

Original Research Article

The Radiological Impact of a Municipal Solid Waste dumpsite on Soil and Groundwater using Gamma Ray Spectroscopy.

ABSTRACT

The radiological impact of a municipal solid waste dumpsite on soil and groundwater in Port Harcourt municipality was investigated by gamma-ray spectroscopy. The objective of the study was to evaluate the radioactivity concentrations in soil and groundwater. Results show that the soil and ground water have been contaminated by dumpsite emissions and radioactive materials throughout the dumpsite area. The primary contaminants found in the site were leachate, waste gases, and the radionuclides of ^{40}K , ^{226}Ra , and ^{228}Ra . The mean absorbed dose rates of 31.98nGy/hr, 10.51nGy/hr and 6.98nGy/hr, and mean dose rate equivalents of 0.28mSv/yr, 0.09mSv/yr and 0.06mSv/yr were obtained for the soil, leachate and groundwater samples, respectively. The mean absorbed and equivalent dose rates in the soil and water samples were greater than their controls, suggesting that the dumpsite area is contaminated. These results are comparable to those reported for other waste sites in the area and lower than the maximum permitted limits for the general public of 1mSv/yr and 0.1mSv/yr for soil and water, respectively. These therefore, have no immediate radiological health burden on the inhabitants who depends on the soil and groundwater for their crops and potable water supply. However, with continuous consumption of crop products and intake of groundwater, increase in the activity concentration and dose rates of these radionuclides may occur over time, which will have adverse effects on humans.

Keywords: Radionuclides, Leachate, Emissions, Contaminants

Keywords: Leachate, Landfill gases, Resistivity Imaging, Contaminant

1. INTRODUCTION

The arbitrary and indiscriminate dumping of wastes in un-engineered landfills has posed serious health challenges to the populace globally. The hazard posed by these point sources of contamination is not only in terms of odour and presence of disease causing micro-organisms, but from radiations emanating from such landfills. Our natural environment is continuously bombarded with ionizing radiations from both natural and man-made sources [1]. The most common radionuclides in soil and groundwater are the radioactive isotopes of the three natural decay series (^{235}U , ^{238}U , and ^{232}Th) and ^{40}K . Waste disposal by landfill has led to the pollution of soil and groundwater resources [2-4].

In Port Harcourt municipality, solid wastes are mostly deposited in un-engineered landfills. The wastes are composed of mainly domestic co-disposed with industrial, agricultural, building and hospital wastes. These wastes contain traces of radiological elements or radionuclides resulting from the use of processing chemicals, fertilizers and pesticides, chemotherapy, food materials, gas and oil production [5-6]. Solid wastes landfills constitute local sites where natural radionuclides are concentrated in the environment. Due to the soil-solute interaction which could lead to the transport of specific contaminants relative to others into groundwater and soil-to-plant transfer processes which results in the accumulation of radionuclides in plants and animals, humans are exposed to high doses of radiation. Humans incur radiations from waste landfills by external irradiations or by incorporation in the body. Their occurrence and distribution in the soil and groundwater are controlled primarily by the local geology, geochemistry, and specific solubilities of the radionuclides. In view of this, it is important to monitor terrestrial background radiations, especially around municipal solid waste landfills. This is because soils and groundwater resources around landfills may contain naturally occurring radionuclides in significant amounts due to land filling activity [7]. The leaching of radionuclides can result in contaminated soil and groundwater with serious implications on the health of humans over time.

The activity concentration and dose rates of radionuclide in soils and groundwater have been investigated in different parts of the municipality [5,7]. This reveals increased activity and dose levels

of radionuclides in the samples, an observation attributed to industrial and exploratory activities in the area.

