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Transfer factors for natural radioactivity into date palm pits

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ABSTRACT

Palm pits are used in various human and animal feed products. In this study, the natural radioactivity levels from soil and date palm pits of 9 samples collected from major date palm farms in three different regions (Buraidah, Al-Zulfi and Al-Majmaah) of Saudi Arabia were determined by using the high purity germanium (HPGe) gamma-ray spectrometer. The mean activity concentrations of ^{226}Ra, ^{232}Th, ^{137}Cs and ^{40}K in soil samples were 12.8 ± 2.2, 10.2 ± 2.1, 0.28 ± 0.10 and 329 ± 87 Bq kg^{-1}, respectively. Similarly the mean activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in date palm pits were 5.6 ± 1.2, 2.8 ± 0.4 and 181 ± 17 Bq kg^{-1}, respectively, whereas ^{137}Cs could not be detected. The geometric mean of TF values (geometric standard deviation in parentheses) of ^{226}Ra, ^{232}Th, and ^{40}K were 0.33 (2.1), 0.22 (1.8) and 0.51 (2.0), respectively.

1. Introduction

Date palm (*Phoenix dactylifera* L.) is a widely consumed fruit throughout the world. In Saudi Arabia, there are many farms of date palm, producing dates for internal consumption and for export. As per report of the Food Authorization Organization (FAO) of United Nations (UN), the mass production of dates world-wide was up to 7.2 million tons in 2010, while annual production of date palm pits was approximately 720,000 tons by considering approximately 10% of total date fruits (FAO, 2011). Generally, date fruit mainly consists of proteins (2.1–3%), fats (2–3.2%), ash (2.5%), dietary fibers (14–18%) and carbohydrates (73–79%), but concentrations of these components depend on the variety of the date fruits (Al-Farsi et al., 2007). Date palm pit is composed of several important minerals such as Ca, Fe, Mg, Na, K and P (Hamada et al., 2002; Ali-Mohamed and Khamis, 2004; Besbes et al., 2004; Al-Farsi et al., 2007; Habib and Ibrahim, 2009; Nehdi et al., 2010). The animals in Middle East occasionally eat the date palm pits resulting significant ingestion of tannins, resistant starches and natural anabolic agents (Elgasim et al., 1995). Date palm pits are also used in broiler starter diets at the level ranging from 5 to 27% (Vandepopuliere et al., 1995). In Arab countries, caffeine-free coffee (plain or mixed) is made from date palm pits by traditionally grinded and roasted them to a coffee color (Rahman et al., 2007). The date palm pits are also used in the formation of oil which has many applications, especially in cosmetic products, biodiesel, soap, cooking oil, nutritional food and diet supplements (Abdul Afiq et al., 2013). Thus it is important to investigate the levels of radioactivity in date palm pits.

Radioactivity has everywhere in our environment due to the occurrence of primordial (^{238}U, ^{232}Th & ^{40}K), cosmogenic (^{7}Be) and anthropogenic (^{137}Cs) radionuclides (UNSCEAR, 2000). The impact of naturally occurring radioactive materials (e.g. soil, rock, sand, water, etc.) pose the significant radiological hazards under the certain conditions (UNSCEAR, 2000). The quantity of primordial radionuclides depends on the geological and geographical formations of naturally occurring radioactive materials (Dragovic et al., 2014; Harb et al., 2012). The transfer factor (TF) from soil-to-plant is a fundamental parameter that has been used to investigate the levels of radionuclides in the food chain which can provide the baseline data to prevent the excessive build-up of radionuclides in the human body through the consumption of food chain. Humans are eating the edible parts of crops and ultimately, they are also carrying primordial radionuclides within their bodies (Hutchison and Hutchison, 1997). The important minerals along with radionuclides may be absorbed from the soil through plant roots and

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transferred to the other parts of plant. Thus, it is very important to assess the quantity of radionuclides in the food chain by estimating the average values of soil-to-plant TF.

In this work, the activity concentrations of primordial radionuclides (^{226}Ra, ^{232}Th and ^{40}K) and anthropogenic radionuclide (^{137}Cs) in soil and date palm pits were measured using an HPGe gamma-ray spectrometer. The TFs from soil-to-date palm pits were estimated.

2. Materials and methods

2.1. Geography and geology of study areas

This study has been conducted at different locations in three districts (Buraidah, Al-Zulfi and Al-Majmaah) of Saudi Arabia. Buraidah (Latitude: 26°20′00″N & Longitude: 43°58′00″E) is the capital city of Al-Qassim region and it has typical desert climate with hot summers, cold winters and low humidity. It has population more than 0.5 million in 2010 and the mean of total rain fall in Buraidah was 12.14 mm from 1982 to 2011 (https://en.wikipedia.org/wiki/Buraidah). Buraidah is located on the border of mostly dry and partly blocked by encroaching sand dunes, so called Wadi Al-Rummah. Buraidah is located around 170 km from Al-Majmaah and 120 km from Al-Zulfi. In Buraidah, the most common or modern economical production sources are the dates, wheat, lemons, orange and other fruits. The geology of Buraidah consists of the Cambrian sedimentary rocks of the Tabuk formation which consist of micaceous silty sandstone (red to pink in colors) (Al-Refeai and Al-Ghamdy, 1994).

Al-Zulfi (Latitude: 26°17′00″N & Longitude: 44°48′00″E) is a city in the Riyadh province and it lies in northern central region of Najad. Al-Zulfi is surrounded with large sand dunes (Al-Thoyr sand formation) and its climate as compared to Buraidah and Al-Majmaah is extremely hot in summer, relatively cool in winters and low humidity throughout the year. Al-Zulfi has the population more than 50,000. Al-Zulfi is located around 270 km from the Riyadh province and 225 km from Al-Qassim. There are also so many farms of date palm which has been a good source of income.

