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Measurement of radioactivity concentration in soil samples around phosphate rock storage facility in Richards Bay, South Africa

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ABSTRACT

Mining, mineral processing and industrial activities have long been linked to increased levels of radionuclides in soil in their vicinity. In this work, concentrations of naturally occurring radionuclides in soil samples collected around a rock phosphate storage facility in Richards Bay in South Africa were determined. A total of 90 soil samples were collected and analyzed for ^{238}U and ^{232}Th using neutron activation analysis and ^{226}Ra and ^{4} K using a HPGe detector. The results revealed the average radioactivity concentrations of ^{238}U, ^{232}Th, ^{226}Ra and ^{4} K in soil samples collected around the rock phosphate storage area were 28.26 ± 11.40, 29.64 ± 11.50, 32.18 ± 11.50 and 146.77 ± 63.30 Bq. kg^{-1}, respectively, which are higher than the corresponding values of 22.26 ± 8.60, 23.09 ± 9.80, 26.52 ± 11.50 and 117.82 ± 10.04 Bq. kg^{-1} in soil samples from the control area about 2.0 km–4.5 km away from the rock phosphate storage facility. Furthermore, the all radiological hazard parameters (i.e annual effective dose equivalent, annual gonadal dose equivalent, the absorbed dose rate in air, the radium equivalent activity and the external Hazard Index) investigated in this study were below the maximum recommended safety limit. The observed ^{238}U, ^{232}Th, ^{226Ra} and ^{4} K levels indicate contributions from anthropogenic activities with no significant health risks to humans or to the environment. Hence, in terms of terrestrial gamma radiation from soil, rock phosphate storage within this area does not pose any significant radiation hazard to the workers and dwellers.

1. Introduction

Uranium-238 (^{238}U) and thorium-232 (^{232}Th) are the parent primordial nuclides that along with their progenies are sources of radiation exposure to which persons are exposed directly or indirectly (Ahmad, Jaafar, Bakhash & Rahim, 2015). Rock phosphate contain natural radionuclides including ^{238}U, ^{232}Th and ^{4} K (Alsaffar, Suhaimi Jaafar, Ahmad Kabir, & Ahmad, 2016; Makweba & Holm, 1993; Masok, Masiteng, Mavunda, & Maleka, 2016). The natural radionuclides of concern in terrestrial environment are mainly ^{238}U, ^{232}Th and ^{4} K (UNSCEAR, 2000). The natural activity concentrations of ^{238}U, ^{232}Th and ^{4} K within the earth environment are generally at levels not harmful to humans (UNSCEAR, 2000). However, anthropogenic activities involving rock phosphate have been found to elevate the concentrations of these radionuclides in the environment (Ahmad, Jaafar, & Alsaffar, 2015; Wassila & Ahmed, 2011; Mlwilo, Mohammed, & Spyrou, 2007; Makweba & Holm, 1993). In the interest of workers and the general public, qualitative and quantitative measurements of radionuclides within working environment and residential places are of great importance.

This study aims to examine the activity concentrations of ^{238}U, ^{232}Th, ^{226}Ra and ^{4} K in soil samples around a rock phosphate storage facility in Richards Bay, South Africa in order to evaluate their associated health risks to workers and nearby residents. Several similar studies have been conducted around the world (Wassila & Ahmed, 2011; Masok et al., 2016; Makweba & Holm, 1993). However, there is currently no available data on the radioactivity levels of soil samples from this area. This study will report for the first

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time radioactivity levels in soils from this location. Hence it will serve as a baseline for monitoring future radioactivity levels in soils from Richards Bay.

2. Materials and method

2.1. Study area

The study was conducted adjacent to the Port of Richards Bay (see Fig. 1). Richards Bay, located at latitude 28° 48′ S and longitude 32° 02′ E, is among the fastest growing industrial towns in KwaZulu Natal Province, South Africa. The town is about 160 km northeast of Durban and approximately 465 km southwest of Maputo and occupies 2155 hectares of land area (Richards Bay, 2016). It has a population of over 50,000 people based on the 2011 population census (SA Census, 2011). The area is known for its industrial activities, harbor facilities, vast coastal grassland, sugar cane plantations and hilly topography with an average yearly rainfall of 1200 mm (City of uMhlathuze, 2017 and Burger, 2008).

Commissioned in 1976 (Richards Bay, 2016), Port of Richards Bay has stimulated the establishment of several industries in Richards Bay including Foskor (Pty) Ltd, Richards Bay Coal Terminal and Richards Bay Minerals (RBM). These companies are associated with mined minerals such as rock phosphate, coal and heavy minerals, respectively. Richards Bay Minerals (RBM) produces about 2.0 million metric tons of heavy minerals annually and approximately 95 percent of the products are exported (Williams & Steenkamp, 2006). The other major company, Richards Bay Coal Terminal (RBCT), opened in 1976 with an original capacity of 12 million tons per annum and is one of the leading coal export terminals in the world (RBCT, 2017). Exportation of coal has been increasing annually up to 71.4 million metric tons in 2014 (Export RBCT, 2015).

