Journal of King Saud University – Science (2017) **29**, 174–181

King Saud University
Journal of King Saud University – Science
www.ksu.edu.sa
www.sciencedirect.com

ORIGINAL ARTICLE

Radioactivity of ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs in beach sand and sediment near to desalination plant in eastern Saudi Arabia: Assessment of radiological impacts

Fatimh Alshahri

Department of Physics, College of Science, University of Dammam, Dammam 1982-31441, Saudi Arabia

Received 26 February 2016; accepted 16 August 2016
Available online 21 August 2016

KEYWORDS

Natural radionuclides;
^{137}Cs;
Sand;
Sediment;
Desalination plant;
Saudi Arabia

Abstract Sand and sediment samples were collected from different locations along the beach near to desalination plant, which is one of the oldest and largest reverse osmosis desalination plants in Saudi Arabia, where the fluid waste is discharged. The activity concentrations of ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs were measured using gamma-ray spectrometry. Radiation hazard indices were calculated to evaluate the radiological risk for the public and environment. This study is the first to evaluate the radiological impacts in the area under investigation. The mean values of radium equivalent activity (Ra_{eq}) were 74.1 Bq kg^{-1} for surface sand samples, 78.8 Bq kg^{-1} for subsurface sand samples and 78.1 Bq kg^{-1} for sediments. The mean values of gamma absorbed dose rate (D) in air and annual effective dose (E) for analyzed samples were lower than the acceptable values. The external radiation hazard indices were lower than unity for all samples.

1. Introduction

Desalination of sea or ocean water is a widespread technology used in many countries around the world. The desalination process is one of mankind's earliest designs to separate fresh water from a salt-water solution (Einav et al., 2002). Desalination involves several processes to remove the excess salt and other minerals from the water to obtain potable water for human usage.

Essentially, a desalination plant is a system to separate saline water into two streams: one with a low concentration of dissolved salts and inorganic materials and the other containing the remaining dissolved salts (brine). The amount of flow

Abbreviations: MDA, minimum detectable activity; UNSCEAR, United Nations Scientific Committee on the Effects of Atomic Radiation; WHO, World Health Organization.

E-mail address: faalshehri@uod.edu.sa

Peer review under responsibility of King Saud University.

ELSEVIER Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.jksus.2016.08.005

discharged to waste as a brine discharge varies from 20 to 70 percent of the feed flow, depending on the technology used in the plant. Brine discharge is the fluid waste from a desalination plant, which contains a high percentage of salt and dissolved minerals (Mohamed et al., 2005). The brine returns to the sea and spreads according to different aspects (wind direction, wave height and tidal). Desalination plants could have several impacts on the surrounding environment. The major concern of these impacts near the outfall brine discharge due to its physical and chemical features (Younos, 2005; Abdul-Wahab, 2007; WHO, 2007).

Radiation and radioactivity in the environment have natural and man-made sources. Exposure to natural radiation represents the most significant part of the total exposure to radiation in the environment (Saleh, 2012; UNSCEAR, 2008). Only natural radionuclides with half-lives comparable with the age of the earth or their corresponding decay products existing in terrestrial material such as ^{232}Th, ^{238}U, ^{235}U, ^{226}Ra, ^{228}Ra and ^{40}K are of great interest. The levels of these radionuclides are relatively distributed in soil based on the nature of its geological formations (Al-Jundi et al., 2003; Orabi et al., 2006).

The Residual Saline Stream contains a range of contaminants, including naturally occurring radioactive materials (NORMs) that may increase the natural radioactivity levels along the shore line. Treatment processes such as dewatering, ion exchange, reverse osmosis, and other volume reduction may concentrate radionuclides to a level of concern (Hamidalddin, 2013). Long-lived radioactive elements such as uranium, thorium and potassium and any of their decay products, (e.g., radium and radon), are examples of NORM. These elements have always been present in the earth's crust and atmosphere. The ^{238}U series decay via a chain containing eight alpha decays and six beta decays to ^{206}Pb (Hamdy et al., 2007; Ahmed and El-Arabi, 2005; UNSCEAR, 1993, 2008).

