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Survey of Radiological Parameters at a Dumpsite Near an Oil and Gas Facility in Bayelsa State, Nigeria

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ABSTRACT
The issue of proper waste management is becoming more critical with the increase of civilization and urbanization. Waste generation and disposal could increase levels of human radiation exposure. The dose rates from possible radioactive materials at Gbaraun-toru dumpsite have been investigated. Radiation survey meter was used to assess the dose rates at the site. Model equations were also used to estimate the health-related radiological parameters for the flux of scavengers and individuals using the dump site. The values of the measured dose rates at the dumpsites lie between (0.01 – 0.016) mRh^{-1} with a mean of 0.013 $mRh^{-1.}$ Absorbed dose rates and equivalent dose rates estimated ranged from (87.4 – 139.4) $nGyh^{-1}$ with a mean of 116.2 $nGyh^{-1}$ and (0876 – 1.402) $mSvy^{-1}$with a mean of 1.113 $mSvy^{-1}$. Annual effective dose rates, organ doses, and the excessive lifetime risk of cancer ranged from (0.357– 0.572) $mSvy^{-1}$ with mean 0.454 $mSvy^{-1}$, (0.139 – 0.248) $mSvy^{-1}$and (0.94 – 1.54) × 10^{-6} with mean of 1.28 × 10^{-6} respectively. Conclusively, the estimated absorbed measured rates for the study are above the safe limit (54 $nGyh^{-1}$), while, others are within the safe limit (1 $mSvh^{-1}$). This suggests that there may be an increment in the level of exposure of the workers at the dump sites, hence, regular radiological studies should be carried out in the study area.

Keywords:
Radiological parameters,
Dumpsite,
Oil and gas facility.

INTRODUCTION

There is global attention on the management of waste from industries because of its environmental impact and possible health effects on humans. Also, humans are unceasingly prone to ionizing effects of radiation released from natural or man-made sources (Al Mugren, 2015). In the last few decades, there have been reports of increasing exposure to ionizing radiation from radionuclides due to human activities (Jibiri *et al.*, 2014). Such activities include human exposure to radiation through waste generation and inappropriate disposal of waste (Kayode *et al.*, 2022) reported an increased background radiation at a Lagos dump site that can pose a potential radiological risk to workers. (Jibiri *et al.*, 2007), reported that the popular foods consumed by humans have evidence of radionuclides and dump sites is the final destination of waste products of staple foods. Acts of indiscriminate waste dumps would eventually lead to soil pollution. The pollution of the soil relates to the misuse of land in such ways that renders the land unfit for future endeavors like building, agriculture or any other form of development needed for human existence. Such acts of indiscriminate dumping may result in hazardous toxic pollution of air and or water. It causes land degradation and makes it wasteful. Apart from the above mentioned, dumpsites may also contribute to the exposure to radiation on the part of scavengers as well as the adverse effects of odor and microbes that cause disease. Waste disposal sites may as well be a source of greenhouse gas generation or production which could likely lead to some health issues. It is therefore, imperative to evaluate radiation exposure level and associated health hazards around the dumpsites.

The knowledge of the exposure levels and the effect of radiation from waste dumpsites will enable one to evaluate possible radiological risks to both humans and environmental health, which could be the outcome of waste generation as well as disposal (Jibiri *et al.*, 2014). In Nigeria, some researchers have reported that dumpsites contribute serious health hazards in comparison to normal surfaces (Okoronkwo *et al.*, 2006;

