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Assessment of Naturally Occurring Radionuclides in a Pre-operational Stage of a Shrimp Farm in Southern Bahia, Brazil

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1. Introduction

Environmental radioactivity has both natural and anthropogenic origins, with radionuclides such as Ra-226, Ra-228, and K-40 found in the Earth's crust and distributed in environments through environmental cycles and the food chain. Human activities, such as oil exploration and nuclear power plants, also introduce radioactive materials into the environment. However, soil movements can also alter environmental radioactivity through the movement of naturally occurring radionuclides. In aquatic environments, radioactive elements can cause processes such as bioaccumulation in animals, posing a global issue requiring monitoring [1].

Due to their sinkhole characteristics and being transitional zones, estuaries are heavily impacted by contaminations. This is because the chemical composition of their sediments is controlled by a complex relationship between physical factors, biogeochemical processes, interactions between river and ocean, as well as the environmental and anthropogenic characteristics of upstream regions [2].

The discharge of sediments from anthropogenic activities affects coastal and marine ecosystems, such as mangroves and coral reefs, including benthic fauna and flora. The concentration of radionuclides and heavy metals in sediments varies over time and can have significant effects and bring serious consequences to the coastal environment. One of the activities gaining momentum on the northeast coast of Brazil is shrimp farming, although there are few studies presenting data linking this activity to environmental contamination, it is not possible to dissociate it from environmental problems [2].

The south region of Bahia is known for its biodiversity and preservation due to various environmental protection areas, as well as communities engaged in ecological extraction in the region. In this context, with the construction of a shrimp farm in the region, data collection on radiation levels was conducted in the growth pond and treatment pond to determine the background radiation levels in the area.

2. Methodology

Study area

The sediment sampling was carried out in the Serinhaém estuary region. The area has approximately 62% forest cover and 17.5% mangroves. The main economic activities consist of coconut and palm extraction, in addition to traditional fishing. The annual precipitation exceeds 2000 mm, with a monthly average of 174.5 mm, with urban areas such as the municipality of Ituberá upstream.

Gamma spectrometry

Using a GS-512i Portable Gamma-Ray Spectrometer for detection of Ra-226, Th-232, and K-40 activity concentrations, 19 samplings were conducted along the breeding pond and 13 in the treatment pond before the farm's operational process. The area was previously a palm farm with natural vegetation and minimal anthropogenic impact, utilized by small communities.

Hazard indices

The collection was conducted in December 2023 to present the background values of the absorbed dose rate (eq. 1) and annual effective dose equivalent (eq. 2).

$$D = 0{,}462A_{Ra} + 0{,}604A_{Th} + 0{,}0417A_{K} \quad (01)$$

Where A_{Ra}, A_{Th}, and A_K are the activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K, respectively.

$$E = D * 8760 * 0{,}2 * 0{,}7 * 10^{-6} \quad (02)$$

In order to obtain a better observation of the results, IDW interpolation was performed on the absorbed dose rate data using QGIS 3.16.4.

3. Results and Discussion

The values of activity concentration, absorbed dose rate, and annual effective dose equivalent in the sediments of the shrimp farm in the Serinhaém estuary are shown in Table I and Table II for Breeding Pond and Treatment Pond, respectively. The activity concentration in the sediments exhibited significant variation across the sampled regions. In the breeding pond, it ranged from 156.5-719.9 $Bq \cdot kg^{-1}$ for K-40, 4.96-44.64 $Bq \cdot kg^{-1}$ for Ra-226, and 19.94-70.0 $Bq \cdot kg^{-1}$ for Th-232. The highest activity concentrations were observed at points 01, 02, and 03.

Table I: Natural Radioactivity of the Breeding Pond

Sample point	Activity concentrations ($Bq \cdot kg^{-1}$)			D ($nGy \cdot h^{-1}$)	E ($mSv \cdot y^{-1}$)
	K-40	Ra-226	Th-228		
01	719.9	34.72	70.00	88.34	0.058
02	688.6	44.64	64.30	88.17	0.058
03	626	34.72	51.69	73.36	0.048
04	657.3	31.00	55.76	75.41	0.050
05	532.1	28.52	56.98	69.78	0.046
06	469.5	18.60	34.19	48.82	0.032
07	532.1	22.32	41.10	57.32	0.038
08	375.6	26.04	37.85	50.55	0.033
08	344.3	19.84	32.15	42.94	0.028
10	469.5	37.20	50.87	67.49	0.044
11	469.5	23.56	33.37	50.62	0.033
12	563.4	22.32	41.92	59.12	0.039
13	500.8	32.24	57.38	70.44	0.047
14	187.8	16.12	19.94	27.32	0.018
15	156.5	13.64	24.42	27.57	0.018
16	406.9	4.96	28.08	36.22	0.024
17	344.3	9.92	32.15	38.36	0.025
18	657.3	33.48	47.62	71.64	0.047
19	156.5	18.60	21.16	27.90	0.018

In the treatment pond, the variation was from 62.6 to 375.6 $Bq \cdot kg^{-1}$ for K-40, 3.72 to 31.0 $Bq \cdot kg^{-1}$ for Ra-226, and 12.21 to 39.88 $Bq \cdot kg^{-1}$ for Th-232. The highest activity concentrations were observed at points 02, 06, 11, and 13.