The radiological impact from the natural radioactivity is due to radiation exposure of the body by gamma-rays and irradiation of lung tissues from the inhalation of radon and its progeny. From the natural risk point of view, it is necessary to know the dose limits of public exposure and to measure the natural environmental radiation level provided by ground, air, water, foods, building interiors, etc., to estimate human exposure to natural radiation sources (Akhtar and Tufail, 2011; El-Taher, 2010). Many studies have been conducted on the concentrations of natural radionuclides in the marine environment in different regions around the world (Price et al., 1998; Higgy, 1999; Sroor et al., 2001; Santawamaitre et al., 2011; Hamzah et al., 2011; Obhodas et al., 2012).

Saudi Arabia is the world's largest producer of desalinated seawater. The Saline Water Conversion Office (SWCO) constructed twenty-four desalination plants along the Saudi Arabian coasts, including the twelve major plants on the western coast on the Red Sea and another three on the eastern coast on the Arabian Gulf. The major three desalination plants in Saudi Arabia are Al-Jubail and Al-Khobar plants on the Arabian Gulf coast and Shoaiba plant on the Red Sea coast.

Al-Khobar desalination plant is located near an important beach, which is situated in the eastern region of Saudi Arabia. This beach is constantly frequented by the general population and many fishermen. In addition, a large number of palm trees spread along the beach. Therefore, this investigation aims to determine radionuclide levels along the beach near to desalination plant where the fluid waste is discharged and evaluate the radiation hazard indexes due to the radionuclides in the beach sand and sediment to identify the area that may be hazardous for public. In addition, these data will be useful for subsequent evaluations of possible future environmental contamination due to non-nuclear industries or any future activities.

2. Materials and methods

2.1. Samples collection and preparation

Thirty-six beach sand and sediments samples were collected from different locations along the beach near the desalination plant with a length interval of 6500 m (Fig. 1). Twenty-four sand samples were collected at 2 m from the shoreline. These samples were taken from surface and subsurface (10–30 cm). From the same locations, 12 sediment samples were collected from seawater at 2 m from the shoreline. Samples were bulked as a single sample and dried in an oven at 70 °C for 24 h. After that, samples were prepared for radiation counting by sieving through 2 mm mesh. Each sample was packed into 152 ml standard size beakers and tightly sealed and stored for 28 days to acquire secular equilibrium between ^{226}Ra and its progenies. Two reference materials were packed into the same standard size beakers for efficiency calibration.

2.2. Experimental setup

A hyper-pure Germanium detector (HPGe), coaxial type, p-type with relative efficiency of 20% was used. The detector is shielded with a low-level background lead shield. The HPGe was calibrated for efficiency using the reference material RGU-1 from IAEA. The certified activity of uranium is 400 ppm which is equivalent to 4960 Bq kg^{-1}. The energy transitions of the ^{226}Ra daughters (^{214}Pb and ^{214}Bi) were used to develop the efficiency calibration curve. A fourth degree polynomial fitting was performed to reach the best R^2 value ($\approx$0.976).

2.3. Gamma-spectrometric analysis

After subtracting the background, the radionuclides were measured at the gamma lines (Table 1). ^{226}Ra was measured using its progenies ^{214}Pb with energies 295.2 keV (19.3%) and 351.93 keV (37.6%), and ^{214}Bi with energies 609.31 keV (46.1%), 1120.29 keV (15.1%) and 1764.49 keV (15.4%). Radium was determined based on the above mentioned energy transitions after achieving secular equilibrium for 28 days after sample packing. For ^{232}Th, the specific activity concentration was determined using the gamma lines 338.40 keV (12.4%) and 911.07 keV (25.8%) for ^{228}Ac and 583.14 keV (33.1%) for ^{208}Tl. The average values were calculated. In the case of ^{40}K and ^{137}Cs, the specific activity concentrations were estimated directly by their gamma lines of 1460.75 keV (10.7%) and 661.7 keV (85.12%), respectively.

The software used for analysis and reduction of the gamma-ray spectra was Quantum Gold, Version 4.04.00.

The minimum detectable activity (MDA) for each isotope (^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs) in the background was calculated