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Research Article

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Radiation Contamination Determination: A Case Study in Niger Delta of Nigeria

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ABSTRACT
The study aims at determining the radiation contamination in some oil and gas sites in the Niger Delta area of Nigeria. Nigerian Nuclear Regulatory Authority (NNRA) calibrated Survey meter and other auxiliary equipment were utilize to collect Background Radiations and Radiation contamination level in the oil rich Niger Delta region of Nigeria. The findings indicate that the mean BIR levels and absorbed dose rates in Site A are slightly lower than those measured in Site B. Notably, the estimated mean AEDE for both sites remains below the permissible limit by UNSCEAR. However, the ELCR values for both locations exceed the standard mean value of 0.29×10^{-3}, highlighting a potential health risk associated with the concentration of radionuclides resulting from exploration activities. This study serves as baseline data for understanding BIR contamination levels in the sites and provides valuable insights for assessing and monitoring future fluctuations in radiation levels.

Keywords: Radiation Protection, Contamination, Geiger Muller Detector, Doses. Niger Delta

Introduction

As crucial as oil production is to Nigeria's economic existence, it comes with significant environmental and health risks. Oil and gas producers have recently used novel techniques that incorporate increased stimulation and horizontal drilling [1-4]. These new techniques, referred to as fracking have altered the radioactivity and volume of oil and gas wastes. Naturally occurring radionuclides, also known as Naturally Occurring Radioactive Materials (NORM), are present in the geologic formations that host oil and gas deposits: Lead-210/ Polonium-210, Potassium-40, Thorium, Radium, and their byproducts [5-7].

The decomposition of marine life at the location of ancient seas contributed significantly to the creation of petroleum and natural gas in the Niger Delta region of Nigeria [8-11]. These shale, petroleum, and gas deposits consequently frequently occur in brine-containing aquifers (salt water). The radionuclides separate and settle out, creating different wastes at the surface, together with other minerals that are dissolved in the brine: pipes with mineral scale. Sludges/sediments equipment or components that are contaminated created waters. These wastes are categorized as technologically enhanced naturally occurring radioactive material since the extraction procedure concentrates the radionuclides that are already present in the environment and exposes them to the surface and human contact (TENORM).

Radiation contamination in the petroleum refining industry primarily arises from the use of naturally occurring radioactive materials (NORM) and technologically enhanced naturally occurring radioactive materials (TENORM) [12-14]. During the extraction, processing, and refining of oil and gas, radioactive isotopes such as radium-226, uranium-238, and thorium-228 can become concentrated in waste products and equipment.

NORM can be released into the environment through various processes, including the formation water that accompanies oil extraction, scaling in pipes, and disposal of waste materials. The presence of these radioactive materials poses health

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risks to workers and nearby communities, necessitating effective monitoring and management strategies to mitigate contamination, as such, this study aims at determining the radiation contamination in some oil and gas sites in the Niger Delta area of Nigeria.

Materials and Method

Study Area

Site A: Between latitudes 3 and 5°N and longitudes 5 and 8°E, of the Niger Delta of Nigeria located in the Gulf of Guinea. With a surface area of over 70,000 km2, it is the biggest delta in Africa. It is also the most biologically diverse and has West Africa's biggest drainage system flowing into the Atlantic Ocean.

Site B: Between latitudes 4.25° and 4.50°N and longitudes 7.00° and 7.15°E, the Bonny River, a 127 km long tidal estuary, forms the eastern side of the Niger Delta. Since it empties into the Atlantic Ocean first, it is both the largest and the most important river in the Niger Delta network.

Oil and gas development and production are severely stressing the ecosystem.

Data collection

Nigerian Nuclear Regulatory Authority (NNRA) calibrated Survey meter and other auxiliary equipment were utilize to collect Background Radiations and Radiation contamination level arising from two sets of barges used to transport radiation sources due to oil exploration and exploitation activities in the oil rich Niger Delta region of Nigeria.