Ogundiran *et al.*, 2008). Industrial wastes that contain high levels of radionuclide are also carelessly and unlawfully disposed on dumpsites. Thus, radioactive materials are found in deposits at waste disposal sites, which if not adequately regulated emits radioactive compounds to the surroundings (Olubosede *et al.*, 2012). Hence, adequate surveying as well as proper estimation of radiation level from dumpsites will assist in giving information that will be useful for environmental monitoring research work that can be used for adequate evaluation of environmental radioactivity within the study area. The selected dumpsite is along Tombia-Amassoma road, and it is generally called Gbaraun-toru dumpsite in Yenagoa. Yenagoa is host to several oil and gas facilities which are associated with multi-faced activities that generate waste (Isinkaye and Emelue, 2015). The city has other industries as well as a population whose activities generate lots of waste. Findings from studies have shown that both wastes from households and industries have different compounds that include radioactive substances that come from chemical processing. Disposal of waste in dumpsites without sufficient management of radioactive pollutants could predispose the human population to radioactive hazards. The objective of the study is to measure the dose rates at the dumpsites and estimate the radiological parameters associated with exposure to ionizing radiation from possible radioactive materials that may find their way to the dumpsite. To the best of the knowledge of the researchers, no investigation has been conducted in the selected area that factored in the estimation of organ doses to users of the dumpsite which is a major goal for this work. The outcomes from the present work will also add value to the extant information in the area of research interest.

Description of the study area

The area of study, Gbaraun-toru dumpsite is about 5 Km from Yenagoa, and about 3 Km from Gbaraun oil and gas facility in Yenagoa Local Government Area, Bayelsa State, Nigeria. Yenagoa Local Government Area is located on longitude 6^0 18' 55.8 E and 4^o 59' 24.88 N and longitude, with an estimated population of over 300,000 inhabitants (Tariwari *et al.*, 2018). From the attainment of State capital in the year 1996, improved industrial, sporadic urbanization and growing commerce in Yenagoa are on the increase. Bayelsa state boasts of a major geological characteristic, being sedimentary alluvial. Abandoned beach ridges result in several tributaries of the river Niger and significant alterations in the geology are obvious in abundance. Various soil types that are prevalent in Bayelsa state are the acid sulphate soils (Sulphaquepts) and the young, shallow poorly drained soils (inceptisol Aquepts). However, differences exist in soil types in Bayelsa State; some occupy large areas in coverage while some are of less extent in coverage. Figure 1 presents the map of the area of the study while Plate 1 shows a section in the Gbaraun-toru dumpsite.