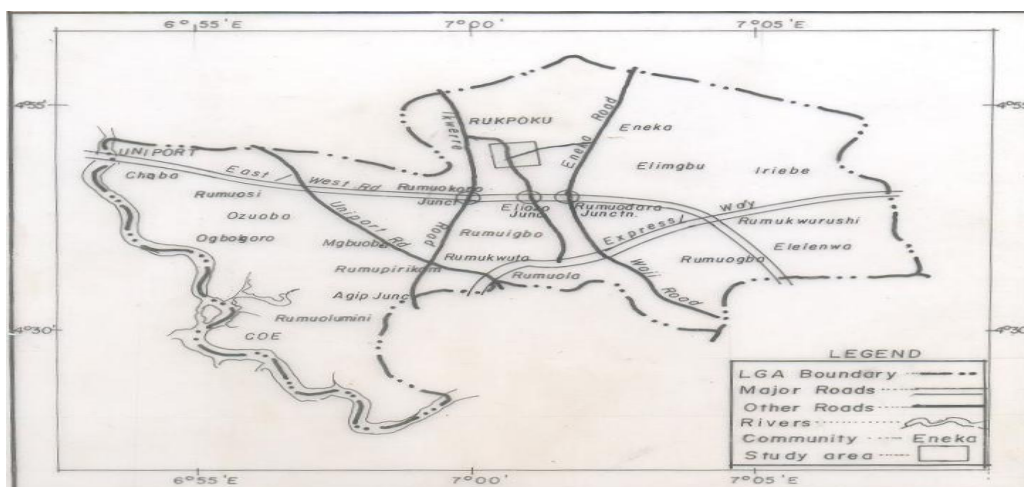
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41 2. LOCATION AND ACCESSIBILITY OF THE STUDY AREA

42 The study area is located along Elioza-Rukpoku road and lies between latitudes $7^{\circ}09'$ to $7^{\circ}38'N$ and
43 longitudes $4^{\circ}15'$ to $4^{\circ}55'E$ within Port Harcourt municipality in Obio/Akpor local government area,
44 Nigeria (Figure 1.0). The survey area is accessible through networks of tarred roads.

45 The area is characterized by alternate wet and dry seasons [8] with total annual rainfall of about
46 240cm, relative humidity of over 90% and mean annual temperature of $27^{\circ}C$ [9].

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49 **Fig. 1.0:** Map of Obio/Akpor Local Government Area showing the study Area.

50 The study area is located in the Niger Delta, in Nigeria. The Niger Delta extends across the study
51 area. Generally, three Formations: Benin, Agbada and Akata exist in the modern Niger Delta.

52 The study area is underlain by the Benin Formation, which is predominantly sandy with a few
53 intercalations of shale beds. The sands are fine to coarse grained in size, granular in texture and
54 hardly consolidated. The sediments represent upper deltaic plain deposits; the sands may represent
55 braided streams channel fills whereas the thin shale intercalations may represent back swamp
56 deposits. The Benin Formation is commonly masked by thick partly weathered layers of the recent
57 Niger Delta sediments and by dense vegetation, which range from secondary to fresh water swamps,
58 and at the coast, mangrove swamps. The unconsolidated and highly porous sands of the Benin
59 Formation have been identified as fresh water bearing [10-11]. It shows a thickness, which ranges
60 from 0 to about 2130 meters in the Niger Delta. This formation constitutes the major aquiferous layer.
61 Both confined and unconfined aquifers are encountered at varying depths.

