frequent migration of radionuclides in the direction of flow of water. The equivalent dose rate ranged from 0.0580 to 0.0938mSv/yr with an average of 0.0791± 0.03mSv/yr. These results are comparable with Awodugba et al(2008) and Avwiri et al (2006) with mean annual effective doses of 0.36 ± 0.12, 0.51± 0.07 and 0.05 ± 0.01mSv/yr respectively and is relatively high due to the radionuclides deposited over a period of time which resulted to infiltration of leachates from the landfill through soils and contaminate groundwater which then migrate following the direction of flow, were below the recommended value of $1mSvy^{-1}$ due to borehole water only and the World Health Organization (WHO) (Geneva, Switzerland) recommended permissible limit of $0.1mSv\ y^{-1}$.

The absorbed and equivalent dose rates calculated for concentration activity of ^{232}Th, ^{238}U and ^{40}K for Eliozu landfill, Port-Harcourt are in the same range with that of other cities in Nigeria (Avwiri (2002) and Odunaike et al (2008).

The obtained results compared with the control samples showed an elevation above the landfill values. This shows that immediate water

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sources of the environment are contaminated. Therefore, residents, Scavengers and workers in landfill areas are exposed to different doses of radiation; these may result to health problems such as radiation poisoning, cancer and cell mutation. Generally, the results are low. Therefore there will be no immediate radiological burden to the host communities.

CONCLUSION

The radionuclide content of a landfill containing medical waste (sorted radioactive) co-disposed with other wastes has been studied. Gamma ray spectrometry was used to determine the soil and water radioactivity concentrations of ^{232}Th, ^{238}U and ^{40}K in samples collected from the landfill. The activity profile of radionuclides has clearly showed the existence of low level activity in the landfill. These activities fall within the lowest range of those measured on worldwide scale reported by authors. Inhabitants of the studied area are subjected to an external gamma radiation exposure which shows that the study area and the immediate environment have been impacted by radionuclides of medical sources present in the landfill.

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