Al-Majmaah (Latitude: 25°54′14″N & Longitude: 45°20′44″E) is the capital city of Sudair region in the Riyadh province and it has arid desert climate. Al-Majmaah has population more than 50,000 and it consists of dry river beds and loose gravel of sand dunes. (https://en.wikipedia.org/wiki/Al_Majma%27ah). Al-Majmaah is located around 200 km from the Riyadh province and 80 km from Al-Zulfi. Al-Majmaah becomes the greenish city in spring season which makes it a national destination. In Al-Majmaah, there are many farms of date palm but other fruits can grow there such as citrus and berry.

The geology of Al-Zulfi and Al-Majmaah districts consists of a large basin with a steep escarpment to east and sand dunes to west. The large basin contains the gravel, silt and sand deposits of Quaternary age underlain with highly weathered clayey green shales of Dhurma formation (Al-Refeai and Al-Ghamdy, 1994).

2.2. Sample collection and preparation

The soil samples at the depth of 20 cm and date palm pits were collected from the major date palm farms located in three different districts (Buraidah, Al-Zulfi and Al-Majmaah) of Saudi Arabia. Additionally, the study areas have similar geological formations. The sampling locations of soil and date palm are presented in Table 1. After the collection of date palm pits samples, they were crushed by compact FRITSCH jaw crusher (PULVERISETTE 1 classic line) and made into a fine powder through a chopper grinder machine. Soil and date palm pits samples were sieved up to grain size ≤1 mm by using variable amplitude test sieve shaker (octagon digital). After that the samples were dried in annealing furnace at 105 °C for 24 h until the sample weight became constant (Benke and Kearfott, 1999). The mass (~1 kg) of dry soil and date palm pits samples were weighted by digital weight balance and then the samples were sealed in 500 mL Marinelli beakers (541G-E, GA-MA & ASSOCIATES, Inc.). Finally, the samples were stored for 4 weeks to bring radon (^{222}Rn) and its short-lived most abundant daughter products into secular equilibrium with radium (^{226}Ra) (ASTM, 1986). For the energy and efficiency calibrations of the detector system, mixed radionuclides source 'soil−375' (a certified reference material source from IAEA) in 500 mL Marinelli beaker also was used for the measurement of gamma-rays.

Table 1
Location of collected samples (soil and date palm pits) along with their latitude and longitude.

Sample ID	Location	Latitude	Longitude
1 A	Buraidah	26°18′11.5″N	43°58′41.0″E
2 A	Buraidah	26°23′15.6″N	44°13′33.8″E
3 A	Buraidah	26°12′20.5″N	44°58′00″E
1 B	Al-Zulfi	26°23′06.3″N	44°42′46.1″E
2 B	Al-Zulfi	26°19′19.9″N	44°48′26.0″E
3 B	Al-Zulfi	26°16′13.5″N	44°44′24.7″E
1 C	Al-Majmaah	25°52′52.1″N	45°18′12.1″E
2 C	Al-Majmaah	25°53′54.0″N	45°19′41.3″E
3 C	Al-Majmaah	25°44′58.3″N	45°16′38.9″E

2.3. Activity concentration measurements (Bq kg^{-1})

The activity concentrations of ^{226}Ra, ^{232}Th, ^{137}Cs and ^{40}K in the samples of soil and date palm pits were measured with the help of high resolution gamma-ray spectrometry. The high resolution gamma-ray spectroscopy system consisted of an n-type coaxial high purity germanium (HPGe) detector (GMX80P4-95) with preamplifier, spectroscopy amplifier, ASPEC MCA (0–8192 channels) and a windows-operated computer loaded with gamma vision software version 7. In-order to reduce the thermally-induced leakage current, HPGe detector was cooled by X-COOLER™ III system (ORTEC). For the reduction of background radiations, the detector was placed in a cylindrical ORTEC shielding of 10.16 cm thickness of lead (Pb) with inner sheet lining of Cu (1.6 mm) and Sb (0.5 mm). The relative efficiency (with respect to 7.62 cm diameter × 7.62 cm long NaI (Tl) scintillation detector) of the detector was 85% at 1332 keV of ^{60}Co source with peak to Compton ratio 63:1 and its resolutions (FWHM) were 746 eV at 5.9 keV of ^{55}Fe source and 2.2 keV at 1332 keV of ^{60}Co source. As a matter of routine practice, the HPGe detector was calibrated with disc shape standard sources at distance 20 cm for 1000 min. For the measurements of background spectrum, an empty Marinelli beaker (500 mL) was kept over the detector for 24 h. The spectrum of IAEA mixed radionuclides source (Soil-375 used as a reference material) in 500 mL Marinelli beaker was collected for 19 h and net counts under the area of photo-peaks were measured for the measurements of photo-peak efficiency of selected radionuclides of different energies of gamma-rays.

The activity concentrations of ^{226}Ra and ^{232}Th in soil or date palm pits samples were measured through the average activity concentrations of their most abundant short-lived daughter products. The gamma-ray lines of ^{214}Pb (241.98, 295.21 and 351.92 keV) and ^{214}Bi (609.92, 1120.287 and 1764.49 keV) were used for the measurement of the activity concentration of ^{226}Ra whereas the gamma-ray lines of ^{212}Pb (238.63 keV), ^{228}Ac (338.32, 463.1, 911.02, 964.64 and 969.11 keV), ^{212}Bi (727.33 keV) and ^{208}Tl (583.19 and 860.56 keV) were used for the measurement of the activity

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