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The Radiological Impact of a Municipal Solid Waste Dumpsite on Soil and Groundwater Using Gamma Ray Spectroscopy

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Authors' contributions

This work was carried out in collaboration between authors GOI and AOB. Authors GOI and AOB designed the study and wrote the first draft of the manuscript. Authors GOI and AOB were involved in the data acquisition. Authors GOI and AOB managed the literature searches, analyses of the processed data from the spectroscopy analysis. Authors GOI and AOB compiled the manuscript. Both authors read and approved the final manuscript.

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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 within the landfill. Results show that the soil and ground water have been contaminated by dumpsite emissions and radioactive materials throughout the landfill. The average value of absorbed dose rates of 52.49nGy hr^{-1} and 10.97nGy hr^{-1} were obtained for soil and groundwater respectively. The average value of dose rate equivalents of 0.46mSv yr^{-1} and 0.09mSv yr^{-1} were obtained for the soil and groundwater samples 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. The monitoring of radionuclides in soil and groundwater samples is very important and the practice of planting crops by farmers and consumption of groundwater within the landfill should be discouraged to prevent

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inhalation and ingestion of these radionuclides in humans. 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 the inhabitants.

Keywords: Radionuclides; activity concentration; leachate; emissions, contaminants.

1. INTRODUCTION

The arbitrary dumping of wastes in landfills has led to the pollution of soil and groundwater [1-3]. The activities of humans create wastes and the methods in which these wastes are collected, stored and disposed in landfills could probably give rise to elevated levels of radionuclides and this can impact negatively on public health and the environment. Solid waste landfill has been identified as one of the major threats to groundwater resources. This is because solid wastes produce leachate which contaminates groundwater and the surrounding soil. Therefore, solid waste landfills pose a serious risk to the quality of soil, groundwater and the inhabitants living within the landfill. Landfills have the possibilities of emitting radiation due to the presence of radioactive waste [4]. It has been shown that staple food stuffs consumed contains traces of radionuclides [5,6], and as a result of these, landfills were identified as a potential recipient of the radioactive materials. Inhabitants who depends on their farm products (crops), there is a possible transfer to humans through injestion and breathing. Wastes from hospitals co-disposed with hazardous wastes have been identified as a potential source of radionuclide pollution [7] in landfills. Studies have been carried out in recent years to investigate the radionuclides activities of landfills [8-10].

The analysis of radionuclides concentration and activity level in the landfill generated from hospital waste co-disposed with agricultural waste, building materials waste and domestic wastes would provide information to evaluate or determine the radiological impact on soil, groundwater and the people living within the vicinity of the landfill.

2. MATERIALS AND METHODS

A total of twenty eight (28) samples were collected from different points in the study area for the measurement of the radionuclides activity present in soil and groundwater. The samples collected from the different points in the study area include groundwater (obtained from borehole) and soil samples. The soil samples weighing 100 g was collected between depths of 12 cm to 15 cm, and was parked in black polythene bag for onward transmission to the laboratory for radiological analysis and labeled A1 to N1. The water samples collected were stored in a 1.5 litre plastic bottle sealed and labeled A2 to N2. 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.

2.1 Sample Processing

The samples were analysed at the centre for energy research and development (CERD) Gamma Ray Spectrometry Laboratory, Obafemi Awolowo University, Nigeria using a Canberra 3"x3" NaI (TI) detector. The detector, enclosed in a 100 mm 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 were carried out using standard sources from IAEA, Vienna.

The method of gamma ray spectrometry has been severally reported [11] and was adopted in the sample analysis. The spectrometer consists of a Canberra 7.6 cm by 7.6 cm 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}TI were used to determine the concentrations of ^{40}K, ^{238}U and ^{232}Th respectively. The soil samples were sieved through a 2 mm mesh screen and then placed in a container for 30 days to enable them reach secular equilibrium before the analysis. The soil samples were placed in 250 ml air tight container sealed and stored until the radioactive equilibrium was achieved and measured for 10000s.The spectral for the soils were measured by counting for two (2) hours and the area under the photo peaks were computed using the algorithm of the MCA. The groundwater samples were transferred to a one litre Marinelli sample

container, which fits into the detector and it was measured for 10000s. 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 groundwater samples was achieved using a Canberra 100 mm thick lead castle and 50 mm thick lead castle was used for the soil [12]. The IAEA, 1989 was used as the standard source for calibration.

