



ISSN 1110-0451



(E S N S A)

## Determination of Radon Exhalation Rates from Sand of Some Beaches in Lagos, Nigeria and Benin

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### ARTICLE INFO

#### Article history:

Received: 24<sup>th</sup> June 2023

Accepted: 4<sup>th</sup> Oct. 2023

Available online: 15<sup>th</sup> Oct. 2023

#### Keywords:

Radon concentration;  
radiation risk indices;  
beach sand and water;  
RAD-7 detector.

### ABSTRACT

The activities of radon content in three seawater samples taken from Lagos and Benin Republic (Sultan, Seme kpoji, and Ojo) Beaches are the focus of the current study. The seawater samples were analyzed using the RAD-7 detector to obtain activity concentration. The obtained values for radon activity concentration are  $1800.0 \pm 1400$  Bq/m<sup>3</sup>,  $3500.0 \pm 1900$  Bq/m<sup>3</sup>, and  $5500.0 \pm 2300$  Bq/m<sup>3</sup>, respectively. The findings showed that the radon concentration levels were higher than the safe levels recommended by the World Health Organization (WHO) and the International Commission on Radiological Protection (ICRP). The estimated radiation hazard indices, which include equilibrium equivalent radon concentration, potential alpha energy concentration, annual absorbed dose, annual equivalent dose, excess lifetime cancer risk, and lung cancer cases per million people per year, were outside of acceptable limits. However, monitoring the environment for Radon against respiratory cancer is crucial for public health. The result of this study adds more data to knowledge.

### 1- INTRODUCTION

Beach sand is a loose surface natural element that covers most off-shore and onshore of the sea. It consists of inorganic particles, matter, and other tracer mineral resources. Beach sand, which results from the decomposition of rocks such as igneous, metamorphic, or sedimentary, may be smooth, fine-textured, or even coarse, infiltrating, with high porosity, and low soil moisture is used for construction and also serves as building materials. The beach sand has a significant deposition of minerals, shells, and other remnants eroded up on the shore.

Understanding the radioactivity level of the various radionuclides in beach sand and sedimentary rocks plays a vital role in health physics [1].

When radon gas is breathed in, it decomposes into radioactive particles that can become stuck in the lungs. These particles generate little energy bursts as they

decompose. Over a lifetime, this can harm lung tissue and result in lung cancer. Not every person exposed to high radon levels will acquire lung cancer but may have other radiation sicknesses, which may take years for the sickness to manifest itself after exposure.

Similar to other environmental contaminants, there is significant ambiguity regarding the severity of the health concerns posed by Radon. However, be more aware of radon dangers than most other cancer-causing risks due to radon gas spontaneous radioactive decay from naturally existing radioactive elements [2–4]. The National academy of science reported that 89% of lung cancer is caused by inhalation of radon-222 escaped from seawater, and 11% of stomach cancer is caused by the intake of radon-222 contaminated water [5].

In regions where the bedrock is made of granite and is rich in uranium, rather large concentrations of Radon are frequently detected in the water from the bedrock [6, 7].

When water with radon contamination is used indoors, the dissolved Radon in the water diffuses and enters the atmosphere. With a half-life of 3.82 days, Radon gradually breaks down into lead, polonium, and bismuth by emitting alpha particles. The consequences for human health are severe. Radon contributes roughly 54% of the total internal radiation to which humans are exposed [8]. Water is a global solvent and is therefore necessary for human intake, residential use, and industrial use. Water sources can be divided into two groups: surface water and groundwater. Surface water includes liquid from oceans, lakes, rivers, and large ponds created by defunct mines. The presence of radium in the water bedrock and nearby soil makes Radon soluble in water which can be detected in significant amounts in surface water [9]. However, researchers have been and are still working on seawater and beach sand in different locations worldwide [10, 11].

As the usefulness of seawater for the human world and aquatic life is unlimited, which includes the consumption of sea foods, transportation, etc., the sea body must be free from dirt, germs, and contaminations such as (chemical, microbial and radiological), which

could threaten human life and may even lead to death. The current study determines radon exhalation rates and risk parameters on three locations of beach sand (Sultan, Seme Kpoji, and Ojo beaches) to assess the radiological risk indices of the inhabitants around these beaches. Therefore, the paper is important from radiation protection point of view, due to it is ensure the radiation risky of the areas under the study, for the two groups of the people, and the stay time of the visitors; hence saving the people from the harmful of the ionizing radiation.