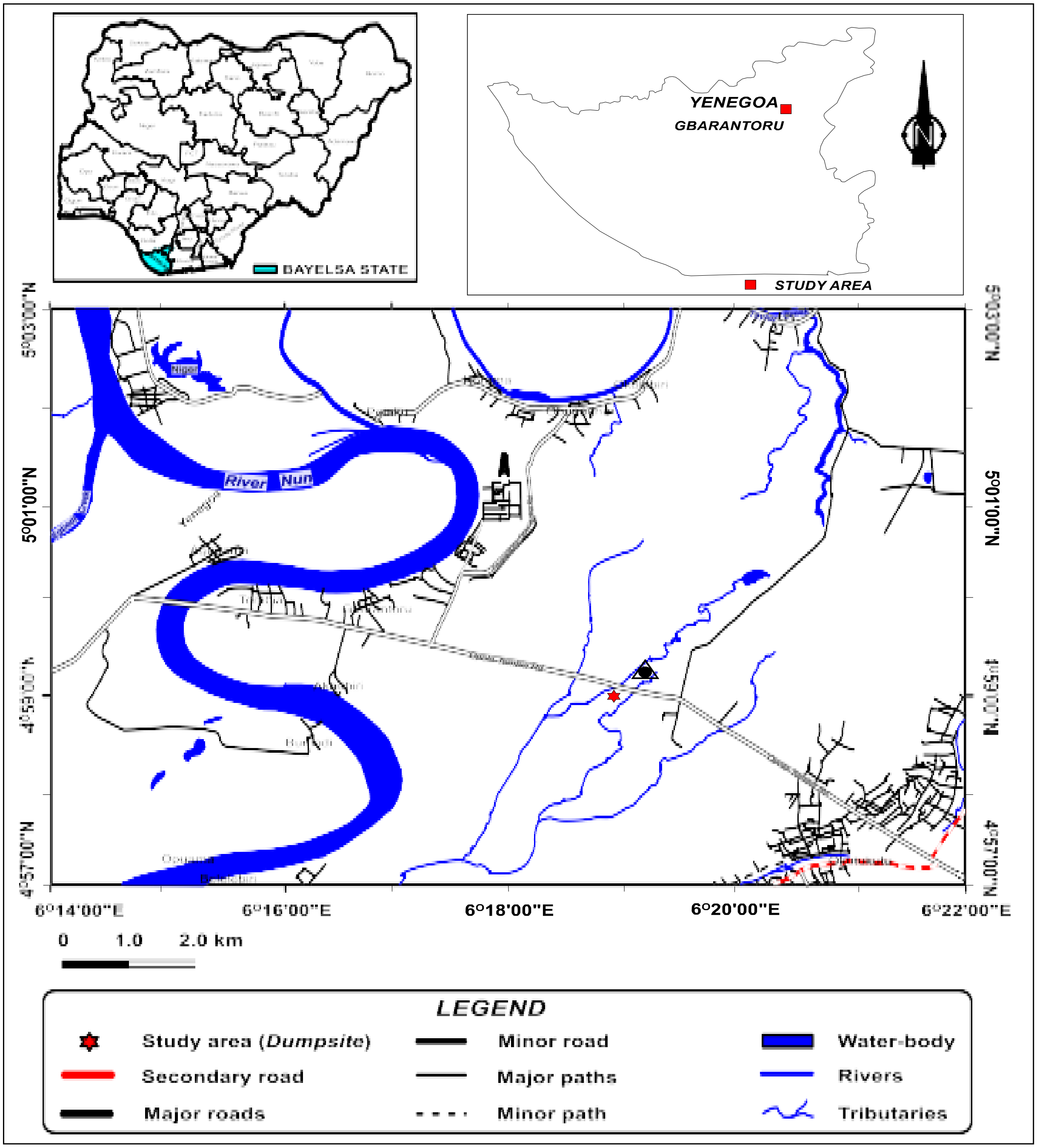

Figure 1: Map of the study area

Plate 1: Sections of Gbaraun-toru dumpsite showing scavenger method of data acquisition using radiation alert inspector

In-situ measurement of background ionizing radiation (BIR) was used in this work to allow for the maintenance of the original environmental properties of samples (Ovuomarie-kevin *et al.*, 2018). A duly and appropriately calibrated nuclear radiation alert inspector monitoring meter was used to measure the dose rate on the field. The radiation alert inspector is a meter that monitors radiation and it contains a Geiger-Muller tube, which is capable of detecting background ionizing radiation (BIR) around the temperature range between -10 ^{o}C to 50 ^{0}C (Anekwe and Ibe, 2017). The Geiger-Muller tube contained in the radiation alert inspector produces a pulse current every time radiation goes into it, then it produces ionization effect (Ovuomarie-kevin *et al.*, 2018). Every pulse generated is detected and registered electronically per count. The calibrated radiation meter has ^{137}Cs source of specific energy which is capable of detecting the exposure rate in mRhr^{-1}, with an accuracy rate ±15%. In other to take the radiation measurement, the radiation monitoring meter can be used by raising it to 1.0 m above ground level, which is a standard. Whereas, the window is made to face suspected sources of radioactivity (Taskin *et al.*, 2009). The dosimeter was kept around the gonad's level - which is 1 m above the ground. The dosimeter was turned on for 150 seconds to measure radiation absorption. This was repeated at every point and two successive readings were recorded at each location and the average values in milli Roentgen per hour (mRh^{-1}) were obtained. Figure 2 shows the radiation alert inspector used for the study.

Figure 2: Radiation alert inspectorDetermination of radiological parameters

To estimate the level of exposure users of the dumpsites to ionizing radiation at the Gbaraun-toru dumpsite in Yenagoa, radiological parameters such as annual effective dose equivalent, absorbed dose rate, equivalent dose rate, the excess lifetime risk of cancer and the effective dose to some human organs were estimated.

