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# $^7$Be in soil, deposited dust and atmospheric air and its using to infer soil erosion along Alexandria region, Egypt

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ABSTRACT

This study investigated the radioactivity behavior of $^7$Be in surface soil, airborne and deposited dust along Alexandria region in Egypt. The results obtained were used to predict scavenging processes of $^7$Be from surface soil to infer soil erosion and land vulnerable to accelerated sea-level rise. The areal activity concentrations of $^7$Be in surface soil were investigated in 30 undisturbed sites and $^7$Be inventories were determined via deposited dust in 10 locations. Results of the former were found to be ranged from 78 Bq/m$^2$ to 104 Bq/m$^2$. High levels were observed in western sites associated with high dust deposition rate. On the other hand, low levels were found in the eastern sites, those may be attributed to scavenging processes such as land erosion toward the direction to the sea. The effective removal rates of $^7$Be were calculated using the box-model, showing a broad special trend of inventories generally decreasing eastwards. The scavenging rates were ranged between 3.13 yr$^{-1}$ in western sites to 5.34 yr$^{-1}$ in eastern ones which denote that the east of the city suffers from rapid soil erosion. The airborne $^7$Be was monthly monitored along the period from October 2014 to September 2015 through one site located at the mid of the city. The results revealed lower values in winter and autumn than in summer and spring ranged between 6.2 mBq/m$^3$ and 10.5 mBq/m$^3$. These levels are comparable with that in other world regions and the seasonal variations are associated with the prevailing climatic conditions in Alexandria region.


## 1. Introduction

Radionuclides occurring in the environment have three main sources: (1) primordial radionuclides, i.e., nuclides which have survived since the time when the elements formed, and their progeny nuclides; (2) cosmogenic radionuclides, formed continuously by the interactions of cosmic-ray particles with matter; and (3) artificial radionuclides, introduced by human activities, such as by detonations of nuclear weapons. Studies of environmental radionuclides can provide us with useful geophysical information, such as the timescales over which natural systems are changing or evolving and the underlying mechanistic causes. They can also be used to assess the radiological or radio-ecological effects of ambient radioactivity (Eisenbud and Gesell, 1997).

$^7$Be (half-life 53.3 days) is one of the cosmogenic radionuclide produced by spallation nuclear reaction of oxygen and nitrogen in the lower stratosphere and upper troposphere by cosmic rays. Therefore, it introduces naturally to the environmental compartments such as air, rainwater, soils and sediments, vegetation, lakes, rivers, and ocean waters. The amount of $^7$Be that reaches the surface of the earth is controlled by many factors and processes including cosmic-ray intensity, wet and dry deposition, vertical transport in the troposphere, horizontal transport from the subtropics, and mid-latitudes into the tropics and Polar Regions (Lal et al., 1958). After $^7$Be has been produced, it rapidly forms BeO or $Be(OH)_2$ by ionic reactions and it becomes associated with submicrometer aerosol particles (Papastefanou and Ioannidou, 1995; Yoshimori, 2005a,b). It decays by electron capture to $^7$Li and a gamma-ray is emitted in around 10% of all $^7$Be disintegrations; the activity of radionuclides is measured through gamma spectrometry.

The continuous and definable production rates of $^7$Be, its relatively short half-life, and reactivity make it a potentially powerful tool for examining environmental processes. Therefore, the number of investigations regarding its application as a tracer of

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environmental processes has increased notably in recent years. This radionuclide has been used in many fields; such as soil redistribution, sediment sources assessment, air mass transport, studying of metal scavenging processes, and many other applications (Kaste et al., 2002; Blake et al., 1999; Steinmann et al., 1999; Walling et al., 1999; Matissoff et al., 2002; Daish et al., 2005; Yoshimori, 2005a,b; Schuller et al., 2006; Sepulveda et al., 2008).

Radiologically, UNSCEAR (2000) reported that the annual effective dose due to cosmogenic $^{7}$Be is 0.03 μSv. This represents around 0.001% of the total annual effective dose received due to all natural radiation sources. Therefore, cosmogenic $^{7}$Be does not pose a radiological health risk to the public.

Alexandria city lies at the center of the Mediterranean Egyptian coastline and on the western edge of the Nile delta. Its waterfront extends along 42 km of the sea's shoreline, from Abu Qir in the east to El-Agami in the west. The region is located between latitudes of 31008′ N and 310 06′ N and longitudes of 290 27′ E and 300 04′ E, as shown in Fig. 1. Its Mediterranean coastline is totally plain with low altitude shrublands along the region, except for the westernmost portion which is formed by a 400 m-high plateau. It is characterized as well by the occurrence of Egypt's five northernmost lakes. These variable topography and vital socioeconomic activities make the potential socioeconomic impacts of accelerated sea-level rise of concern. In addition, it is Egypt's main summer tourist resort. The city originally developed on the remnants of three parallel and intermittent calcareous sand stone and limestone ridges or hills, with elevations that vary between 5 and 30 m above mean sea level. South of the limestone ridges is an extensive lowland, with a width of more than 20 km and the Lake of Mariout. Most of this lowland lies outside the Governorate. This whole area is vulnerable to inundation, waterlogging, increased flooding, and salinization given accelerated sea-level rise. Alexandria usually experiences several northwest and southwest storm surges during the period from October to May. Alexandria is suffering from severe environmental changes. Soil erosion and disturbances is major environmental problems. Annual precipitation averages 189 mm, most of which falls during the period from October to February of each year and causes severe soil erosion. The annual mean temperature is 20 °C, average of wind speed is 13 km/h and sea wave height of 0.5–1.0 m. The soil textures in the area are ranged from dominant sand affected by desert at the west to clay at the eastern side affected by Nile River (El-Raey et al., 1995, 1999; El-Raey, 1997).

