Journal of Environmental Radioactivity 137 (2014) 71–78

Contents lists available at ScienceDirect

Journal of Environmental Radioactivity

journal homepage: www.elsevier.com/locate/jenvrad

# Environmental hazards and distribution of radioactive black sand along the Rosetta coastal zone in Egypt using airborne spectrometric and remote sensing data

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ARTICLE INFO

*Article history:*
Received 12 May 2014
Accepted 3 June 2014
Available online

*Keywords:*
Radioactive black sand
Radiation hazards
Airborne gamma ray spectrometry
Rosetta promontory and remote sensing techniques

ABSTRACT

High-resolution airborne gamma ray spectrometry, conducted in 2003, was used to estimate radioactive elements spatial abundance along the Rosetta coastal zone area. It was noticed that both Uranium and Thorium are concentrated in the black sand deposits along the beach. In contrary, Potassium was observed in high level abundance at the cultivated Nile Delta lands due to the accumulated usage of fertilizers. Exposure Rate (ER), Absorbed Dose Rate (ADR) and Annual Effective Dose Rate (AEDR) were calculated to evaluate the radiation background influence in human. Results indicated that the human body in the study sites is subjected to radiation hazards exceeds the accepted limit for long duration exposure. In addition, the areas covered by the highest concentration of Uranium and Thorium show the highest level of radiogenic heat production. Detection the environmental hazards of the radioactive black sands in the study site encouraged this research to monitor the spatial and temporal distribution of these sediments. The Landsat Thematic Mapper images acquired in 1990, 2003 and 2013 were analyzed using remote sensing image processing techniques. Image enhancements, classification and changes detection indicated a positive significant relationship between the patterns of coastline changes and distribution of the radioactive black sand in the study sites. The radioactive black sands are usually concentrated in the eroded areas. Therefore, in 1990 high concentration of the radioactive black sands were observed along the eastern and western flanks of the Rosetta promontory. Distribution of these sediments decreased due to the construction of the protective sea walls. Most of the radioactive black sands are transported toward the east in Abu Khashaba bay under the effect of the longshore currents and toward the west in Alexandria and Abu Quir bay under the action of the seasonal reverse currents.



## 1. Introduction

The Nile Delta coast is a dynamic system formed by the Nile river sediments discharged into the Mediterranean sea through the historic seven Nile branches (Stanley, 1988) which have subsequently silted up and been replaced by the present day two branches, Rosetta and Damietta. Since the construction of the High Aswan Dam in 1964, no additional sandy sediment reaches the coast (Badr and Lotfy, 1999). Waves and currents continue to move the relict sediment alongshore, so that some beaches are eroding while others are accreting. The Egyptian black sands are derived from the River Nile tributaries in Ethiopia and Central Africa (Mowafi and El Tahawy, 2009). These sediments are believed to be of Quaternary age (El Shazly et al., 1975). Gamma ray was utilized to detect, identify, classify and measure the density of the radionuclides and realize its sources (El Saharty, 2013). This research aims at to study the influence of coastal processes on the spatial and temporal distribution of the radioactive black sands existing along the Rosetta beach during 1990–2013. Airborne radiometric data will be used to estimate the degree of radioactive hazard on humanity.

## 2. Site description

The study area is located to the east and west of the Rosetta branch between latitudes 31°22‘ and 31°32' North and longitudes

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http://dx.doi.org/10.1016/j.jenvrad.2014.06.006
0265-931X/

30°19‘and 30°50' East (Fig. 1A). The Nile Delta deposits are dominated by unconsolidated coarse sands and gravel with occasional clay lenses (Shata and El Fayomy, 1970). Analyses of beach sand compositions and grain size at the beach profile surveys at 65 positions along the coastline of the Nile Delta spanning the years 1971–1990 have established that there is a general correspondence between sediment characteristics and the patterns of shoreline erosion versus accretion (Frihy and Komar, 1993). The eroded areas are typically associated with finer-grained beach sands rich in heavy minerals (opaque and garnet), (Fig. 1B). Inversely, the areas of shoreline accretion are characterized by coarser sands that are poor in heavy minerals (augite, hornblende and epidote) and rich in light minerals (Frihy, 1994, 2007; Frihy et al., 1995; Frihy, 2007). It was explained by Carter and Woodroffe (1994) that as the results of high competency of water at eroded beaches having steep slope, it has ability to carry and remove coarse sand that is poor in heavy minerals content. It was noticed by Abo Zed and Shereet (2005) that light and heavy minerals are subjected to sorting processes under the effect of waves and waves induced longshore current. The heavier and more stable minerals (opaque, garnet, zircon, tourmaline, rutile and monazite) are concentrated in the surf zone. In contrary, the lighter and less stable minerals (hornblende, augite and epidote) are transported offshore.