Absorbed dose rate

Absorbed dose is the energy deposited on the human body or an object due to exposure to ionizing radiation (CNSC, 2012). The average exposure given as mRh^{-1} obtained from the study area was changed to absorbed dose rate in $nGyh^{-1}$ using equation 1, given by (Ajayi and Laogun 2006), as shown below:

$$1\ \mu Rh^{-1} = 8.7\ nGyh^{-1} \quad (1)$$

Equivalent dose rate

The level of damage different radiation types would cause to the same tissue is accounted for by the equivalent dose provided by a single unit (CNSC, 2012). In a bid to evaluate the whole-body effect of the equivalent dose rate for a year, the recommendation by the National Council on Radiation Protection and Measurement was made use of, and it's shown in equation 2.

$$1\ mRh^{-1} = \frac{n \times 24 \times 365}{100} mSvy^{-1} \quad (2)$$

where n is the exposure rate.

Annual effective dose equivalent (AEDE)

The annual effective dose rate is the quantity of radiation hazard that is connected with the absorbed dose rate which is represented in the dose quantity of the stochastic effect of low-level radiation on the human tissue. The annual effective dose equivalent assimilated by an individual in the study area was determined from the absorbed dose rate, a dose conversion factor of 0.7 Sv/Gy, and the occupancy factor outdoors 0.67 (16/24). It is presumed that people stay approximately 16 hours outdoors, by estimation (UNSCEAR, 2000). Annual effective dose equivalent is determined using equation (3) as given by (Anekwe and Ibe 2017).

$$AEDE_{(outdoor)} \left(\frac{mSv}{y}\right) = absorbed\ dose\ rate \left(\frac{nGy}{h}\right) \times 8760\ h \times 0.7 \left(\frac{Sv}{Gy}\right) \times 0.67 \quad (3)$$

Excess life cancer risk (ELCR)

Excess lifetime cancer risk (ELCR) is measured by the likelihood of cancer occurrence in any given population aimed at a specific lifetime exposure. Calculation of excess lifetime cancer risk was done using an equation as given by (Anekwe and Ibe, 2017).

$$ELCR = AEDE \times DL \times Risk\ Factor\ (RF) \quad (4)$$

where AEDE is annual effective dose equivalent, with DL being the duration of life (which is 55 years in Nigeria) (Anekwe & Onoja, 2020), and RF represents the risk factor (Sv^{-1}). For low-dose background radiations that are considered to produce substantial stochastic effects, the ICRP 60 made use of values of 0.05 Sv^{-1} for the public (Taskin *et al*., 2009).

The effective dose rate (Dorgan) in $mSvy^{-1}$ to different body organs and tissues.

Every tissue and organ in the human body differs in the way they respond to exposure to radiation. For example, the bone marrow of a human being is more radiosensitive than muscle or nerve tissue, when in contact with radioactivity. To ascertain an indication of how exposure affects the overall health of humans, equivalent dose is multiplied by a tissue weighting factor (WT) related to the risk for a given tissue or organ affected by radiation. This calculation gives the effective dose of radiation absorbed by the body. In a situation where several organs are exposed to radiation, the sum of the effective doses received by each exposed organ gives a whole-body effective dose. The effective dose for the organs, for this study was estimated using equation 5 as proposed by (Agbalagba, 2016).

$$\text{Dorgan}\ (mSvy^{-1}) = O \times AEDE \times F \quad (5)$$

Where, O is occupancy, 0.67, AEDE is annual effective dose equivalent, and F is conversion factor for the organ dose from ingestion.

RESULTS AND DISCUSSION

The measured background ionizing radiation (BIR), the absorbed dose rates (ADR), the equivalent dose rate (EDR), annual effective dose equivalent (AEDE) and excess lifetime cancer risk (ELCR), as well as, dose to organs are shown in table below. The measured BIR at the thirty randomly selected sampling points ranges from (0.001−0.016) mRh^{-1} with an average of 0.013 mRh^{-1}, this value is same as the allowable limit of 0.013 mRh^{-1}, which is set by (ICRP, 1991). Absorbed dose estimated from the exposure rates ranging from 8.7 $nGyh^{-1}$ − 165.3 $nGyh^{-1}$, with an average of 116.2 $nGyh^{-1}$. The average value for absorbed dose rate measured at the dumpsite however, exceeds the world-acceptable average of 57 $nGyh^{-1}$ (UNSCEAR, 2000). The estimated values of equivalent dose rates to individuals and scavengers in the Gbaraun-toru dumpsite ranged from (0.088 – 1.402) $mSvy^{-1}$ and with an average of 1.113 $mSvy^{-1}$. This is below the recommended allowable limit of 1.3 $mSvy^{-1}$, (UNSCEAR, 2000). Whereas, the annual effective dose rates ranged from (0.013 - 0.213) $mSvy^{-1}$, with an average of 0.169 $mSvy^{-1}$ and the values that were obtained in this survey are below 1$mSvy^{-1}$, the permissible limit for public exposure (Fredrick and

