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Spatio-Temporal Variability of Gamma Radiation Profile Along the Southern-Indian Coastline (Poompuhar to Nagapattinam Stretch)

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ABSTRACT

The present study is aimed at evaluating the radiation profile along the coast of the Poompuhar-Nagore range, which is known to be hydrodynamically active and is enriched with anthropogenic activities. The study of radiation on the coastal belt and evaluating their dynamics (magnitude and spatio-temporal variability) is crucial both for the coastal inhabitants as well as possible exploration of rare-earth minerals. The effective gamma radiation during the new moon along the coastal range varies between 0.9 to 3.55 $\mu sv.h^{-1}$, respectively. The annual equivalent dose is estimated up to gamma radiation of 0.26 to 2.80 $\mu sv.h^{-1}$. Generally, the concentrations of the gamma radiation measured are elevated in certain areas namely Chinnagudi, Kuttiyandiyur, and Chandrapadi. In particular, the gamma radioactivity is high at Chandrapadi and Chinnagudi during the new moon as it shows considerable amounts of radiation. There is a definite variation due to the moon phase on the gamma radiation profile of the area studied. Out of the eight coastal villages under study, about 60% of the coastal line shows high levels of gamma radiation during both new moon and full moon phases.

INTRODUCTION

Natural radioactivity is widespread in the Earth's environment, and it exists in various geological formations such as earth crust, rocks, soils, plants, water, sand, sediments, and air. The concentrations of natural radioactive materials depend primarily on geological conditions and vary by soil level of different geographical regions (Abinesh et al.2016). Beach sands are composed mainly of quartz, feldspar, and other minerals resistant to wave abrasion. They are mineral deposits formed by the combination of weathering, fragmentation, and degradation (Ching-Jiang et al.1993, Kanse et al. 2016, Lal 1991). Studies concerning the radiation hazards arising from the use of sand or soil showed that natural radiation is the largest contribution to external dose to the world population (Papadopoulos et al. 2014 & 2016). Ionizing radiations are a grave threat around the high background regions of the globe. The presence of monazite sand along the beaches among other factors has contributed to these dreaded radiations (Malathi et al. 2005, Mishra 1990, Monica et al. 2017, Singh et al. 2007). Predominant natural radiation affecting terrestrial systems and the most studied radio-nuclei is radon. Dynamics between terrestrial and cosmic processes on radiative distribution on various hydro-litho-climatic reasons are widely ventured, however, no integrated model has been developed so far (UNSCEAR 2000).

Study on dynamics of radiation in Indian coastline and their effect is scarce in peered-reviewed literature. India with its long coastline –supports a major fisherman population. Indian Rare Earth mining, exclusively located at coasts, is known to be enriched in monazite, garnet, and rutile (Ragel et al. 2008, Radhakrishna et al. 1993, Sivakumar et al. 2002). Risks associated with natural radiation due to coastal radiation is yet to be studied extensively. Hence, there is a need for the study of coastal radiation dynamics and delineation of radiation-risk prone zones.

The main objective of this study was to measure the gamma dose rates during the waxing phase along the coastal regions under study and thereby evaluation of the radiation profile vis-e-vis the altitude of the coastline of the study area (along and across the sea). Also evaluating the effect of the tide and regional topography on the radiation profile (stability and migration) to delineate the radiation-prone zone and identification of cause thereof by stratigraphic analysis.

STUDY AREA

The study area covers along the southern Indian coastline from Poompuhar to (Longitude 79°51'26.604" E to 79°51' 03.654" E) to Nagore (Latitude 11°08'23.94" N to 10°49' 26.892" N) comprising eight coastal villages namely Poompuhar, Chinnagudi, Kuttiyandiyur, Chandrapadi,

Kottucherrymedu, Karaikkal, Vadakkuvanjore, and Nagore, which covers a coastline stretch of about 40 km (Fig. 1). Each location is separated by a distance of four kilometers approximately.