The rock phosphate storage facility at Richards Bay currently has a capacity of about 80,000 tons (Foskor, 2012). Foskor Phalaborwa mine rock phosphate from Phalaborwa in Limpopo province of South Africa and transport this by rail about 770 km to Richards Bay where they are stored for use as raw materials by Foskor acid division in Richards Bay or for export via the port of Richards Bay (Foskor, 2012). In 2016, 1.1 million tons of rock phosphate was railed to the Acid Division while about 336,726 tons were exported (Foskor, 2016). Foskor acid division in Richards Bay undertakes the beneficiation of phosphate rock into sulphuric acid (H_2SO_4) and phosphoric acid (P_2O_5) as well as phosphate based granular fertilizers (Foskor, 2017). At full capacity, Foskor acid division can produce 2.2 million tons of H_2SO_4, 720,000 tons of P_2O_5 and 300,000 tons of fertilizer per annum (Foskor, 2017). The GPS coordinates of each sampling site as recorded was used to plot a map of this study area as shown in Fig. 1.

2.2. Sample collection

A total of 90 soil samples were collected from 30 sampling sites see Fig. 1. The sampling areas were grouped into three; the coal area (4 sampling positions), the rock phosphate storage area (17 sampling position) and undisturbed area referred to as the control area (9 sampling position) ranging from about 1.1 km to about 4.5 km away from the rock phosphate storage area. Over 50% of soil samples studied were collected around the rock phosphate storage area because it is the area of interest for this study. The distance of the control area from the rock phosphate storage area range from about

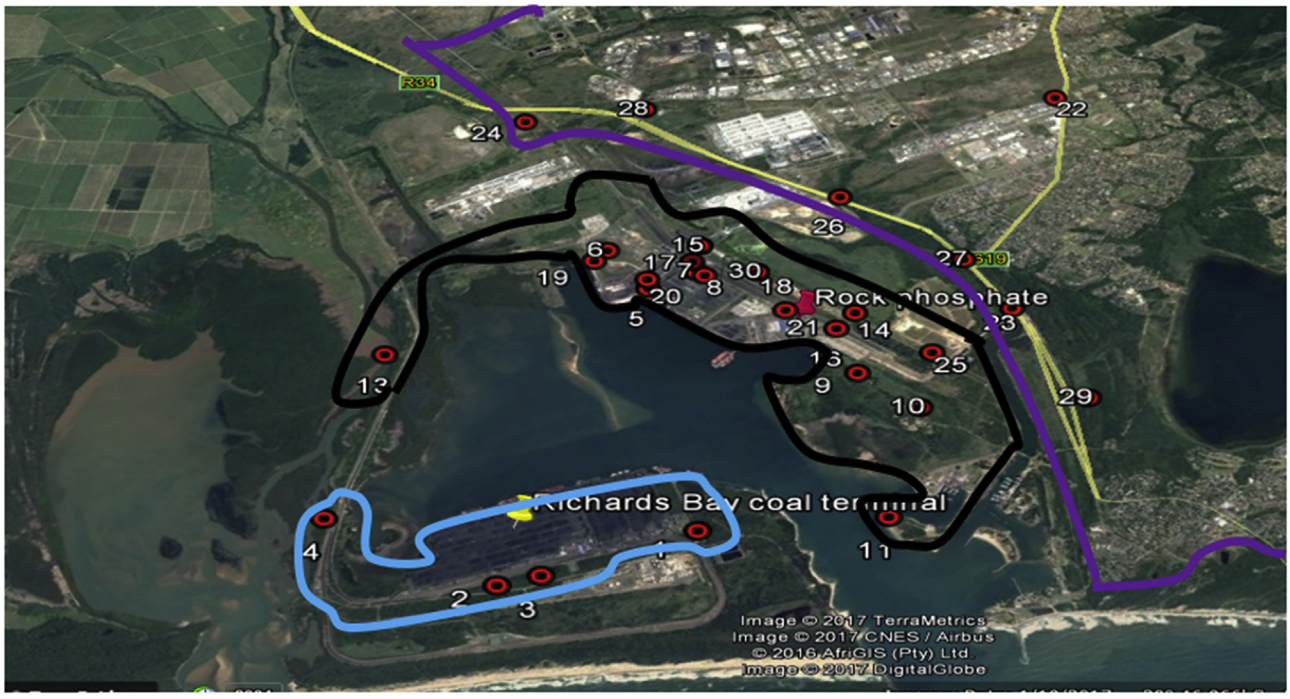

Figure 1. Map of study area showing; sampling sites (red colour), John ross high way (yellow colour)

Fig. 1. Map of study area showing; sampling sites (red colour), John ross high way (yellow colour).
sampling site coal area Rock phosphate area Control area National road.