Title: First probabilistic radiological risk appraisal of Bay of Bengal beach sands: Explicit spatial hot-spot analysis

Author names: Jahanara Habib Zesha , Md. Abdullah-Al Mamun , Abu Reza Md. Towfiqul Islam , Md. Ahosan Habib , Rahat khan

Abstract: Coastal beach pollution caused by primordial radionuclides has emerged as a global environmental concern. This study presents the first integrated probabilistic–spatial framework for assessing radiological risk in the Bay of Bengal (BoB) beach sands. Twenty-two surface sediment samples (10–15 cm depth) from Darianagar, Himchari, and Nidania beaches along the BoB were analyzed using HPGe gamma spectrometry. Geometric mean (range) activity concentrations (Bq kg^{-1}) were 77.6 (15.1–1914.3) for ^{226}Ra, 123.1 (8.12–1847.3) for ^{232}Th, and 312.8 (122.4–562) for ^{40}K, exceeding global averages for ^{226}Ra and ^{232}Th by factors of 2.2 and 4.1 times, respectively. Principal component analysis (PCA) identified natural mineralogical controls, primarily monazite and K-feldspar rather than distinct anthropogenic sources, while Monte Carlo simulations revealed 95th-percentile radiological indices (Raeq, D_out, ELCR) exceeding international safety thresholds (8.5×10^{-4} to 23.3×10^{-4}). Deterministic calculations yielded mean values higher than probabilistic medians, reflecting right-skewness. All radionuclide concentrations followed lognormal distributions, indicating significant spatial variability. Sensitivity analysis showed ^{232}Th (∼75 %) as the primary contributors to total radiological risk. GIS-based spatial modeling delineated localized high-risk hotspots requiring restricted access, hazard signage, and periodic radiological monitoring. This study establishes benchmark data and a transferable methodological framework for coastal radiation surveillance and sustainable management, supporting evidence-based regulation of BoB and similar global beach systems.

Keywords: Cox's Bazar beach; Primordial radionuclides; Spatial modeling; Monte-Carlo simulation; Probabilistic health risks; Radiological hotspots

10.1016/j.marpolbul.2025.118966