Results and Discussion

Table 1 shows the radiation dose rates for the various sampled points in Site A and Site B

Table 1: Radiation count for Site A and Site B

	Site A	Site B
Sampling Points	**Dose Rate (µSv/h)**	**Dose Rate (µSv/h)**
Background	0.12	0.24
left wing	0.12	0.12
Right wing	0.18	0.12
Anchor holder 1	0.12	0.12
Anchor holder 2	0.12	0.24
Anchor holder 3	0.24	0.18
Anchor holder 4	0.18	0.3
Anchor holder 5	0.18	0.12
Anchor holder 6	0.18	0.24
Anchor holder 7	0.12	0.06
Anchor holder 8	0.06	0.18
Anchor holder 9	0.18	0.24
Anchor holder 10	0.16	0.06
Anchor holder 11	0.18	0.12
Hand Rail A	0.18	0.18
Hand Rail A B	0.06	0.24
Hand Rail AC	0.18	0.06
Hand Rail AD	0.12	0.12
Space 1	0.18	0.18
Space 2	0.12	0.06
Space 3	0.06	0.012
Space 4	0.12	0.3

As shown in Table 1, the dose rate within Site A ranges from 0.06 µSv/hr to 0.24 µSv/hr with mean dose rate of 0.14 µSv/hr. The estimated AEDE within the site is between 0.006 mSv/yr and 0.26 mSv/yr with mean value of 0.08 mSv/yr as shown in Table 2. These values are slightly lower than that measured within Site B which ranges between 0.01 µSv/hr and 0.3 µSv/hr with mean of 0.16 µSv/hr for the dose rate and 0.006 mSv/yr to 0.32 mSv/yr with mean value of 0.18 mSv/yr for the AEDE as presented in Table 3. The difference in value can be attributed to high radionuclides concentration escaping the earth's crust as a result of oil exploration. When naturally occurring radionuclide trapped within rocks are cracked from oil exploration, radionuclides are released into the immediate environment. The measured dose rates in both Sites are slightly lower than the 0.274 µSv/hr global average natural dose of background ionizing radiation [15, 16]. The estimated mean AEDE for Site A and Site B are due to concentration of natural radionuclides (^{238}U, ^{232}Th and ^{40}K) [17] which depends entirely on the geophysical and geological conditions of the environment [18].

The result of the background ionizing radiation (BIR) in Site A and Site B is presented in Table 2 and 3, which analyzed the radiation risk parameters with the exposure rate of both Sites.

Table 2: Background Ionization Radiation in Site A

S/N	Sampling Points	Exposure Rate (mR/h)	Equivalent Dose (mSv/yr)	Absorbed Dose (nGy/hr)	Annual Effective Dose Equivalent (mSv/yr)	ELCR (X 10^{-3})
1	Background	0.012	1.01	104.4	0.13	0.46
2	Left Wing	0.012	1.01	104.4	0.13	0.46
3	Right Wing	0.018	1.51	156.6	0.19	0.67
4	Anchor 1	0.012	1.01	104.4	0.13	0.46
5	Anchor 2	0.012	1.01	104.4	0.13	0.46
6	Anchor 3	0.024	2.02	208.8	0.26	0.91
7	Anchor 4	0.018	1.51	156.6	0.19	0.67
8	Anchor 5	0.018	1.51	156.6	0.19	0.67
9	Anchor 6	0.018	1.51	156.6	0.19	0.67

10	Anchor 7	0.012	1.01	104.4	0.13	0.46
11	Anchor 8	0.006	0.50	52.2	0.006	0.21
12	Anchor 9	0.018	1.51	156.6	0.19	0.67
13	Anchor 10	0.016	1.35	139.2	0.17	0.60
14	Anchor 11	0.018	1.51	156.6	0.19	0.67
15	Hand Rail A	0.018	1.51	156.6	0.19	0.67
16	Hand Rail AB	0.006	0.50	52.2	0.006	0.21
17	Hand Rail AC	0.018	1.51	156.6	0.19	0.67
18	Hand Rail AD	0.012	1.01	104.4	0.13	0.46
19	Space 1	0.018	1.51	156.6	0.19	0.67
20	Space 2	0.012	1.01	104.4	0.13	0.46
21	Space 3	0.006	0.50	52.2	0.006	0.21
22	Space 4	0.012	1.01	104.4	0.13	0.46
	Mean Value	0.013	1.21	125.0	0.08	0.59