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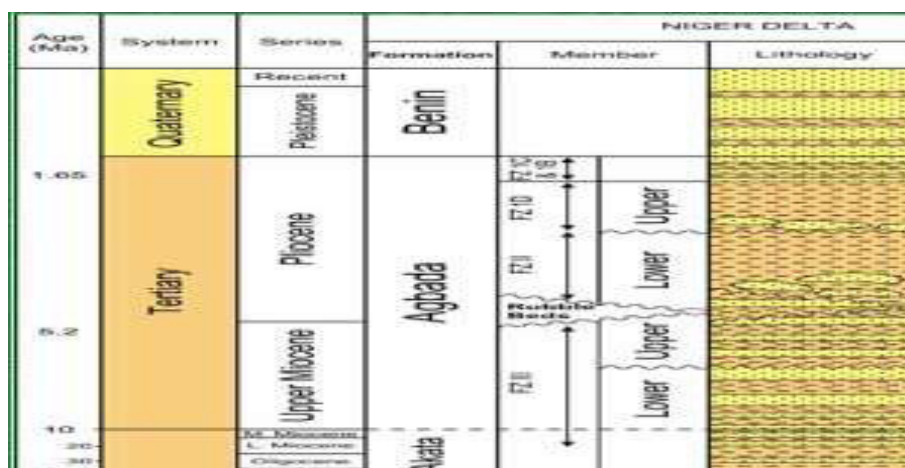


Fig 2.0: Geologic and Stratigraphic map of the area

The sands are fine to coarse grained, granular in texture and hardly consolidated [11]. The shale intercalations in the formation has resulted in a multi aquifer system, and both confined and unconfined aquifers are encountered at varying depths and horizons, which serves as the major source of potable water supply in the area. The depth to the water table varies from 3m during the peak of the rainy season to 15m during the dry season. The dept to the usable aquifer in the area is approximately 30-45m, which is penetrated by most boreholes in the vicinity of the dump. These aquifers are recharged predominantly by infiltrations from surface precipitation.

3. MATERIALS AND METHODS

A total of eight samples were collected from different points in the study area for the measurement of the radionuclides present in soil, leachates and groundwater. The samples collected from the different points in the study area include water (obtained from borehole), leachates and soil samples. The water and leachate samples collected were stored in a 1.5litre plastic bottle sealed and labelled. The soil samples weighing 100g was collected between depths of 12cm to 15cm, and was parked in black polythene bag for onward transmission to the laboratory for radiological analysis

The samples collected were prepared and stored in the laboratory for four weeks to attain a state of secular equilibrium for the respective daughter nuclides of Uranium and Thorium. When this equilibrium is attained, the activity of each nuclide of a given series is equal to the activity of the parent nuclide

3.1 SAMPLE PROCESSING

The samples were analysed at the CERD Gamma Ray Spectrometry Laboratory, Obafemi Awolowo University, Ile Ife using a Canberra vertical high purity 3"x3" NaI (TI) detector. The detector, enclosed in a 100mm thick lead shield, was connected to a computer program SAMPO 90 that matched gamma energies to a library of possible isotopes. Since the accuracy of the quantitative measurements depends on the calibration of the spectrometry system, adequate energy and efficiency calibration of the system was made possible using standard sources from IAEA, Vienna.

3.2 MEASUREMENT OF RADIONUCLIDE CONCENTRATION

The method of gamma ray spectrometry has been severally reported [12] and was adopted in the analysis. The spectrometer consists of a Canberra 7.6cm by 7.6cm NaI (TI) (Model No 802-series) detector coupled to a Canberra series 10 plus Multichannel Analyzer (MCA) through a preamplifier base (Model No 2001). The transition lines of 1.460MeV of ^{40}K , 1764.5KeV of ^{214}Bi and 2614.7KeV of ^{208}Tl were used to determine the concentrations of ^{40}K , ^{238}U and ^{232}Th respectively. The soil samples were sieved through a 2mm mesh screen and then placed in a container for 30days to enable them reach secular equilibrium before the analysis. The spectral for the soils were measured by counting for two hours and the area under the photo peaks were computed using the algorithm of the MCA. The water and leachate samples were transferred to a one litre Marinelli sample container, which fits

into the detector. Counting was done for ten hours because of the natural low activities of radionuclides in water. The areas under the photo peaks were similarly computed as in the soil samples. Environmental shielding for the water and leachate samples was achieved using a Canberra 100mm thick lead castle and 50mm thick lead castle was used for the soil [5]. 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 [13].