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] and is represented by equation (1).

$$A_c = \frac{AA^S cm^s}{A^S m} \quad (1)$$

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
m = Mass of sample

The absorbed dose rates D, were calculated using the [13] relation and is represented by equation (2).

$$D = 0.042\ A_{ck} + 0.429\ A_{cu} + 0.666\ A_{cth} \quad (2)$$

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 and is represented by equation (3)

$$E.D.R = 0.00876 \times D \quad (3)$$

2.2 Presentation of Radionuclide Concentration of the Various Samples

The average activity concentrations of the radionuclides in the soil and groundwater samples are presented in (Tables 1 and 2).

3. RESULTS AND DISCUSSION

The results of the absorbed dose rate and equivalent dose rate are presented in (Tables 3-4).

The results of gamma ray spectroscopy analysis carried out show that the radionuclides identified in the soil and groundwater samples are Ra-226 and Ra-228, which belongs to the decay series of U-238 and Th-232 respectively as well as the single occurrence radionuclide K-40.

The activity concentration of K-40 in the soil samples ranges from 126 ± 25 to 658 ± 89 $Bqkg^{-1}$ with an average value of 374 ± 57 $Bqkg^{-1}$. This result is higher than the average value of 131.80$Bqkg^{-1}$ for soil samples reported by [15], around a nuclear research establishment in Nigeria and lower than 375.66±20.5 $Bqkg^{-1}$reported [16] in some selected dumpsites

Table 1. Radionuclide concentrations of soil samples ($Bqkg^{-1}$)

Samples	K-40	U-238(Ra-226)	Th-232(Ra-228)
Soil A1	485± 35	34 ± 9	15 ± 6
Soil B1	297 ± 25	19 ± 8	8 ± 3
Soil C1	223 ± 22	26 ± 4	9 ± 2
Soil D1	301 ± 32	23 ± 8	11 ± 4
Soil E1	658 ± 89	26 ± 6	29 ± 11
Soil F1	126 ± 25	27 ± 10	23 ± 8
Soil G1	505 ± 99	48 ± 16	26 ± 8
Soil H1	176 ± 37	34 ± 11	38 ± 8
Soil I1	334 ± 78	50 ± 11	62 ± 10
Soil J1	325 ± 70	36 ± 9	50 ± 10
Soil K1	617 ± 88	47 ± 10	66 ± 9
Soil L1	400 ± 75	39 ± 8	47 ± 6
Soil M1	151 ± 29	29 ± 10	34 ± 8
Soil N1	633 ± 87	38 ± 11	60 ± 9
Average values	374 ± 57	36 ± 9	34 ± 7

Table 2. Radionuclide concentrations of groundwater samples (Bql^{-1})

Samples	K-40	U-238(Ra-226)	Th-232(Ra-228)
Water A2	274 ± 25	3 ± 1	2 ± 1
Water B2	99 ± 15	3 ±1	2 ± 1
Water C2	132 ± 15	2 ± 1	2 ± 1
Water D2	110 ± 23	2 ± 1	2 ± 1
Water E2	24 ± 8	11 ± 4	8 ± 3
Water F2	34 ± 9	10 ± 4	10 ± 3
Water G2	35 ± 11	12 ± 2	11 ± 4
Water H2	27 ± 8	11 ± 4	10 ± 3
Water I2	33 ± 11	10 ± 3	9 ± 3
Water J2	40 ± 9	13 ± 4	10 ± 4
Water K2	23 ± 8	11 ± 4	7 ± 3
Water L2	36 ± 10	10 ± 4	7 ± 3
Water M2	29 ± 9	8 ± 3	8 ± 3
Water N2	49 ± 11	8 ± 2	10 ± 3
Average values	68 ± 12	8 ± 3	7 ± 3

Table 3. 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
Soil E1	57.87	0.51
Soil F1	32.49	0.28
Soil G1	62.22	0.54
Soil H1	47.06	0.41
Soil I1	76.90	0.67
Soil J1	62.33	0.55
Soil K1	89.91	0.79
Soil L1	49.58	0.43
Soil M1	43.48	0.38
Soil N1	85.07	0.75
Average value	52.49	0.46

Table 4. Results of groundwater samples in absorbed dose rate and equivalent dose rate