Eugene, 2017; Avwiri *et al*, 2016). Estimated excess lifetime cancer risk for individuals and scavengers at the Gbaraun-toru dumpsite ranged from (0.94 -1.57) × 10^{-6} with an average of 1.28 × 10^{-6}. This value is, however, lower than the world average of 0.29 × 10^{-3} (UNSCEAR, 2000).

Table 1: Estimated radiological parameters related to radiation exposure at the dumpsite

Spots	BIR (mRh^{-1})	ADR ($nGyh^{-1}$)	EDR ($mSvy^{-1}$)	AEDE ($mSvy^{-1}$)	ELCR (x10^{-6})
1	0.016	139.2	1.402	0.572	**1.57**
2	0.011	95.7	0.964	0.393	**1.08**
3	0.012	104.4	1.051	0.429	**1.18**
4	0.014	121.8	1.226	0.500	1.38
5	0.013	113.1	1.139	0.465	1.28
6	0.014	121.8	1.226	0.500	1.38
7	0.011	95.7	0.964	0.394	1.08
8	0.015	130.5	1.314	0.536	1.47
9	0.016	139.2	1.402	0.572	1.57
10	0.013	113.1	1.139	0.465	1.27
11	0.011	95.7	0.964	0.393	1.08
12	0.012	104.4	1.051	0.429	1.18
13	0.014	121.8	1.226	0.500	1.38
14	0.015	130.5	1.314	0.536	1.47
15	0.011	95.7	0.964	0.393	1.08
16	0.013	113.1	1.139	0.465	1.28
17	0.014	121.8	1.226	0.500	1.38
18	0.012	104.4	1.051	0.429	1.18
19	0.016	139.2	1.402	0.572	1.57
20	0.011	95.7	0.964	0.393	1.08
21	0.012	104.4	1.051	0.429	1.18
22	0.014	121.8	1.226	0.500	1.38
23	0.013	113.1	1.139	0.465	1.28
24	0.014	121.8	1.226	0.500	1.38
25	0.011	95.7	0.964	0.393	1.08
26	0.015	130.5	1.314	0.536	1.47
27	0.016	139.2	1.402	0.572	1.57
28	0.013	113.1	1.139	0.46	1.28
29	0.011	95.7	0.964	0.393	1.08
30	0.010	87.4	0.876	0.357	0.94
Mean	**0.013**	**116.2**	**1.113**	**0.454**	**1.28**

The measured values of ambient dose rates in this present study were lower compared to the work of (Usikalu *et al.,* 2017) with measured dose rates that ranged from 0.015 - 0.028 mRh^{-1}. Consequently, the absorbed dose rates and annual equivalent dose for the study area (95.7 -139.2) $nGyh^{-1}$ and (0.013 - 0.213) $mSvy^{-1}$ respectively were also lower than the values reported by (Usikalu *et al.,* 2017), (150 - 280) $nGyh^{-1}$ and (1.13 - 2.28) $mSvy^{-1}$. The annual effective dose rates for the present work were again lower when compared to those reported by (Odunaike *et al.,* 2008), (21,000 - 70,000) $nGyh^{-1}$. This may be due to the nature and size of waste productsat the Lagos dump site being a city with different types of companies with possible radioactive wastes. However, the measured ambient dose rates for this study are of a higher level than that of (Ugochukwu *et al.,* 2015), with a reported value that ranged from (10.78 - 13.20) μRh^{-1}. Also, the estimated absorbed dose rates for this study were above the values reported by (Ajetunmobi *et al.,* 2014) with values that ranged from (64.0 – 128.0) $nGyh^{-1}$. The plot in Figure 3 shows that there is a high and positive correlation with the value of 0.823 between annual effective dose and excess lifetime cancer risk. The radiological implication of the estimated correlation is that there may be a possible present and future link between annual effective doses accrued by workers and users of the dump site and the excess lifetime cancer risk. This suggests the need to continuously carry out radiological studies on the radiological safety of the dumpsite.

