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Natural radioelement concentrations in fertilizers and the soil of the Mila region of Algeria

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ABSTRACT

The addition of inorganic fertilizers to treat crop soil and increase its production has become a necessity and a tool used around the world. These fertilizers contain different quantities of uranium and thorium. Therefore, tons of radionuclides from natural radioactive series ^{238}U, ^{235}U and ^{232}Th are dispersed in the environment due to a high use of fertilizer in agriculture. In this work, the radioactivity levels were determined in two fertilizers and in fertilized and unfertilized soil samples collected at various depths from the Algerian agricultural region of El-Athmania Mila, using high resolution gamma ray spectroscopy. The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K for fertilized and unfertilized soil samples were found unchanged as a function of depth and ranged from 23.72 ± 2.37 to 65.47 ± 5.06 $Bq.Kg^{-1}$; 32.48 ± 9.84 to 49.83 ± 5.31 $Bq.Kg^{-1}$ for ^{226}Ra, from 26.45 ± 0.78 to 27.10 ± 0.80 $Bq.Kg^{-1}$; 27.56 ± 0.75 to 28.70 ± 0.90 $Bq.Kg^{-1}$ for ^{232}Th and from 220.80 ± 10.01 to 260.70 ± 8.24 $Bq.Kg^{-1}$; 283.50 ± 8.41 to 290.10 ± 10.50 $Bq.Kg^{-1}$ for ^{40}K respectively. The presence of $^{137}Cs$is found in all measured samples and its average activity for all soil samples was 3.12 ± 0.13 $Bq.Kg^{-1}$. To assess the radiological hazard, the radiation equivalent activity (Ra_{eq}), the representative level index ($I_{\gamma r}$), the external hazard (H_{ex}), the internal hazard (H_{in}) and the absorbed dose rate due to three primordial radionuclides for soil samples were calculated. The measured values were compared with the published data in different countries and were found to be safe for the public and the environment.

1. Introduction

People are exposed to ionizing radiation from the radionuclides that are present in different types of natural sources (Ghosh, Deb, Bera, Sengupta, & Patra, 2008), of which soil is one of the most important one, Hence, they can be exposed to radiation either externally by a close source of radiation or internally by radioactive material that has entered the body. Soil not only acts as a source of continuous radiation exposure to humans but also as a medium of migration for transfer of radionuclides to biological systems (Senthilkumar & Narayanaswamy, 2016), which can cause harmful biological effects such as DNA damage and cancer.

At present, studies of health effects due to ionizing radiations have provided substantial evidences that exposure to a high level of radiations can cause illness or even death. Despite a well-known effect of cancer, scientists have long known that ionizing radiations with high doses may also cause mental retardations in the children of mothers exposed to radiations during the pregnancy period (Rafik et al., 2014).

All types of food including wheat and apples contain a detectable amount of radioactivity which successively relocates into the human body via the ingestion pathway. We know also, that the activity of food is strictly linked to the activity of the soil where the food was grown. Among various earth samples, the soils of wheat and apples have been chosen for radioactivity studies because these crops are very widespread. The natural radionuclides present in soil and fertilizers consist mainly of ^{238}U, ^{232}Th isotopes, along with their daughter products, and ^{40}K.

Knowledge of the concentration and the distribution of the radionuclides in these materials is very important because they provide useful information for the monitoring of environmental contamination by natural radioactivity (Ahmed & El-Arabi, 2005).

The uptake and distribution of radionuclides in soil depends on

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several factors such as soil pH, type and amount of clay, exchangeable Ca and K and organic matter contents, physico-chemical properties of the radionuclide, type of crop (crop species and variety, and cultural practices), fertilizer application, irrigation, plowing, liming and climate conditions (Asaduzzaman, Khandaker, & Amin, 2015). In order to reach high agricultural productivity, the present practice of replacing nutrients in soils is by supplying substances and this is done by the application of chemical fertilizers, mostly compounds commercially named MAP (Mono Ammonium Phosphate) and Urea (46 % Urea Nitrogen). Relatively large concentrations of natural radionuclides present in phosphate fertilizers contaminate the environment and agricultural lands during cultivation (Chauhan, Chauhan, & Gupta, 2013). Exposure of workers and the public to radiation from phosphate rock and fertilizer is therefore not unlikely (Scholten & Timmermans, 1995) because application of fertilizers, particularly phosphates, significantly increases the level of radioactive activity of the cultivated soil compared to the soil of the arid land (Ahmed & El-Arabi, 2005). Many researchers have found the high value of radionuclide content in fertilizers, especially phosphates produced from phosphate fertilizers (Chauhan et al., 2013); (Khater & AL-Sewaidan, 2008) (Kumar & Chauhan, 2014); rich in uranium-238 (Asaduzzaman et al., 2015).

