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Radiological characterization of beach sediments along the Alexandria–Rosetta coasts of Egypt

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Abstract

In the present study, 52 sediment samples were collected from 14 sites along the area extending from west of Alexandria (El-MAX) to the eastern side of the Rosetta promontory (the terminal of the Nile River with the Mediterranean Sea). The collected samples were analyzed for radioactive contents. ^{226}Ra, ^{228}Ra, ^{40}K and ^{137}Cs were detected. The distribution of radionuclide activity and mass concentrations of Th and U displayed a specific pattern that reflects the mineralogical formations and beach stability. Radiological hazards were investigated by calculating the following radiological parameters: the radium equivalent, radiation hazard index and annual effective dose. It was observed that the levels of radiological parameter are higher in eastern locations than in western ones. In addition, the western side displayed radiological parameters higher than the recommended world-wide values.

Keywords: Effective radiation dose; Beach sands; Radiation hazard index; Radioactivity; Th and U

1. Introduction

Human environment is naturally radioactive, and human beings are exposed to radiation arising from natural sources, including cosmic and terrestrial origin, in addition to artificial radioactivity from fallout in nuclear testing and medical applications. Natural sources contribute approximately 80% of the environmental radiation [1]. Littoral areas of the environment receive radioactive pollution, either natural or anthropogenic, through rivers and rainfall [2]. Marine sediments are essential reservoirs for natural and artificial radionuclides due to their diverse composition. The uptake of radionuclides by marine sediments depends on their physical and chemical properties [3]. The radionuclides distribution in marine sediments provides essential information concerning sediments movement and accumulation that provide a strong signal indicating sediment origin [3]. The concentration and distribution of ^{226}Ra, ^{232}Th and ^{40}K in sands are not uniform throughout the world [4], and their distribution in soil is based on the nature of its geological formation [5,6].

Mahdavi [7] studied the concentrations of thorium, uranium and potassium in beach sands of the Atlantic and Gulf coasts. He concluded that thorium and uranium in

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beach sand are contained mainly in resistant heavy minerals such as monazite, zircon and xenotime. Moreover, the highest concentrations found in beach sands were 1–2 mg/kg for thorium and 0.3–0.6 mg/kg for uranium. He also found that beach sands have a thorium/uranium ratio of approximately 2.5–3.0. The locations and areas of black sands that contain monazite minerals are of interest for researchers. This is because monazite sand is considered an important geological material [8] because it may contain 0.1–0.3% uranium and 5–7% thorium, which are the main elements used in nuclear power plants [9]. Around the world, several authors have been studying radionuclide concentrations in sand beaches in the Kerala and Tamil Nadu coastal regions of India [10], in Bangladesh [9] and in southwestern Australia [11]. Also in India, Kannan et al. [12] analyzed the distribution of natural and anthropogenic radionuclides in beach sand and soil from the Kalpakkam area by using gamma ray spectrometry.

In certain beaches of Egypt, Brazil and along the west coast of India, there are areas that are well known for their high background radiation. The Rosetta and Damietta beaches on the Mediterranean coast of Egypt present high radiation due to the presence of black sands that contain zircon and monazite minerals.

2. Study area

The study area extends along the Mediterranean coast of Alexandria–Rosetta in Egypt and covers 14 sampling sites for beach sands from west of Alexandria (El-Max site) to the east side of the Rosetta Nile promontory (the terminal of the Nile River with the Mediterranean Sea). The ground positions of the El-Max site (1) to the east side of the Rosetta site (14) are (31°09′ N, 29°50′ E) to (31°27′ N, 30°22′ E), respectively, as illustrated on the map in Fig. 1.

The ground positions (latitudes and longitudes) and the local names of the studied sites are given in Table 1.

The beach sediments in the study area are characterized by their variability in geological formations. The bottom sediments of the inshore area are covered predominantly by sand, which vary from fine in the west to coarse shelly in the east. This sandy zone merges seawards into a silty-sand belt. In the northwest area, the silty-sand gradually changes into sand–silt–clay. The sand–silt is followed outward by a clayey-silt in the northeast. Minerals of light fraction are represented by calcium carbonate, which is introduced in the form of shells or shell fragments. The sediments at the El-Max area were poor in the amount of heavy minerals compared with those at the Abu Qir site. This is characterized by high frequencies of pyroxenes, amphiboles and epidotes and by low percentages of tourmaline and zircon of 1.1% and 2.4%, respectively. The main source of heavy minerals is mostly the Nile sediments, which decrease westward [13]. Mineralogically, the shelf of Alexandria is subdivided into three main provinces: (1) aragonite/calcite in the western part, (2) calcite/aragonite/quartz in the middle part and (3) quartz/calcite/aragonite in the eastern part.

Table 1
The ground positions and local names of the study sites.

ID	Site name	Latitude	Longitude
1	El-Max	31°09′17.17″	29°50′32.11″
2	Anfushi	31°12′19.69″	29°52′38.32″
3	Manshia	31°12′03.82″	29°53′40.06″
4	Chatby	31°13′00.33″	29°55′13.78″
5	Sporting	31°13′58.56″	29°56′40.45″
6	Gleem	31°14′51.44″	29°57′33.26″
7	Asafra	31°16′48.87″	30°00′27.54″
8	Abu-Qir (W)	31°19′36.07″	30°03′56.07″
9	Abu-Qir (E)	31°18′06.48″	30°04′41.43″
10	El-Tarh	31°16′41.01″	30°06′58.07″
11	El-Maadyia	31°16′54.91″	30°12′37.60″
12	Edku	31°23′33.08″	30°20′07.10″
13	Rosetta (W)	31°27′29.04″	30°21′40.00″
14	Rosetta (E)	31°28′19.02″	30°22′10.50″

In the west, the major minerals are carbonates; on the other hand, on the eastern side, heavy minerals are dominant. The distribution of heavy mineral assemblages has been recognized as two mineral groups [14,15]. The first group includes heavy minerals of low density and coarse size (augite, hornblende and epidote). Heavy minerals in this group increase from west to east along the area, as it is easy to entrain and transport the coastal sediments toward the east by wave currents. In contrast, the second group includes heavy minerals of high-density (opaque, garnet, zircon, rutile, tourmaline and monazite). These minerals are difficult to entrain and transport by wave-current actions. Hence, minerals in this group form a lag deposit within the delta and sand beaches. Rosetta is highly affected by the black sand deposits that are transported to Rosetta beaches by the Nile River water current during the time period before building the High dam in Upper Egypt.

Black sands are characterized by heavy mineral contents, such as monazite, which contains, overall, two orders of magnitude more of ^{232}Th and ^{238}U and an order of magnitude less of ^{40}K compared to light minerals. Radiometric analysis of various fractions of heavy mineral sands showed that the monazite and zircon sands have highly radioactive contents (U and Th) compared