Journal of Radiation Research and Applied Sciences xxx (2017) 1–6

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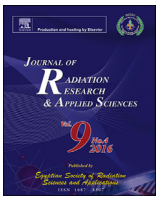
Journal of Radiation Research and Applied Sciences

journal homepage: http://www.elsevier.com/locate/jrras



Determination for levels of uranium and thorium in water along Oum Er-Rabia river using alpha track detectors

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ARTICLE INFO

Article history:
Received 11 March 2017
Received in revised form
2 May 2017
Accepted 6 May 2017
Available online xxx

Keywords:
Uranium
Thorium
Conductivity
Water
SSNTD

ABSTRACT

Different river water samples have been collected and analyzed from different locations along Oum Er-Rbia River in Morocco. The uranium and thorium concentrations were investigated in the studied river and dam water samples. Mean activity concentrations of uranium and thorium in water were found to be between 12 and 37 Bq.m^{-3} and 2−10 Bq.m^{-3}, respectively. The pH measured at all river water simples was slightly alkaline and ranged from 7.5 to 8.75. The electrical conductivity ranged from 2790 to 794 μS cm^{-1}. It was found that uranium and thorium concentrations were correlated with some chemical parameters in Oum Er-Rabia River water. Uranium and thorium measurements in this river are important for monitoring environmental radioactivity and to know the geochemical behaviour of these radionuclides in the surficial water bearing environments.

1. Introduction

The Oum Er-Rabia river is located in central of Morocco. It has a total length of 550 km with an average water debit of 105 m^3/s. It springs from the Middle Atlas, to 1800 m altitude, passing through the chain of the Middle Atlas, the Tadla plain, the Messeta area and discharging in the Atlantic Ocean in Azemmour city. Oum Er-Rbia is the second largest river in Morocco. Although not navigable, it is a perennially torrential river and a major source of hydroelectric power and irrigation. The basin has the largest number of dams among the Moroccan Basins. Oum Er-Rabia river runs on more than a dozen dams and a total storage capacity of 5.090 billion m^3. Water quality is one of the most important parameters of environmental studies. A large number of a few big cities in Morocco such as Beni Mellal, Khouribga, Oued Zem, El Jadida, Casablanca, Settat, and Berchid, etc use the water of Oum Er-Rabia river in their everyday life activities. Oum Er-Rabia River is used for drinking, washing, traditional fishing, irrigation, bathing, agro-food and other large manufacturing industries. In hydrological systems, this river flows through different geological materials (rocks and soils) that contain a high level of the solid radionuclides belonging to the ^{238}U and ^{232}Th series, which are the main radioactivity that could have a severe effect on human health (Marques, Santos, & Geraldo, 2004; UNSCEAR, 1993). The occurrence of radionuclides in natural waters supply (river, reservoir dams, wells and springs) depends, first of all, on the concentration and distribution of the parent element in the rock matrix; second, on the solubility of the parent element; third, on the solubility of the radionuclide itself; fourth, on the rate of release of the radionuclide by weathering (leaching) and by recoil relative to the rate of geochemical reactions controlling or limiting mobility and fifth, on the residence time of Oum Er-Rbia River's water. The global average concentration of Uranium in river water is about 0.3μg.L^{-1} (Langmuir, 1978; Palmer & Edmond, 1993). The World Health Organization (WHO) guidelines propose a limit of 2μg U/L for drinking water (WHO, 1996). The occurrence of radionuclides in river water gives rise to internal and external exposure, directly via the decay of radionuclides taken into the body through ingestion and inhalation and indirectly when they are incorporated as part of the food chain (Reimann & Banks, 2004). This makes it necessary to measure the radionuclide content of river water samples (Oum Er-Rabia river water) to assess potential radiation doses, focusing on investigating places of high levels and, if necessary, to take action to avoid the exposure of consumers to radiation. Oum Er-Rabia river was chosen because of the geological nature of river basin and because we find along the valley a series of dams, mostly equipped with water treatment plants to provide a

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Peer review under responsibility of The Egyptian Society of Radiation Sciences and Applications.

http://dx.doi.org/10.1016/j.jrras.2017.05.002

Please cite this article in press as: Amrane, M., & Oufni, L., Determination for levels of uranium and thorium in water along Oum Er-Rabia river using alpha track detectors, Journal of Radiation Research and Applied Sciences (2017), http://dx.doi.org/10.1016/j.jrras.2017.05.002

range of Moroccan cities with drinkable water and other uses. In this study, the main aim is to systematically study the distribution and migration of the naturally occurring radionuclides, ^{238}U and ^{232}Th, in the Oum Er-Rabia river water by using CR-39 and LR-115 type II Solid State Nuclear Track Detectors, SSNTDs, for detecting alpha-particles emitted by the uranium and thorium families and exploiting the corresponding track densities for evaluating uranium and thorium concentrations. The passive method using (SSNTD) technique is widely used to measure radon, uranium and thorium concentrations, and has been well documented, and has found large application (Moharram, Suliman, Zahran, Shennawy, & El Sayed, 2012; Oufni, 2003; Oufni, Ta, Manaut, & Eddouks, 2011; Raj Prakash, SanjeevVijay Kumar, Siddappa, Nayak, & Saxena, 2011). The relevant ranges of α-particles emitted by the uranium and thorium series in the studied water samples and SSNTDs were calculated by means of a TRIM program (Biersack & Ziegler, 1992). Some physicochemical parameters of the water of Oum Er-Rabia river (temperature, electrical conductivity and pH) were determined onsite using electronic probes and a portable multiparameter instrument.