Table 3: Background Ionization Radiation in Site B

S/N	Sampling Points	Exposure Rate (mR/hr)	Equivalent Dose (mSv/yr)	Absorbed Dose (nGy/hr)	Annual Equivalent Dose Equivalent (mSv/yr)	ELCR (X 10^{-3})
1	Background	0.024	2.02	208.8	0.26	0.91
2	Left Wing	0.012	1.01	104.4	0.13	0.46
3	Right Wing	0.012	1.01	104.4	0.13	0.46
4	Anchor 1	0.012	1.01	104.4	0.13	0.46
5	Anchor 2	0.024	2.02	208.8	0.26	0.91
6	Anchor 3	0.018	1.51	156.6	0.19	0.67
7	Anchor 4	0.03	2.52	261	0.32	1.12
8	Anchor 5	0.012	1.01	104.4	0.13	0.46
9	Anchor 6	0.024	2.02	208.8	0.26	0.91
10	Anchor 7	0.006	0.50	52.2	0.006	0.21
11	Anchor 8	0.018	1.51	156.6	0.19	0.67
12	Anchor 9	0.024	2.02	208.8	0.26	0.91
13	Anchor 10	0.006	0.50	52.2	0.006	0.21
14	Anchor 11	0.012	1.01	104.4	0.13	0.46
15	Hand Rail A	0.018	1.51	156.6	0.19	0.67
16	Hand Rail AB	0.024	2.02	208.8	0.26	0.91
17	Hand Rail AC	0.006	0.50	52.2	0.006	0.21
18	Hand Rail AD	0.012	1.01	104.4	0.13	0.46
19	Space 1	0.018	1.51	156.6	0.19	0.67
20	Space 2	0.006	0.50	52.2	0.006	0.21
21	Space 3	0.012	1.01	104.4	0.13	0.46
22	Space 4	0.03	2.52	261	0.32	1.12
	Mean Value	0.02	1.38	142.4	0.18	0.52

Table 2 presents the absorbed dose rates measured at Site A, which range from 52.2 nGy/hr to 208.8 nGy/hr, with a mean value of 125.0 nGy/hr. Notably, this mean value exceeds comparable value of 84.0 nGy/hr given by UNSCEAR [15, 16]. In comparison, the values measured in Site B are slightly higher. The absorbed dose rate there ranges from 52.2 nGy/hr to 261 nGy/hr, with a mean value of 142.4 nGy/hr. Figure 1 illustrates the comparison of absorbed dose values with the UNSCEAR recommended limits across both sites. The data indicate that over 80% of the absorbed dose measurements are above the UNSCEAR standard.

Furthermore, the absorbed dose rates recorded in this study are higher than those reported by Aman and Avwiri [19], which fell within international standard values.

The estimated Annual Effective Dose Equivalent (AEDE) within Site A ranges from 0.06 mSv/yr to 0.26 mSv/yr, with a mean value of 0.08 mSv/yr. This mean value is notably lower than the UNSCEAR standard value of 1.0 mSv/yr.

For AEDE, Site B reports a range of 0.06 mSv/yr to 0.32 mSv/yr, with a mean value of 0.18 mSv/yr (as shown in Table 3). Figure 2 clearly illustrates that the values are below the permissible limits of 1.00 mSv/yr for the general public and 20.00 mSv/yr for occupational workers, as recommended by ICRP [20] and UNSCEAR [15]. This finding indicates that the radiation levels in Sites A and B are within acceptable limits, suggesting no immediate radiological health risks to workers, visitors, or residents of the host community due to absorbed doses from BIR.

The observed differences in radiation values may be attributed to the presence of radionuclides, including 238U, 232Th and 40K along with their decay products [21, 22]. These radionuclides can be released as a result of exploration activities that disturb and release trapped materials from the Earth's crust within and around the refineries.