$$A_c = \frac{A A^s m^s}{A^s m} \quad (1.0)$$

where A_c = Activity of sample

A = Full Peak area of samples

A^s = Activity Concentration of standard sample

m^s = Mass of standard sample

A^s = Full peak of the standard sample

m = Mass of sample

The absorbed dose rates D , were calculated using the [13] relation.

$$D = 0.042 A_{ck} + 0.429 A_{cu} + 0.666 A_{cth} \quad (1.1)$$

where 0.042 = Dose constant for ^{40}K

0.429 = Dose constant for ^{238}U

0.666 = Dose constant for ^{232}Th

The equivalent dose rate (E.D.R) of the various samples was computed using the [14] relation

$$\text{E.D.R} = 0.00876 \times D \quad (1.2)$$

3.3 PRESENTATION OF RADIONUCLIDE CONCENTRATION OF THE VARIOUS SAMPLES

The average activity concentration of the radionuclides in the soil, leachate and water samples are presented in (Tables 1 to 3) and the bar charts shows radioactivity concentration in the samples (Figures 2-4).

Table 1: Radionuclide Concentrations of Soil Samples (Bqkg^{-1})

Samples	K-40	U-238(Ra-226)	Th-232(Ra-228)
Soil A1	484.70±34.92	34.26 ± 9.25	15.27 ± 6.07
Soil B1	296.81 ± 24.82	19.08 ± 8.22	8.27 ± 3.02
Soil C1	223.02 ± 21.92	25.82 ± 3.98	9.24 ± 2.11
Soil D1	301.35 ± 32.09	23.16 ± 7.92	11.09 ± 3.97
Mean Values	326.47±28.44	25.58±7.34	10.97±3.79

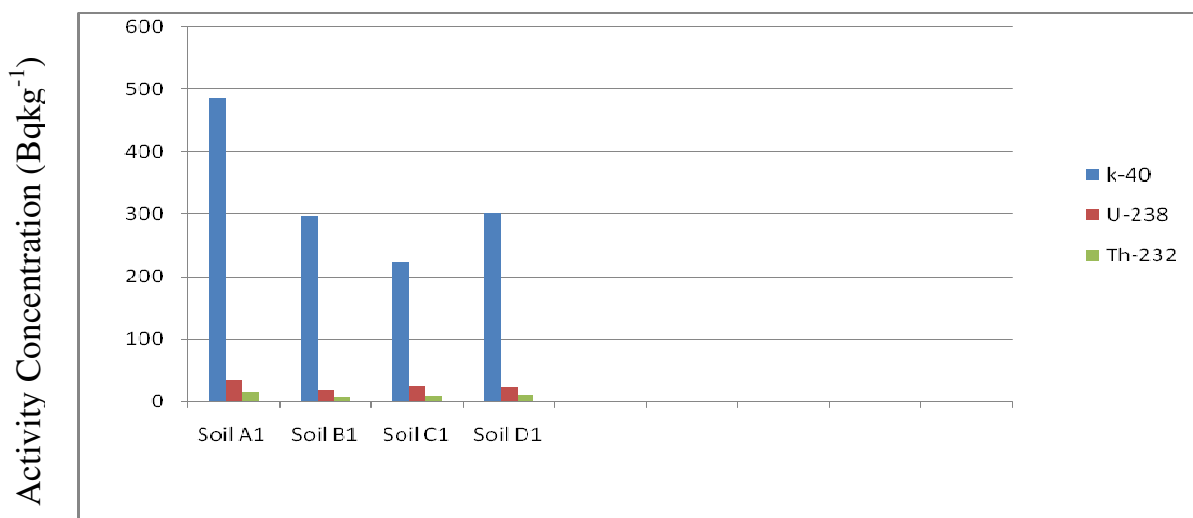


Fig 2: Bar charts showing radioactivity concentration in soil samples.