The geology of the study area consists of alluvium, laterites, quartzites and biotite, hornblende-biotite, granite, and gneisses. The foliation and joints on these sand rocks control the course of the seashore, causing them to form a trellis drainage pattern, particularly to the south of the area. The sedimentary sand rock sequences are from cretaceous to recent; consist of grey sand intercalated with brown to dark grey clay.

MATERIALS AND METHODS

Selection of the Measurement Sites

The geo-coordinates of the locations were recorded (Latitudinal and Longitudinal position) using a handheld Global Positioning System (Standard GPS). Survey of coastal stretches along and across (every 5kms along the coast and 100 meters across) the coastline of the study area.

Gamma Absorbed Dose Measurements Using Portable Dosimeter

The ambient gamma absorbed dose rates were measured in the sampling locations using a GM counter-based dosimeter (Belvar- PKC-107). The gamma radiation levels were measured both inside and outside the dwellings at the surface of the ground. About 20 readings were taken at different points in each location.

Measurement of Radionuclide Activity Concentrations

A hand-held gamma radiation counter was used for profiling the dose rates along and across the coastline, before and after tidal cycles during the waxing phase (New moon, First Quarter & Full moon). The gamma radioactivity was recorded on beach sand samples by placing on the sand surface at all locations with a 10-meter interval (between each sampling point). The radiation measurements were recorded from the beach face that extends up to the berm, perpendicular to the shoreline (0 to 100 meters). The data was collected during the waxing phase i.e., periodically between the full moon and new moon phases. The recorded values were analyzed statistically. The average gamma radioactivity map and delineation of gamma radiation were prepared using the ARC-GIS Spatial Analyst tool (ArcGIS, Ver.10.3).

RESULTS AND DISCUSSION

Gamma Absorbed Dose Rates

The gamma absorbed dose rates along the coastal region under study measured using a portable dosimeter, are presented in Table 1. The overall gamma dose, measured using the dosimeter, varied in the range of 0.1 to 3.6 $\mu sv.h^{-1}$ with the mean value of 2.34 $\mu sv.h^{-1}$ (Fig. 2).

Comparison of Dose Measured Along the Stretch under Study

The highest activities were recorded along the Chinnankudi and Kutiyandiyur and Chandrapadi regions. The gamma-ray activity was directly related to the abundance of the pri-

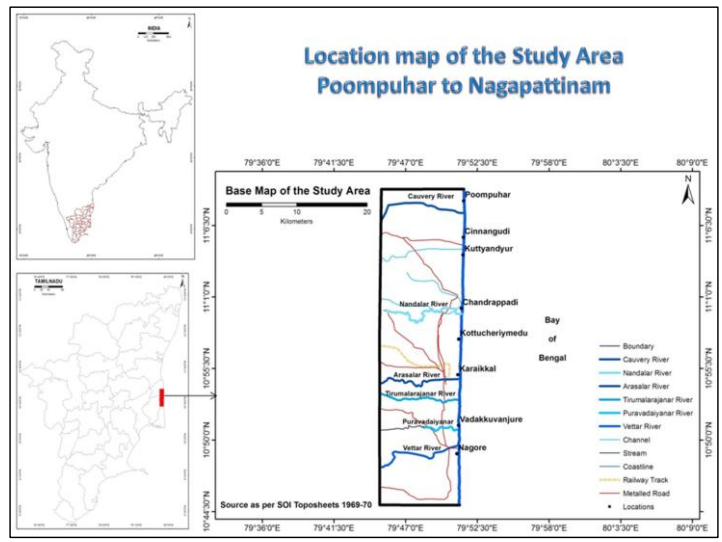

Fig. 1: Map of the study area.