## 2- MATERIALS AND METHOD

### 2.1. Geological setting

Three sea water samples were collected from different beaches in (Lagos and the Benin Republic. The seawater samples were stored in sterilized, 150cl labeled airtight bottles. The geographical location of Sample A  $6^{\circ}.3922^{\circ}\text{N}$ ,  $2^{\circ}.8330^{\circ}\text{E}$  (Sultan Beach of Badagry, Southwest, Lagos state), Sample B ( $6^{\circ}24'0\text{N}$ ,  $2^{\circ}40'0\text{ East}$ ) Seme kpoji, Queme Benin Republic and Sample C ( $6^{\circ}28'\text{N}$ ,  $3^{\circ} 11'\text{E}$ ) Ojo bar Beach) Lagos as shown in fig. (1).

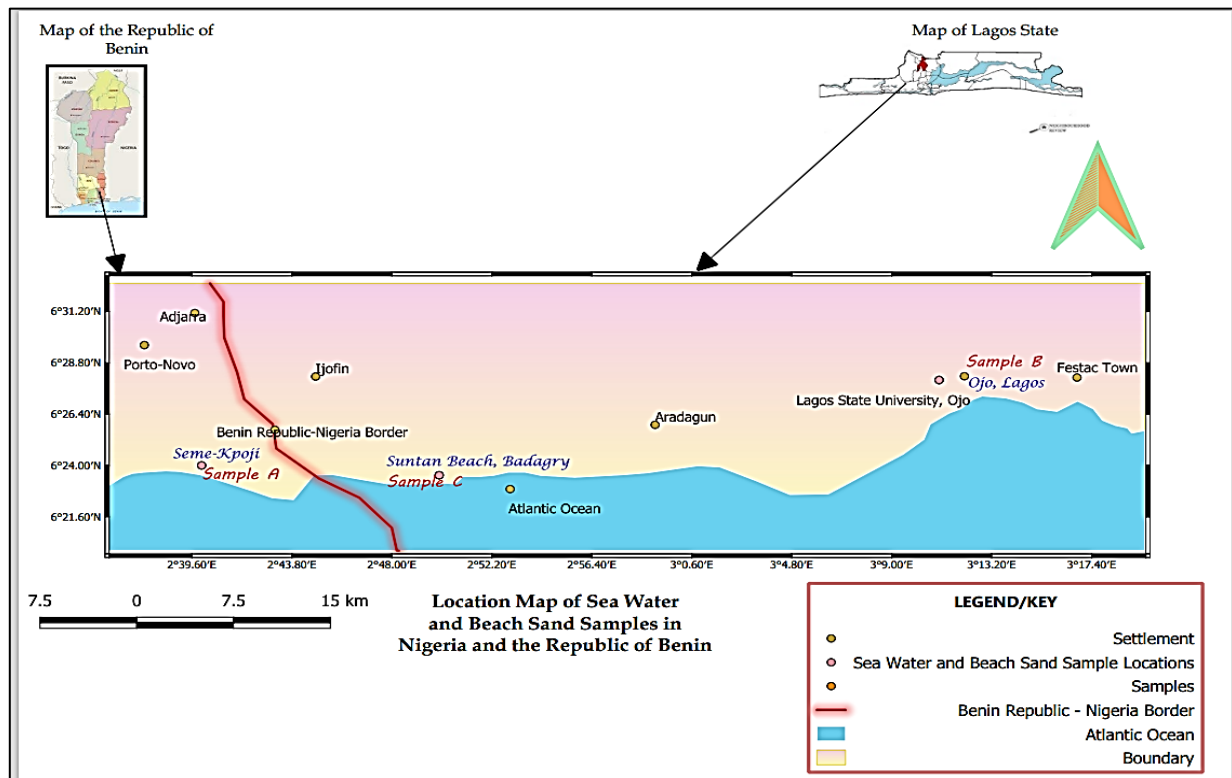


Fig. (1): Geological map showing a selected area of study.