Currently, there is not much information on radioactivity levels in the agricultural environment in Algeria, there is only a limited number of studies which evaluate soil radioactivity, including the Mila region. The basic studies of radioactivity in the agricultural environment are: a measure of natural radionuclide concentrations in two phosphate ores of east Algeria (Lakehal, Ramdhane, & Boucenna, 2010) and evaluate of radioactivity level of virgin and fertilized soils which were collected from outlying Setif region (Algeria) and of phosphate fertilizers used in these areas (Boukhenfouf & boucenna, 2011).

For these reasons, we decided to measure the concentration of natural radionuclides in soil widely cultivated by wheat and apple trees collected from Mila area (Algeria) and fertilizers used for the soil and to determine the radium equivalent activity (Ra_{eq}), the representative level index $I_{\gamma r}$, the radiation hazard index (H_{ex} and H_{in}) and absorbed dose rate for the studied area. Comparison of the results obtained with those of national and world averages are presented and the studies of this sort are expected to serve as baseline data of natural radioactivity level and will be useful in assessing public doses.

2. Experimental procedures

2.1. Study area

Soil samples were collected from El Athmania Mila region in the northeast of Algeria. Mila province lies in the longitude of 6 16′ E and in the altitude of 36 27’ N. It covers an area of 9375 km^2 and has a population of 768419. Mila among the best producers of cereals across the national territory and several pilot farms of fruit trees. The region included in the present investigated as shown in Fig. 1.

2.2. Samples collection and preparation

In order to measure the natural radioactivity in uncultivated soil and in the soil planted with apples and wheat, eight soil samples were collected from the El Athmania agricultural region of Mila in Algeria. We took two samples of uncultivated soil, three samples of soil planted with wheat and three samples of soil planted with apples, at different depths ranging from 10 to 50 cm. The distance between the sites was 100 m. The planted sites were fertilized with

Fig. 1. Map of The investigation area.

the Cross Fertilizers MAP and the Cover Fertilizer Urea 46 % and the quantities used annually are about:

- 2 Quintals/hectare for Cross Fertilizers MAP (12 % Ammonia Nitrogen. 52 % phosphate pentoxide).
- 1.5 Quintals/hectare for Cover Fertilizer Urea 46 %(46 % Urea Nitrogen).

The material used for soil sampling: shovel, plastic bucket, boxes, pen or marker. The soil was collected in a clean plastic bucket and mixed well. Samples of 0.5 kg were ground, homogenized and sieved to have grains of 0.2 mm. They were dried for 48 h to ensure that the moisture is completely removed. Each sample was placed in a plastic box with a radius of 50 mm and a depth of 14 mm. Before making the gamma measurement, the boxes had remained hermetically sealed for four weeks, in order to establish radioactive secular equilibrium between the radionuclides with short half-lives. This step was necessary to ensure that radon gas is confined within the volume and that the daughter nuclei will also remain in the sample (Baykara and Doru, 2005).

2.3. Experimental setup

The measurement was carried out at the laboratory of low activities in Grenoble (LBA/LPSC) equipped with two low-noise HPGe detectors. Each detector is surrounded by two cm of archaeological lead exempt from natural radioactivity and 15 cm of purified lead. The two detectors and their shielding is positioned at the center of a cube with a dimension of two square meters on the side surfaces. Each face of the cube, with the exception of the ground, is in fact a liquid scintillation detector. These detectors act as a veto prohibiting the acquisition of data during the passage of a cosmic ray.

The energy calibration of the detectors was done using the europium-152 (^{152}Eu) multi gamma sources. The resolution of the detectors in these measurements was 0.85 keV and 1.85 keV at energies 122 keV ^{57}Co and 1332.5 keV ^{60}Co, respectively.

Calibration sources IAEA-RGU-1 and IAEA-RGTh-1 were prepared on behalf of the International Atomic Energy Agency by the