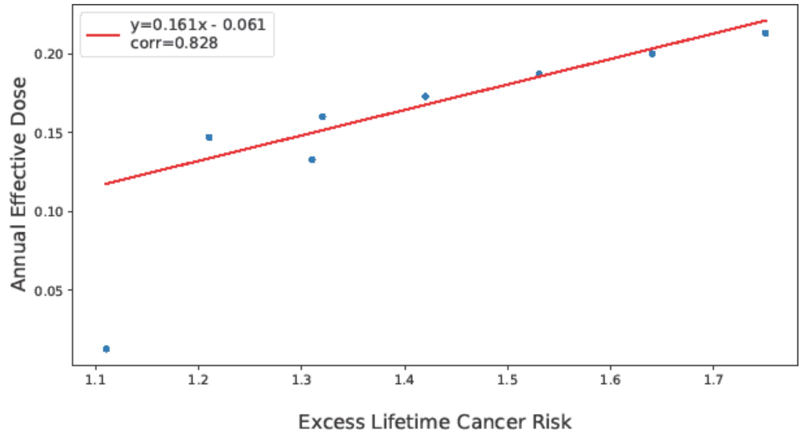

Figure 3: Plot of Annual effective dose against Excess lifetime cancer risk

Figure 4 presents bar chart for dose rates with selected spots at the study location with dose rates greater than the permissible limit set by UNSCEAR, 2000 (57nGy/h)

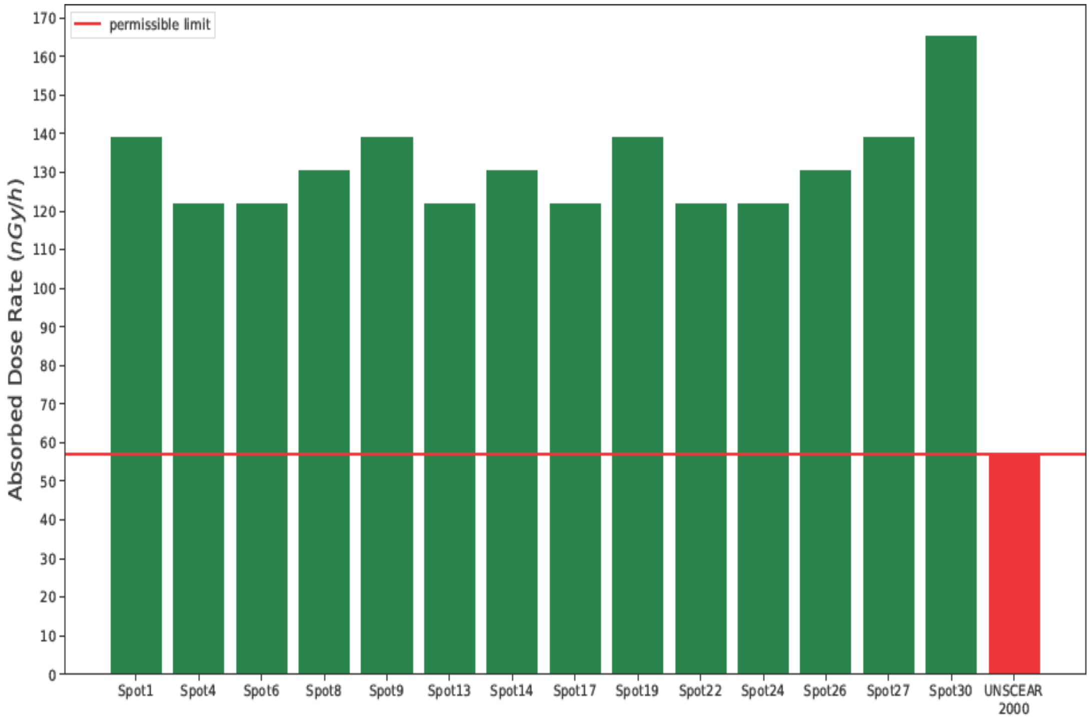

Figure 4: Bar chart dose rates for selected spots for the study in comparison with UNSCEAR, 2000

Effective dose rates for different body organs and tissues are shown in Table 2. The highest estimated effective dose is to the testes, while, the least is to the liver. The pictorial representation is shown in the bar chart in Figure 5.