## 2.2. Radon Detector (RAD-7)

The RAD-7 detector is an active electronic instrument made by the DurrIDGE Company in the USA (see figure 2). The seawater samples were analyzed using the RAD-7, a real-time monitoring device that uses the alpha spectrometric technique. In analyzing Radon in water, an accessory, RAD-H2O, was connected to RAD-7. The decay of the Radon in the RAD-7 chambers results in the generation of polonium isotopes, which produces measurable alpha radiation in about 30 minutes, making it a relatively fast technique [12].



Fig. (2): RAD-7 electronic detector (DurrIDGE Radon capture & Analytics)

## 2.3. The radiological risk indices

The equilibrium radon concentration (ERC) is an essential indicator in assessing radiological hazards. It is also required to calculate the equivalent potential alpha energy concentration (PAC) for the daughter nuclides that are present in the atmosphere and measured in Bq/m<sup>3</sup>. Also, the equilibrium factor is needed to be added to convert the radon concentration to EEC, which is directly employed for dose estimate and may be evaluated in Bq/m<sup>3</sup> using Eq. 1 because Radon and its decay products are not typically in radioactive equilibrium [13, 14]. The ICRP established a global standard equilibrium factor of 0.4 for indoor environments and an equilibrium factor (of 0.7) for outdoor environments [8, 14].

$$ERC \text{ (Bq/m}^3\text{)} = C(\text{Rn}) \times EF \quad (1)$$

where  $C(\text{Rn})$  is radon concentration in (Bq/m<sup>3</sup>), E.F. is an equilibrium factor set to 0.7 for outdoors. Evaluation of PAC in mWL, as in Eq. 2, describes the concentration of radon decay products in the air [14, 15]. The concentration of all the short-lived substances is referred to as PAC. It uses a single number to represent the concentration of the transient radon progeny.

$$PAC = \frac{ERC}{3700} \quad (2)$$

The annual absorbed dose  $D(\text{Rn})$  in mSv/y was calculated using Eq. 3 [14, 16, 17].

$$D(\text{Rn}) = EF \times C(f) \times O(f) \times C(\text{Rn}) \times T(y) \quad (3)$$

where  $C(f)$  is the dose conversion factor = 9 nSv/Bq.h.m<sup>3</sup>. The occupancy factor,  $O(f)$  value is 0.2. [18, 19], while  $T(y)$  is time.

$H(E)$  is the annual equivalent dose, ( $W_R$ ) is the radiation weighting factor for alpha particles = 20, and ( $W_T$ ) is the tissue weighting factor = 0.12 [18, 20, 21].

$$H(E) = D(\text{Rn}) \times W_R \times W_T \quad (4)$$

Excess lifetime cancer risk (ELCR) and the number of risks of lung cancer cases per million people (RLC) were calculated using equations 5 and 6, respectively [18, 22, 23].

$$ELCR = H(E) \times L_D \times R_F \quad (5)$$

$$RLC = D(\text{Rn}) \times 18 \times 10^{-6} \quad (6)$$

where  $L.D.$  is the life expectancy (70 y) and  $R.F.$  is the risk factor in mSv/y (0.05 Sv<sup>-1</sup>).