Table 2: Radionuclide Concentrations of Leachate Samples (BqL⁻¹)

Samples	K-40	U-238(Ra-226)	Th-232(Ra-228)
Leachate A2	274.12 ± 24.91	2.73 ± 1.09	2.22 ± 0.97
Leachate B2	98.65 ± 15.44	3.01 ± 1.08	2.13 ± 1.02
Mean Values	186.39±20.17	2.87±2.70	2.18±0.99

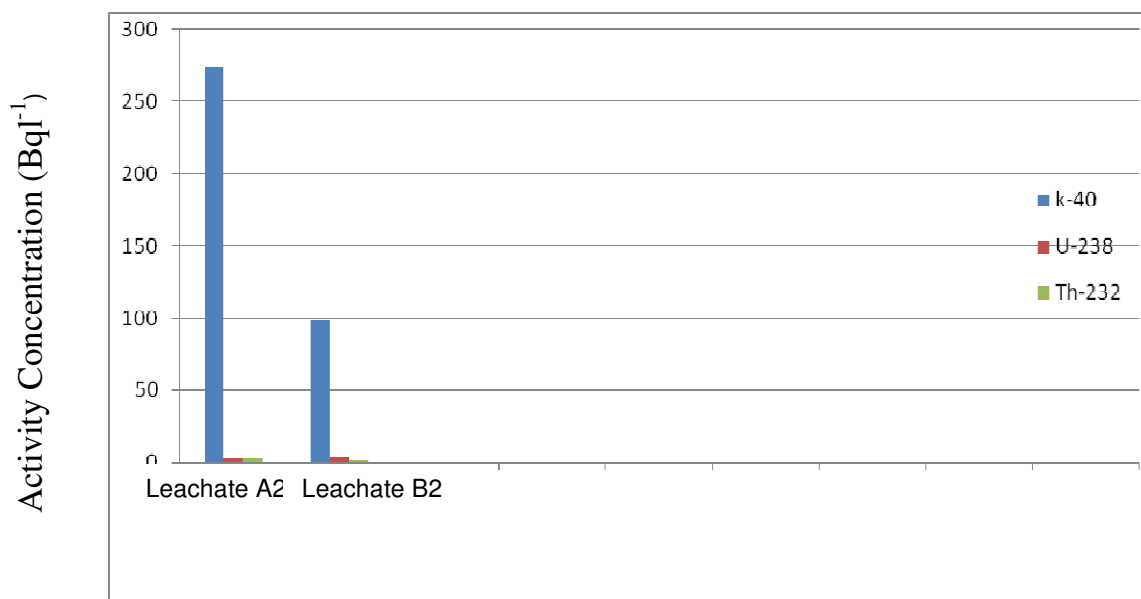


Figure 3: Bar charts showing radioactivity concentration in leachate Samples.

Table 3: Radionuclide Concentration of Water Samples (BqL⁻¹)

Samples	K-40	U-238(Ra-226)	Th-232(Ra-228)
Water C2	132.31 ± 14.53	2.45 ± 0.99	1.99 ± 0.98
WaterD2	109.66 ± 22.90	1.44 ± 0.77	2.03 ± 1.00
Mean Values	120.50±37.43	1.95±0.84	2.01±0.09