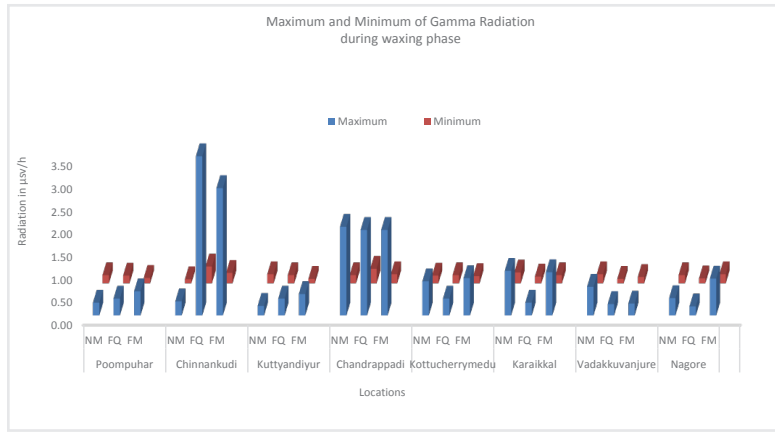

Fig. 2: Maximum and minimum gamma radiation during waxing phase.

mordial radionuclides in the area. The gamma values were the highest at Chinnankudi with 3.55 µsv.h^{-1}, followed by 1.72 µsv.h^{-1} at Chandrapadi (Table 1). It may be due to the fact that these two areas form strategic regions on either side of Chandrapadi with high amounts of radiations (i.e., Kuttiyandiyur and Kottucherimedu). Delineation of gamma dose rates at various locations during the period of study was analyzed with a spatial analyst tool. The values are found to be comparatively high in these regions (Fig. 3).

The calculated dose rates of gamma radiations of these regions indicate values as high as 3.55 µsv.h^{-1}. The comparably high values are certainly a major threat, affecting the region populated by the fishermen community. However, it is discomforting to know that still there are areas with thick mineral deposits, especially around the large fishermen population who defy any effort to remove the huge deposits, fearing erosion of their natural boundaries by the sea waves.

Table 1: Gamma radiation values during the period of study at all locations.

Horizontal Distance M	Poompuhar			Chinnangudi			Kuttyandiyur			Chanadrappadi		
	NM	FQ	FM	NM	FQ	FM	NM	FQ	FM	NM	FQ	FM
0	0.18	0.17	0.12	0.09	0.37	0.23	0.12	0.18	0.15	0.18	0.35	0.2
10	0.26	0.19	0.20	0.13	0.38	0.28	0.2	0.20	0.21	0.43	0.32	0.38
20	0.24	0.21	0.17	0.18	1.26	0.24	0.13	0.22	0.22	0.37	0.34	0.42
30	0.23	0.22	0.16	0.22	2.46	0.39	0.23	0.26	0.27	0.55	0.41	0.52
40	0.21	0.24	0.17	0.26	2.86	1.2	0.36	0.28	0.1	0.88	0.72	0.91
50	0.25	0.27	0.16	0.28	3.12	1.88	0.18	0.33	0.35	1.95	1.82	1.85
60	0.28	0.29	0.22	0.31	3.46	3.55	0.21	0.35	0.41	1.31	1.72	1.45

Horizontal Distance M	Kottucherrymedu			Karaikkal			Vadakkuvanjure			Nagore		
	NM	FQ	FM	NM	FQ	FM	NM	FQ	FM	NM	FQ	FM
0	0.17	0.18	0.16	0.2	0.15	0.4	0.2	0.1	0.14	0.18	0.12	0.2
10	0.17	0.20	0.21	0.3	0.32	0.3	0.59	0.14	0.12	0.23	0.20	0.25
20	0.32	0.22	0.33	0.3	0.18	0.4	0.42	0.16	0.14	0.25	0.11	0.28
30	0.19	0.26	0.45	0.2	0.2	0.2	0.32	0.15	0.14	0.35	0.15	0.39
40	0.71	0.28	0.66	0.4	0.17	0.2	0.63	0.19	0.26	0.29	0.22	0.45
50	0.34	0.33	0.73	0.3	0.21	0.2	0.42	0.21	0.17	0.34	0.18	0.59
60	0.75	0.35	0.75	0.4	0.2	0.2	0.37	0.23	0.16	0.38	0.19	0.67