The main objectives of this work are: (1) to use the radioactivity measurements of $^{7}$Be in different environmental compartments to infer scavenging processes and the possible consequences on the environment such as soil erosion and land vulnerable to accelerated sea level rise; (2) to identify the areas suffering from high rates of soil erosion and require intervention and reform to be more suitable for future urban expansion.

## 2. Experimental work

### 2.1. Surface soil sampling

Soil samples were collected from 30 sites of undisturbed surface along the studied area. Each site was selected to be in an open area and not subjected to disturbances or surfaces alteration. Samples were taken from the surface to about 3-cm depth as shown in Fig. 1. The area for each sampled site was measured for calculating the areal concentration of $^{7}$Be. The samples were collected along the time from 20 October 2014 to 20 January 2015. The samples were packed in PVC bags then transferred to the radiation laboratory at the Institute of Graduate Studies and Research (IGSR), Alexandria University. There, the samples were dried in an oven at 110 °C for approximately 24 h; then they were sieved through a 2-mm mesh-size to remove any macro-impurities. The homogenized samples were weighed and packed in counting vessels (1000-cm$^{3}$ Marinelli) for radioactivity measurements by high purity germanium

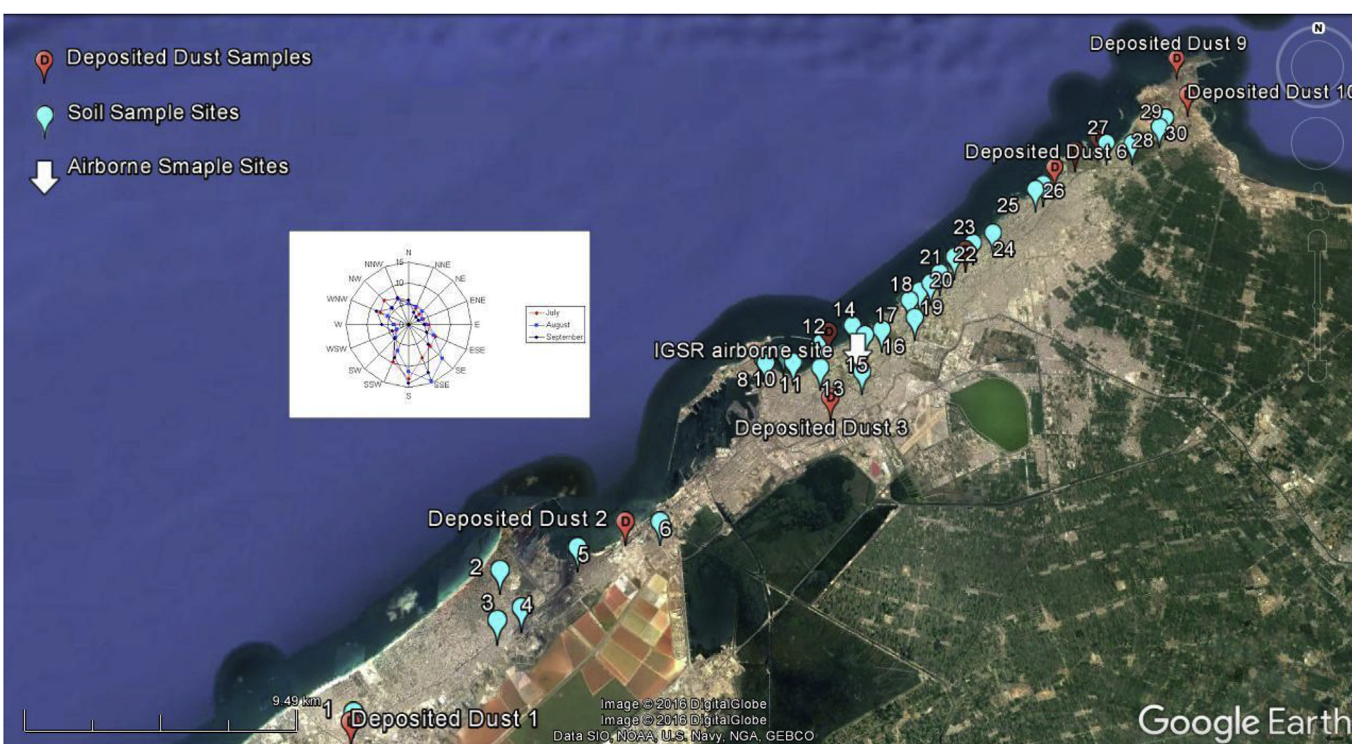


Fig. 1. The locations of sampling.