## 3. Airborne gamma ray spectrometric data and results

Gamma ray is an ionizing electromagnetic radiation of extremely high frequency ($10^{20} - 10^{24}$Hz) and high energy

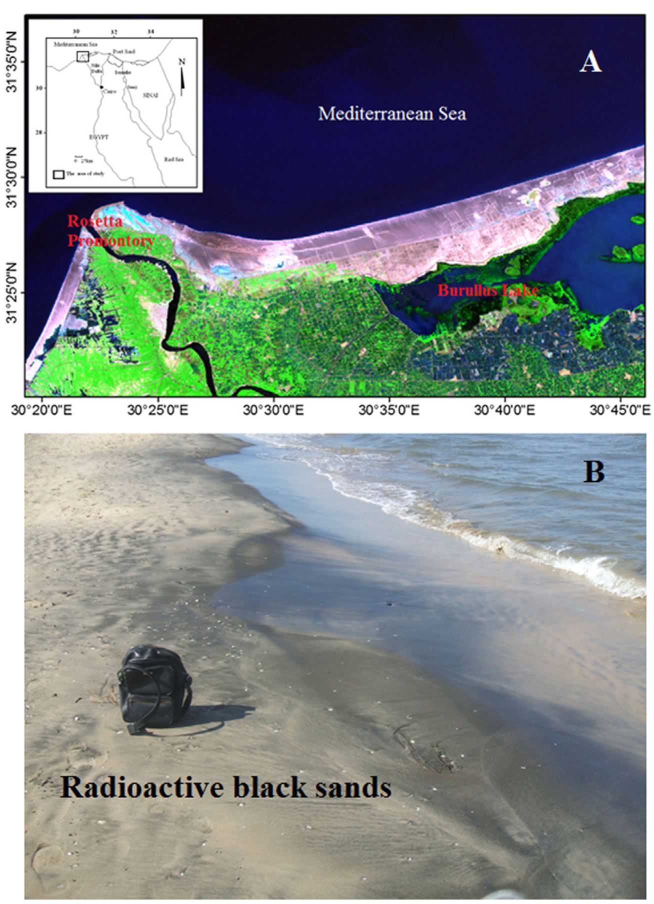


**Fig. 1.** A) The area of study and B) The black sand sedimentation along the Mediterranean Sea.

(0.4–3.0 MeV). Airborne gamma ray spectrometry (AGRS) is a non-invasive rapid method used for geological mapping, minerals exploration and gamma radiation mapping (Grasty and Shives, 1997; Minty, 1997; Minty et al., 1997). AGRS data can be plotted as maps showing spatial distribution and concentration of radioactive elements (Charbonneau et al., 1976). The method depends on measuring the discreet energy of different gamma rays produced during the decay of the high energy states of the atomic nuclei of the Natural Occurring Radioactive elements (NOR) including Potassium$^{40}$K, Uranium $^{235}$U and$^{238}$U and Thorium$^{235}$Th. The records are used to calculate the abundances of the NOR elements using appropriate calibration procedures (IAEA, 1991; Grasty, 1977; Minty, 1997). Measurements of gamma radiation emissions due to the presence of $^{40}$K can be used to estimate the abundance of total potassium present in nature. Since $^{40}$K represents 0.012% of the total potassium exists in the natural environment$^{40}$K/K, it is usually expressed as a percentage (Wilford et al., 1997; Rybach, 1988). Uranium and Thorium are expressed in equivalent concentrations "eU" and "eTh", which indicates that their concentrations are inferred from daughter elements in their decay chains. Both "eU" and "eTh" are expressed in parts per millions (ppm).

In 2003, the Nuclear Material Authority of Egypt conducted an airborne gamma ray spectrometry survey, covering the targeted area of study. The plane is equipped with a multi sensor airborne geophysical systems, comprises a high-sensitivity 256-channel gamma-ray spectrometer. The system is able to measure the terrestrial radiation, through a downward-looking detector, and the cosmic radiation through an upward-looking detector. The survey was flown at a low altitude, of 120 m average. Instruments were calibrated, and the acquired measurements were corrected, leveled, and stripped. Data were compensated for the effect of flight altitude attenuation. Finally, the acquired measurements, of each channel, were reduced to elemental concentrations measurements of eU, eTh, K, and the total count TC.

Statistical analyses and correlation coefficients of the data show strong linear correlation between eU and eTh (Table 1). A strong correlation values between eU, eTh, and TC are 0.96 and 0.95 respectively. On the other hand, Potassium has a moderate correlation with eU and eTh, which are 0.61 and 0.58 respectively.

Oasis Montaj ver. 8.1 software package (Geosoft, 2013) was used to convert the numerical spectrometry data digital maps with appropriate scale and projection. The results show the spatial concentration distribution of potassium K in (%), equivalent uranium eU in (ppm) and equivalent thorium eTh in (ppm). In addition, color composite map is used to represent a ternary radioelement which combines the three NOR elements K, eTh and eU in red-blue-green color, respectively (Duval, 1983; IAEA, 1988; IAEA, 2003). Anomalous zones displaying high concentrations of the NOR elements show bright white spots (Fig. 2D).

As the spectral radiometric ratios are sensitive to any variation in radioelement concentrations it was used to illustrate the relative spatial distribution of the NOR elements. Radioactive

**Table 1**
Statistical summary and linear correlation matrix of the measured GRS data.

| | Statistics | | | Correlation | | | |
|---|---|---|---|---|---|---|---|
| | Mean | Median | SD | TC | eU | eTh | K |
| TC (μR/h) | 7.13 | 7.43 | 6.43 | 1.00 | | | |
| eU (ppm) | 4.65 | 4.19 | 3.00 | 0.96 | 1.00 | | |
| eTh (ppm) | 8.06 | 6.69 | 7.06 | 0.95 | 0.98 | 1.00 | |
| K (%) | 1.34 | 1.58 | 0.58 | 0.78 | 0.61 | 0.58 | 1.00 |