Table 2: Estimated effective dose to organ for the study

S/N	Body organ	Conversion factor	Organ effective dose (mSv/y)
1	Lungs	0.64	0.194
2	Ovaries	0.58	0.176
3	Bone marrow	0.69	0.208
4	Testes	0.82	0.248
5	Kidney	0.62	0.187
6	Liver	0.46	0.139
7	Whole body	0.68	0.205
Mean			0.194

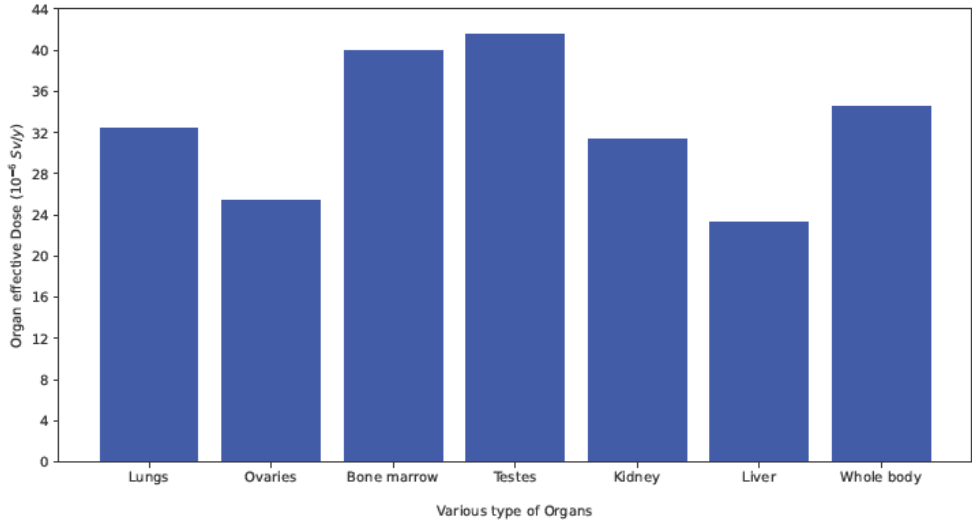

Figure 5: Plot of effective dose to various organs (mSvy^{-1}) Vs types of organs

The estimated effective doses to various organs at the Gbaraun-toru dumpsite ranged from (0.139 – 0.248) $mSvy^{-1}$ with an average of 0.194 $mSvy^{-1}$. The range of the estimated organs doses at the dumpsite is less than the 1.0 $mSvy^{-1}$ allowable threshold (Fredrick and Eugene 2017; Avwiri *et al.*, 2016).

CONCLUSION

The survey of exposure rate to assess radiological hazards to workers and the public due to possible radioactive waste at the Gbaraun-toru dump site shows that 58.06 % of absorbed dose rate values obtained are twice above the recommended world average. Estimated absorbed dose rate average is 116.2 $nGyh^{-1}$. This value is above the world average of 57 $nGyh^{-1}$ by a factor of over 100%. Other estimated radiological parameters were still within the safe limit at the time this research was carried out. The average of measured ambient exposure rates Gbaraun-toru dump site (0.013 mRh^{-1}) is roughly within the safe limit (0.013 mRh^{-1}). This suggests that further increment of the radiation level at the dump sites as a result of continual usage and possible links between the dump sites and the oil and gas processing unit could elevate background ionizing radiation levels. Hence, routine study of radiological safety of the dump site is recommended also, activity concentration in soil and water samples around the dump site can be regularly investigated.

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