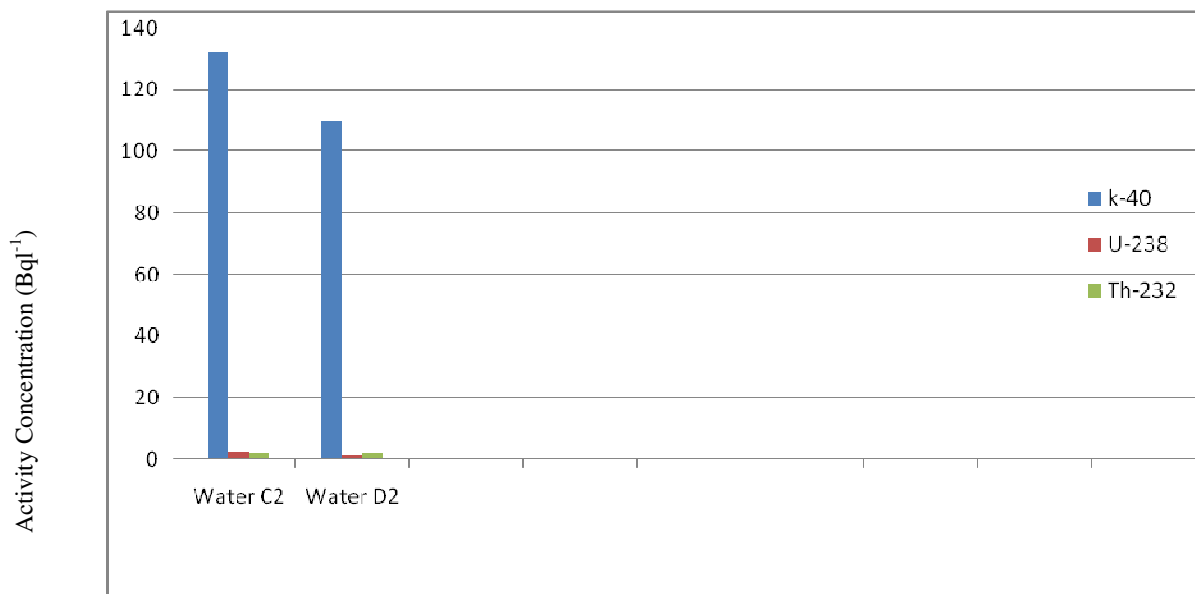


Fig 4: Bar Chart showing radioactivity concentration in water samples.

The dose rate D , of the various samples was calculated using the [13], relation (Equation 1.1), while the equivalent dose rates of the various samples were calculated using the [14] relation (Equation 1.2)

4. RESULTS IN ABSORBED DOSE RATE AND EQUIVALENT DOSE RATE

The results of the absorbed dose rate and equivalent dose rate are presented in (Tables 4- 6).

Table 4: Results of Soil Samples in Absorbed dose rate and Equivalent dose rate

Samples	Absorbed Dose Rate (nGy/hr)	Equivalent Dose Rate (mSv/yr)
Soil A1	45.22	0.40
Soil B1	26.16	0.23
Soil C1	26.60	0.23
Soil D1	29.98	0.26
Mean Values	31.98	0.28

Table 5: Results of Leachate Samples in Absorbed dose rate and Equivalent dose rate

Samples	Absorbed Dose Rate (nGy/hr)	Equivalent Dose Rate (mSv/yr)
Leachate A2	14.16	0.12
Leachate B2	6.85	0.06
Mean Values	10.51	0.09

Table 6: Results of Water Samples in Absorbed dose rate and Equivalent dose rate.

Samples	Absorbed Dose Rate (nGy/hr)	Equivalent Dose Rate (mSv/yr)
Water C2	7.93	0.07
Water D2 (Control)	6.03	0.05
Mean Values	6.98	0.06

5. RESULTS AND DISCUSSION

The results of gamma spectroscopy analysis carried out shows that the radionuclides contaminant identified in the soil and water samples are Ra-226 and Ra-228, which belongs to the decay series of U-238 and Th-232 respectively as well as the non series radionuclides K-40.

The activity concentration of K-40 in the soil samples ranges from 223.02-484.7Bqkg⁻¹, with a mean value of 326.47± 28.44Bqkg⁻¹. This result is greater than the mean value of 131.8Bqkg⁻¹ for soil samples reported by [15], around a nuclear research establishment in Nigeria and lower than 375.66±20.5Bqkg⁻¹ reported [16] in some selected dumpsites in southwest Nigeria. The activity concentration of ²³⁸U (Ra-226) ranges from 19.08 to 34.26Bqkg⁻¹ with a mean value of 25.58±7.34Bqkg⁻¹. This is lower than the mean value of 53.83±17.5Bqkg⁻¹ reported by [16]. The activity concentration of ²³²Th (Ra-228) ranges from 8.27 to 15.27Bqkg⁻¹, with a mean value of 10.97±3.79Bqkg⁻¹. This is lower than the mean value of 64±17 Bqkg⁻¹ reported by [16]. The ⁴⁰K is the largest contributor of radionuclide activity concentration in soil samples in the area.