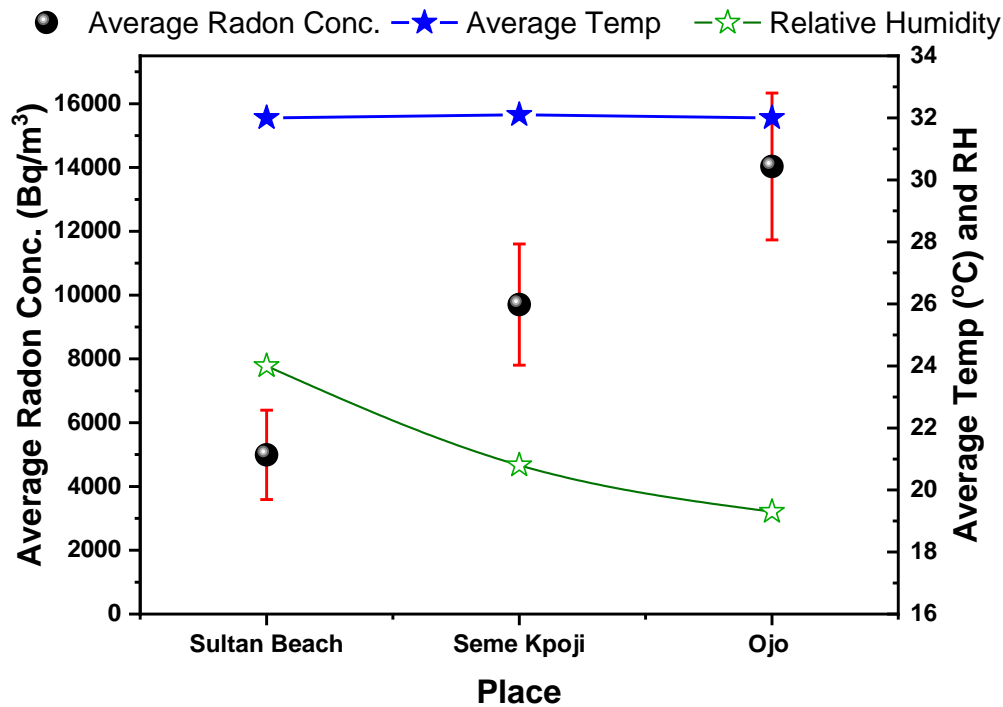
## 3. RESULTS AND DISCUSSION

After measuring and evaluating the activity concentration of Radon for three seawater samples (Sultan Beach, Seme koji, and Ojo bar Beach) from Nigeria, the results are listed in table (1) as 1800.0±1400, 3500.0± 1900, and 5500.0±2300 Bq/m<sup>3</sup> for Sultan, Seme kpoji and Ojo bar Beaches respectively. The findings revealed that very high radon concentrations were observed. The relationships between radon levels in water and air, and temperature and relative humidity as shown in fig. (3). The average radon concentration in the regions was higher than the values advised by the ICRP, 1993 which range 200 to 600 Bq/m<sup>3</sup>.

**Table (1): The average result of activity radon concentration, temperature, and relative Humidity**

Sample Areas	Average Temp (°C)	Relative Humidity (%)	Decay Correction Factor	Average Radon Conc. (Bq/m <sup>3</sup> )
Sultan Beach	32.0	24.0	2.77	4989.9 ±1400
Seme kpoji	32.1	20.8	2.77	9702.7 ±1900
Ojo	32.0	19.3	2.55	14031.5 ±2300

The average temperature is 32.03°C, while the relative Humidity ranges from 19.3 to 24 %.

**Fig. (3): the activity concentration of Radon, average temperature, and relative Humidity.****Table (2): The radiation risk indices parameters in seawater samples.**

Sample Areas	ERC (Bq/m <sup>3</sup> )	PAC (mWL)	D(Rn) mSv/y	H(E) mSv/y	ELCR	RLC ×10 <sup>-6</sup> (mSv/y)
Sultan Beach	3493.0	0.94	11.5	27.5	106.0	206.5
Seme Kpoji	6791.9	1.84	22.3	53.5	206.2	401.6
Ojo	9822.0	2.65	32.3	77.4	298.1	580.8

Also, the equilibrium equivalent radon concentrations are 3493 Bq/m<sup>3</sup>, 6791.9 Bq/m<sup>3</sup>, and 9822 Bq/m<sup>3</sup> in Sultan, Seme Kpoji, and Ojo beaches, respectively. Based on the highest radon concentration displayed in Table 2, the highest equilibrium equivalent concentration in three locations was depicted in Fig. 4a. When the short-lived radon decay product has the same activity concentration in the air as Radon (radon progeny is in

secular equilibrium with Radon), the prospective alpha particle energy concentration can be used to determine the lung dose from alpha energy caused by inhaling Radon. Generally, PAC varies with the weather, people's habitats, and time [24]. The PAC results obtained in this study are 0.94, 1.84, and 2.65 mWL for Sultan, Seme Kpoji, and Ojo beaches, respectively, as shown in Figure 4b. they revealed that the PAC is high.

Table 2 and Figs. 4c and 4d show the maximum annual absorbed and effective dose in different sample areas. The absorbed doses are 11.5, 22.3, and 32.3 mSv/y, and the annual equivalent dose equals 27.5, 53.5, and 77.4 mSv/y for Sultan Beach, Seme Kpoji, and Ojo Label, respectively. The obtained data reveals that the annual effective dose and absorbed radiation from the chosen sample areas are unsafe compared to the stipulated world health organization values of 1-3 mSv/y. Table 2 and Fig. 4 (e, f) showed the maximum excess lifetime cancer risk (ELCR) and risk of lung cancer (RLC).