Samples	Absorbed dose rate (nGy/hr)	Equivalent dose rate (mSv/yr)
Water A2	14.16	0.12
Water B2	6.85	0.06
Water C2	7.93	0.07
Water D2	6.58	0.06
Water E2	10.97	0.10
Water F2	12.27	0.11
Water G2	13.65	0.12
Water H2	12.45	0.11
Water I2	11.79	0.10
Water J2	13.85	0.12
Water K2	11.10	0.10
Water L2	10.57	0.09
Water M2	9.19	0.08
Water N2	12.17	0.11
Average values	10.97	0.09

in southwest Nigeria. The radioactivity concentration of ^{238}U (Ra-226) in soil ranges from 19 ± 8 to 50 ± 11 $Bqkg^{-1}$ with an average value of 36 ± 9 $Bqkg^{-1}$. This is lower than the mean value of 53.83 ±17.5$Bqkg^{-1}$ reported by [16]. The activity concentration of ^{232}Th (Ra-228) in soil ranges from 8 ± 3 to 66 ± 9 $Bqkg^{-1}$, with an average value of 34 ± 7 $Bqkg^{-1}$. This is lower than the average value of 64 ± 17 $Bqkg^{-1}$ reported by [16]. The ^{40}K is the largest contributor of radionuclide activity concentration in soil samples in the area.

The absorbed dose rate of soil samples ranges from 26.16 to 89.91 nGy hr^{-1}, with an average value of 52.49 nGy hr^{-1}. This moderately lies within the range of previously measured values ranging from 20.831 to 44.95 nGy hr^{-1}, with an average value of 33.65 nGy hr^{-1} in the five Niger delta states [17]. This is higher than the average value of 29.30nGy hr^{-1} reported by [18] in a dumpsite in Abeokuta, Nigeria, 20.04 nGy hr^{-1} reported by [5] from a dumpsite in Port Harcourt, 19.96nGy hr^{-1} reported by [19] in eighteen cities across Nigeria, but lower than the mean value of 76.83nGy hr^{-1} 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 average equivalent dose rate of the soil samples varies between 0.23 to 0.79 mSv yr^{-1}, with an average value of 0.46 mSv yr^{-1}. This value is higher than 0.24 mSv yr^{-1} for a similar study in Port Harcourt [5].

The activity concentration of ^{40}K in groundwater samples ranges from 23 ± 8 to 274 ± 25 Bql^{-1}, with an average value of 68 ± 12 Bql^{-1}. This result is higher than the average value of 0.3624 ± 0.19Bql^{-1} for groundwater samples reported by [8]. The activity concentration of ^{238}U (Ra-226) in groundwater samples ranges from 2 ± 1 to 12 ± 2 Bql^{-1} with an average value of 8 ± 3 Bql^{-1}. This result is lower than the average value of 48.29 ± 12.07 Bql^{-1} for groundwater samples reported by [8]. The activity concentration of ^{232}Th (Ra-228) in groundwater samples ranges from 2 ± 1 to 11 ± 4 Bql^{-1}, with an average value of 7 ± 3 $Bqkg^{-1}$. This result is higher than the average value of 0.0379 ± 0.0296 Bql^{-1} for groundwater samples reported by [8].

The absorbed dose rate of groundwater sample range from 6.58 to 14.16nGy hr^{-1}, with an average value of 10.97 nGy hr^{-1} and is less than 20.76 nGy hr^{-1} as reported by [8]. The average equivalent dose rate for the groundwater samples varies between 0.06 to 0.12 mSv yr^{-1}, with an average value of 0.09 mSv yr^{-1} and is less than 0.18 mSv yr^{-1} as reported by [8], [20]. The activity concentration of groundwater samples could be as a result of the hospital wastes co-disposed with other hazardous waste within the landfill.

The results of the study shows that the radiological health impact due to the activities of municipal solid waste landfill on the people depending on soil and groundwater within the landfill for their day to day activities is insignificant and has no immediate radiological implication. However, the continuous intake of groundwater and consumption of farm (crops) products, the activity concentration and dose rates of these radionuclides may increase over time, which will have adverse effects on humans.

4. CONCLUSION

The study of the radionuclide concentration levels of soil and groundwater within a municipal solid waste landfill containing domestic waste, building materials waste, agricultural waste co-disposed with hospital waste has been studied. The radionuclides detected in the soil and groundwater samples were all natural occurring radionuclides. Gamma ray spectroscopy was used to determine the activity concentrations of Potassium-40 (K-40), Uranium-238 (U-238) and Thorium-232 (Th-232). The average equivalent dose rate obtained for soil and groundwater within the landfill are 0.46mSv yr^{-1} and 0.09mSv yr^{-1} respectively. These values obtained are lower than the maximum permissible limit and therefore do not pose radiological health burden to the people who depends on soil and groundwater for their day to day activities but this might increase with longer period of operation of the landfill. At present, no proper legislations are in place to monitor routinely radiological burden in this present field of study as the fields have been reclaimed. Therefore, the need for continuous monitoring of the level of radionuclides within the study area and environs through researches is recommended.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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