It is important to note that the development of cancer due to exposure to ionizing radiation is not an immediate effect; it may take several years, if it develops at all. The term "excess lifetime cancer risk" (ELCR) is defined as the probability that an individual will develop cancer over their lifetime due to radiation exposure [23]. In Sites A and B, the ELCR values range from 0.21 to 0.91 and 0.19 to 1.12, respectively, with calculated mean values of 0.59 and 0.52, as presented in Table 1 and Table 2. These mean values for ELCR exceed the average standard of 0.29 [15, 16].

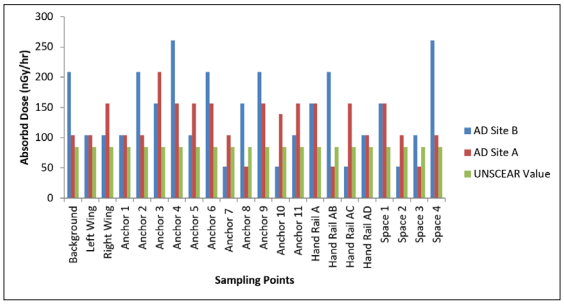

Figure 1: Comparison of Absorbed Dose in both Sites with UNSCEAR [15] Standard

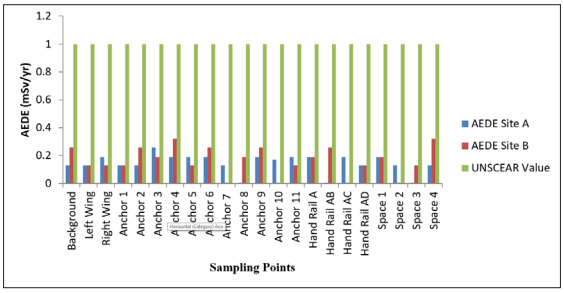

Figure 2: Comparison of AEDE in both Sites with UNSCEAR [15] Standard

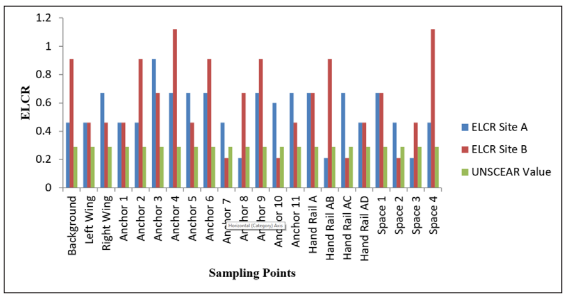

Figure 3: Comparison of ELCR in both Sites with UNSCEAR [15] Standard

This study, when compared with other research [24], is consistent with international standard values. Therefore, there should be strict monitoring of radiation levels, and work should be conducted on a shifting basis [25]. There is a potential risk of cancer-related health hazards and other radiation sicknesses as proposed.

Conclusion

This study assessed the radiation contamination levels, annual effective dose (AEDE), and excess lifetime cancer risk (ELCR) associated with background ionizing radiation (BIR) within Site A and Site B. The findings indicate that the mean BIR levels and absorbed dose rates in Site A are slightly lower than those measured in Site B. Notably, the estimated mean AEDE for both sites remains below the permissible limit of 1.00 mSv/yr. However, the ELCR values for both locations exceed the standard mean value of 0.29×10^{-3}, highlighting a potential health risk associated with the concentration of radionuclides resulting from exploration activities.

This study serves as baseline data for understanding BIR contamination levels in the sites and provides valuable insights for assessing and monitoring future fluctuations in radiation levels. Such information is crucial for developing effective strategies for radiation protection and risk management in these industrial settings.

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Data availability

Research data are not available (Not applicable)

Author Contribution

Igoniye Williams: Conceptualization and Investigation
Amiegbereta, Edwin Ehis: Literature, Reviewing and editing
Nwabuoku Augustine Onyema: Formal analysis
Precious Onuchuku and Christopher F. Njeh, PhD: Reviewing and editing

Declaration of Competing Interest

The authors declare that there are no conflicts of interest.

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