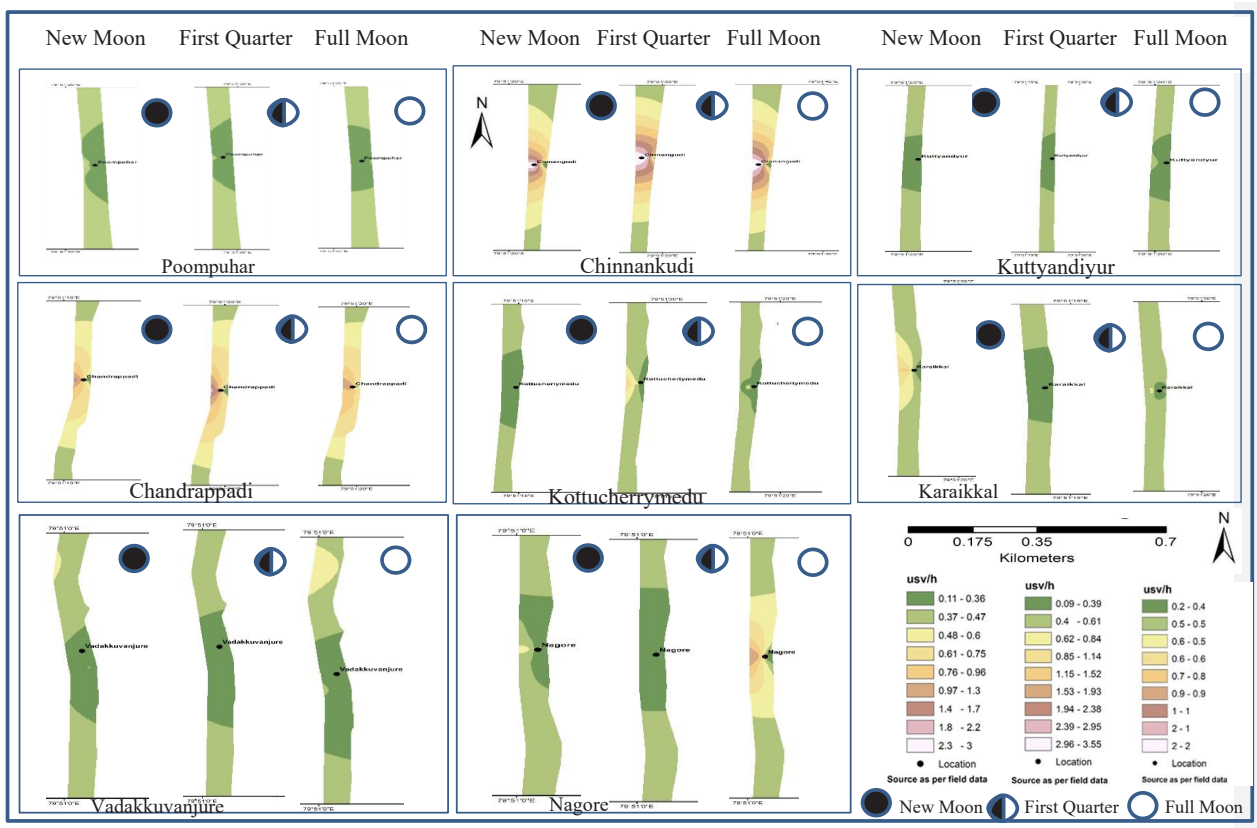

Fig. 3: Delineation of gamma dose rates at various locations during the period of study.

CONCLUSIONS

The effective gamma radiation during the new moon along the coastal range varies between 0.9 to 3.55 μsv.h^{-1}, respectively. The annual equivalent dose is estimated up to gamma radiation of 0.26 to 2.80 μsv.h^{-1}. Generally, the concentrations of the gamma radiation measured are elevated in certain areas namely Chinnagudi, Kuttiyandiyur, and Chandrapadi. In particular, the gamma radioactivity is high at Chandrapadi and Chinnagudi during the new moon as it shows considerable amounts of radiation.

There is a definite variation due to the moon phase on the gamma radiation profile of the area studied. Out of the eight coastal villages under study, about 60% of the coastal line shows high levels of gamma radiation during both new moon and full moon phases. It is obvious that gamma radiation variation mostly dependent on coastal hydro geomorphology and prevalent oceanic parameters.

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