Table II: Natural Radioactivity of the Treatment Pond

	Activity concentrations ($Bq \cdot kg^{-1}$)				
Sample point	K-40	Ra-226	Th-228	D ($nGy \cdot h^{-1}$)	E ($mSv \cdot y^{-1}$)
01	219.1	22.32	27.67	36.16	0.024
02	281.7	17.36	34.59	40.66	0.027
03	156.5	11.16	14.24	20.28	0.013
04	250.4	3.72	16.68	22.23	0.014
05	187.8	17.36	21.97	29.12	0.019
06	375.6	18.6	37.85	47.11	0.031
07	219.1	27.28	25.64	37.23	0.024
08	62.6	12.4	12.21	15.71	0.010
08	187.8	14.88	27.67	31.42	0.020
10	219.1	19.84	30.11	36.49	0.024
11	344.3	31.0	39.88	52.77	0.035
12	62.6	18.6	21.57	24.23	0.016
13	344.3	22.32	35.40	46.05	0.030

Observing Figure 1, generated through an interpolation process, it's noticeable that the region of the treatment pond doesn't have values exceeding the worldwide average, according to UNSCEAR [3], of 57 $nGy \cdot h^{-1}$. However, the pond has several areas that surpass this value. The region with values above 57 $nGy \cdot h^{-1}$ is close to the mangrove, which may indicate a higher concentration of activity in this area. The annual effective dose equivalent in the sediments was lower than the limit established by The International Commission for Radiological Protection of 1.0 $mSv \cdot y^{-1}$.

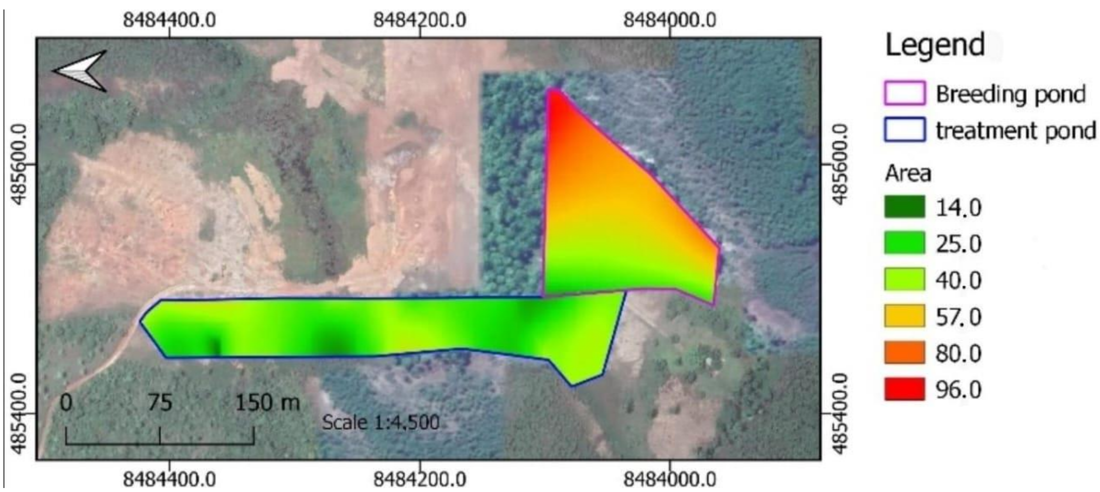

Figure 1: Absorbed Dose Rate Map in the Treatment and Breeding Ponds

Although the area does not have a concerning activity concentration, the fact that the values in the soil exceed the global averages of 32 $Bq \cdot kg^{-1}$ for Ra-226, 420 $Bq \cdot kg^{-1}$ for K-40, and 45 $Bq \cdot kg^{-1}$ for Th-232 [4] in the breeding pond, requires monitoring of the shrimp raised there. Due to the bioaccumulation process, high values of radiation and radionuclides can follow the trophic chain, potentially causing issues for individuals. In a mangrove environment, where the treated effluent will be discharged, monitoring is necessary, as there may be a concentration of these radionuclides in that area directly affecting the fauna and flora of the region, in addition to the risk of mobility of these elements [5].

4. Conclusions

The background value of activity concentration in the shrimp farm region in southern Bahia showed considerable levels, especially in the breeding pond, which is closest to the mangrove. Due to the shrimp's characteristic of feeding on part of the pond substrate, monitoring of the individuals produced there is necessary to ensure that they are not exposed to elevated radiation doses. It is also essential to monitor the effluents generated by the activity, as they will be discharged into the mangrove, and even with treatment, they can cause damage to the ecosystem.

References

[1] Akbar Abbasi, Hesham M H Zakaly, Fatemeh Mirekhtiary, "Baseline levels of natural radionuclides concentration in sediments East coastline of North Cyprus", *Marine Pollution Bulletin*. Vol. 161 (2020).

[2] Veronica Ogolla Wayayi Wanjeri, Eric Ochieng Okuku, Mattia Barsanti, Antonio Schirone, "Baseline radionuclide and heavy metal concentrations in sediments of Sabaki River estuary (Kenya, Indian Ocean)", *Marine Pollution Bulletin*. Vol. 164 (2021).

[3] UNSCEAR (United Nation Scientific Committee on the Effects of Atomic Radiation), Sources and effects of ionizing radiation. Report to General Assembly, with scientific annexes., New York, vol. 1 (2000).

[4] UNSCEAR (United Nation Scientific Committee on the Effects of Atomic Radiation), Sources and effects of ionizing radiation. Report to General Assembly, with scientific annexes, New York, vol. 1 (2008).

[5] Pungtip Kaewtubtim, Weeradej Meeinkuirt, Sumalee Seepom, John Pichtel, "Occurrence of heavy metals and radionuclides in sediments and seawater in mangrove ecosystems in Pattani Bay, Thailand," *Journal of Environmental Science Pollution Research*, vol. 24, pp. 7630–7639 (2017).