The ELCR values were reported to be 106, 206.2, and 298.1 for Sultan Beach, Seme Kpoji, and Ojo beaches, respectively. RLC data were  $206.5 \times 10^{-6}$ ,  $401.6 \times 10^{-6}$ , and  $580.8 \times 10^{-6}$  mSv/y per million people annually for Sultan Beach, Seme Kpoji, and Ojo beaches, respectively, which is greater than the ICRP (1993) guideline of 170-230 per million people. The results show that the presence of radon gas has potentially harmful consequences in the three research areas. The majority of radon-induced lung cancers are caused by low and moderate radon concentrations rather than by high radon concentrations, because less people are exposed to high radon concentrations. In the current paper, there are large number of vacationers, while the ratio of the population is small; compared to them. Therefore, the paper is important from radiation protection point of view, due to it is ensure the radiation risky of the areas under the study, for the two groups of the people, and the stay time of the visitors: hence saving the people from the harmful of the ionizing radiation.

The authors device that the implementation of restrictions on stay times for individuals below the age of 18 in regions with potential ionizing radiation hazards constitutes a critical facet of radiation protection and public health management. These restrictions serve as a proactive measure to mitigate the adverse effects of ionizing radiation exposure, particularly in a vulnerable demographic cohort. By limiting the duration of stay and integrating supervision and educational components, these measures aim to safeguard the health and well-being of minors. Age-specific guidelines cater to the varying susceptibility levels within this age group, acknowledging that younger individuals may be more susceptible to radiation-induced health risks. Furthermore, the enforcement and monitoring of these restrictions, coupled with exceptions for essential activities, contribute to a comprehensive strategy to strike a balance between necessary access and radiation risk reduction. This multidimensional approach aligns with established global

safety standards and embodies a proactive stance in preserving the health of minors and minimizing long-term radiation-related health concerns.

The following recommendations for the future in study area can be made:

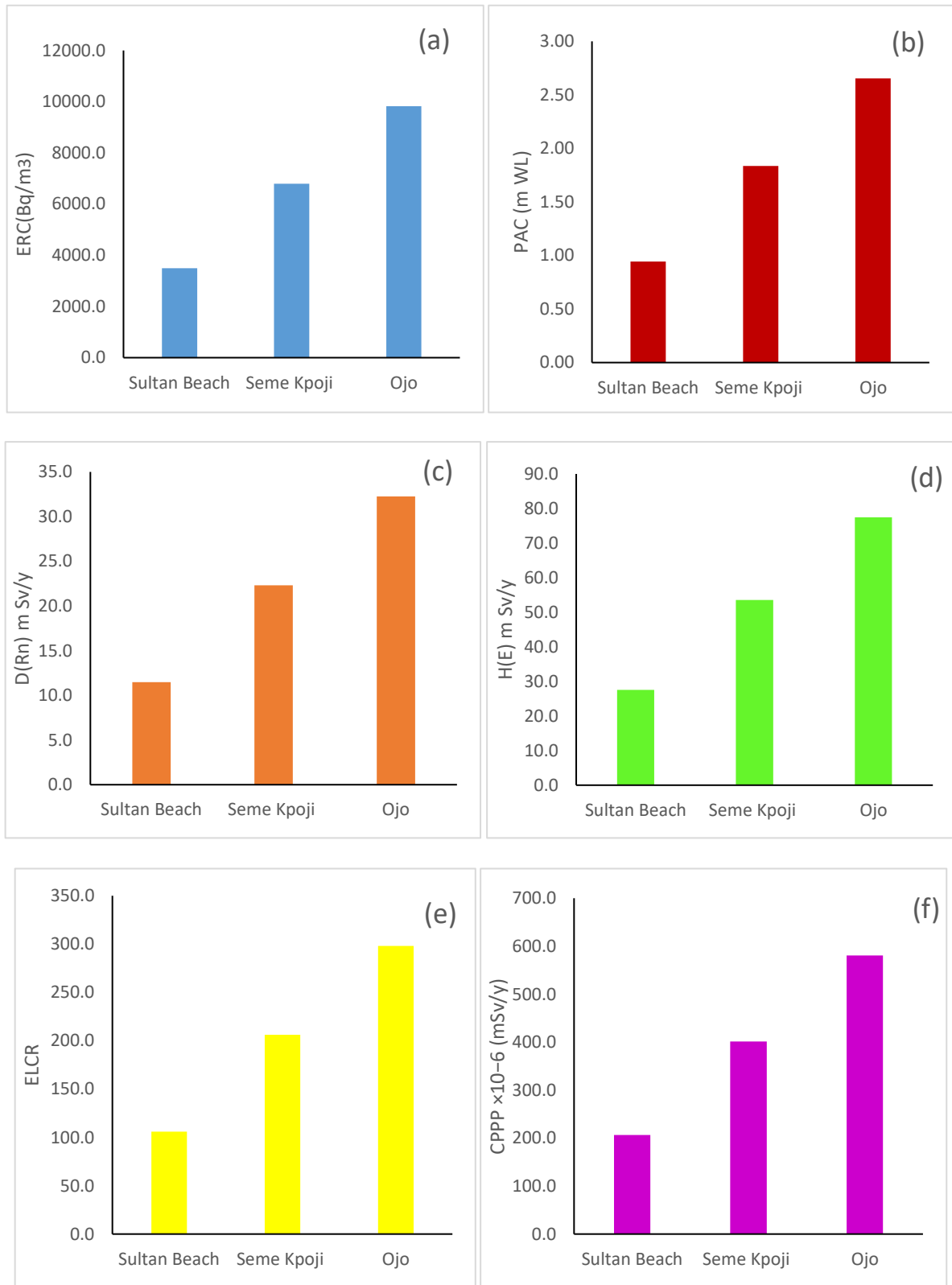
- Targeted Monitoring and continuous monitoring specifically in areas under investigated.
- Launch public awareness campaigns to educate both residents and vacationers about radon exposure risks. Provide information on the potential health effects and preventive measures that can be taken, especially for those residing in the area for extended periods.
- Tourist Accommodation Guidelines for radon testing and mitigation in tourist accommodations. Encourage hotels, resorts, and other temporary lodging facilities to regularly test for radon and take necessary measures to mitigate risks, ensuring the safety of guests.
- Encourage ongoing research in the area, focusing on understanding radon dispersion patterns and the effectiveness of mitigation techniques. Continuous research provides valuable data for future decision-making and policy development.
- Regular Review of radon exposure data and update policies and recommendations accordingly. Radon levels and exposure patterns can change over time, so it's vital to stay up to date with the latest research findings and adjust strategies as needed.

By following these recommendations, informed by the paper's results, the area can take proactive measures to minimize radon exposure, protect public health, and create a safer environment for both residents and visitors.

## CONCLUSIONS

The current research investigated the levels of radon activity concentration in three sites of seawater samples from three of the main beaches in Lagos, Nigeria, using a RAD-7 electronic detector. The calculated activity of radon concentration depicts the possibility of health effects due to the radioactive risk on the nearby residents; as a result, high radiation risk indices exceeded the standard levels published by (ICRP, 1993 and WHO 2009).

According to this study, the radon levels outside the area where the public resides are higher than the safe levels. The data obtained from this research can be used as baseline information. Additionally, further research is recommended in this line.



**Fig. (4): The radiation risk indices recorded in seawater samples. (a) ERC, (b) PAC, (c) D(Rn), (d) H(E), (e) ELCR, and (f) RLC.**

**Data availability of data and material:** All data are included in manuscript.

**Funding:** No funding was obtained for this study

**Competing interests:** No, I declare that the authors have no competing interests as defined by Springer, or other interests that might be perceived to influence the results and/or discussion reported in this paper.

**Authors' Contributions:** **Mostafa, Mostafa and Mansour, Howaida** wrote the main manuscript text **Khalaf, Hyam and Israa. K. Ahmed** prepared the figures. **Olaoye, Morohunfoluwa Adeola and Elijah Selome, John Taiwo** collects samples and made measurements, **Ademola, Augustine Kolap and Olaoye, Morohunfoluwa Adeola** planned the work. **Mostafa, Mostafa and Khalaf, Hyam** made an analysis of the results, and **Mansour, Howaida and Mostafa, Mostafa** made the discussion and conclusion. **All authors** reviewed the manuscript.

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