The absorbed dose rate of ⁴⁰K ranges from 26.60 to 45.22nGy/hr, with a mean value of 31.98nGy/hr for the soil samples. This moderately lies within the range of measured values (20.831-44.95) nGy/hr, with a mean value of 33.65nGy/hr in the five Niger delta states [17]. This is higher than the mean value of 29.3nGy/hr reported by [18] in a dumpsite in Abeokuta, Nigeria, 20.04nGy/hr reported by [5] from a dumpsite in Port Harcourt, 19.96nGy/hr reported by [19] in eighteen cities across Nigeria, but lower than the mean value of 76.83nGy/hr reported by [18], in some selected dumpsites southwest Nigeria. The high values of activity concentration and absorbed dose rates reported by [18] were attributed to the basement rock exposures in the area contributing to the background radiation.

The mean dose equivalent of the soil samples varies between 0.23-0.40 mSv/yr, with a mean of 0.28mSv/yr. This is greater than the value of 0.24 mSv/yr for a similar study in Port Harcourt [5]. The activity concentration of leachate samples for ⁴⁰K ranges from 98.65 to 274.12 (BqL⁻¹) with a mean value of 186.39± 20.17 (BqL⁻¹), for ²³⁸U (Ra-226), this ranges from 2.73 to 3.01 (BqL⁻¹), with a mean value of 2.87± 2.70 (BqL⁻¹) and 2.13 to 2.22 (BqL⁻¹), with a mean of 2.18±0.99 (BqL⁻¹) for ²³²Th (Ra-228). The mean absorbed and equivalent dose rates of the leachate samples are 10.51nGy/hr and 0.09mSv/yr, respectively.

The activity concentration of groundwater samples ranges from 109.66 to 132.31 (BqL⁻¹), with a mean of 120.50 ± 37.43 (BqL⁻¹), 1.44 to 2.54 (BqL⁻¹), with a mean value of 1.95±0.84 (BqL⁻¹), and 1.99 to 2.03 (BqL⁻¹), with a mean of 2.01±0.01 (BqL⁻¹) for ⁴⁰K, ²³⁸U (Ra-226) and ²³²Th (Ra-228), respectively. The mean dose rate and equivalent dose rate of the water samples are 6.98 nGy/hr and 0.06mSv/yr, respectively.

The study revealed elevated concentration of the radionuclides in the soil, groundwater and leachate samples in the vicinity of the dump than their controls. This suggests that the waste dumpsite area has been contaminated by the activities of the dump site. The absorbed dose rate and the equivalent dose rate of the samples are however, within the world average of 55.0nGy/hr [1] and 1.0mSv/yr [20] respectively, for the soil samples, and 0.1 mSv/yr for groundwater [20].

7. CONCLUSION

The radionuclides present in the soil, leachate and water samples due to the landfill are Potassium-14 (K-14), Uranium-238 (U-238) and Thorium-232 (Th-232). The activity concentration of radionuclides present in the water samples within the vicinity of the landfill was higher than that obtained outside the landfill site. This probably may be associated with the presence of radioactive waste such as hospital waste, building materials waste, agricultural waste and domestic waste. The average effective dose rate of 0.28mSv/yr, 0.09mSv/yr and 0.06mSv/yr were obtained for the soil leachate and water samples respectively. These values are lower than the maximum permissible limit and therefore do not pose health problems to the inhabitant who depends on borehole water within the landfill. However, these values may increase with longer period of operation of the landfill site.

8. REFERENCES

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