2. Materials and methods

Measurements of uranium and thorium concentrations in water samples were made at 20 sampling locations collected from different sites along of Oum Er-Rabia river and various dams built-on this valley. A total of 60 water samples (five measurements for each sample) were collected from river waters and Dams reservoir in the second half of 2014 during spring when air temperature was not below 16 °C. The water samples were collected at around 10 a.m. When the samples were collected, the temperature of the water was between 20 and 29 °C. Water samples were collected in bottles at least 5 min after extracting water from the dam and river waters. Each water sample was separately placed in close contact with disk shaped Pershore Moldings CR-39 (500 mm thickness) and Kodak LR-115 type II (12 mm cellulose nitrate on 100 mm polyester base) SSNTD films in a hermetically sealed cylindrical plastic container for one month and a half (Fig. 1). During this exposure time, α-particles emitted by the nuclei of ^{238}U, ^{232}Th and their daughters inside the natural water samples bombard the SSNTD films. After the irradiation, the exposed SSNTDs were etched in two NaOH solutions: One was of 2.5 Normality at 60 °C during 2 h for the LR-115 II films and the other of 6.25 Normality at 70 °C for 7 h for the CR-39 detectors [12]. After chemical treatment, the track densities registered on the CR-39 and LR-115 II SSNTDs were determined by means of an optical microscope. Backgrounds on the CR-39 and LR-115 II SSNTDs were evaluated by placing these films in sealed plastic containers, containing ambient air, identical to those used for analyzing the water samples for one month and counting the resulting track densities. For the experimental etching conditions, the residual thickness of the LR-115 type II detectors measured by means of a mechanical comparator is 5μm. This thickness defines the lower (E_{min} = 1.6MeV) and upper (E_{max} = 4.7MeV) energy limits for registration of tracks of alpha-particles in LR-115 type II films.

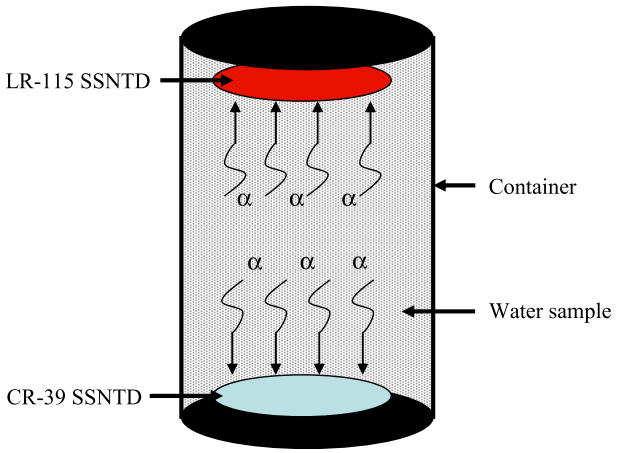

Fig. 1. Arrangement of the solid state nuclear track detectors on a studied sample in a cylindrical plastic container.

The global track density rates (tracks.cm^{-2}.s^{-1}), due to α-particles emitted by the uranium and thorium series inside the water sample, registered on the LR-115 II and CR-39 detectors, after subtracting the corresponding backgrounds, are respectively given by:

$$D_G(LR) = \frac{d_s}{4}\cos^2\theta'_c A_c(^{238}U)\Delta R_s\left[8 + 6\frac{A_c(^{232}Th)}{A_c(^{238}U)}\right] \quad (1)$$

and,

$$D_G(CR) = \frac{d_s}{4}\cos^2\theta_c A_c(^{238}U)\left[\sum_{i=1}^{8} k_i R_{i\alpha} + \frac{A_c(^{232}Th)}{A_c(^{238}U)}\sum_{i=1}^{7} k_i R_{i\alpha}\right] \quad (2)$$

where: $D_G(LR)$ and $D_G(CR)$ are the track density rates (tracks cm^{-2} s^{-1}) registered on the LR-115 type II and CR-39, $A_c(^{238}U)$ and $A_c(^{232}Th)$ are the uranium (^{238}U) and thorium (^{232}Th) α-activities (Bq.g^{-1}) inside the studied water sample, k_i is the branching ratio corresponding to the disintegration of the nuclei of uranium and thorium groups, $R_{i\alpha}$ is the range of α-particle of energy $E_{\alpha i}$ in the water sample and it is calculated by means of the TRIM program, d_s is the water density, θ'_c and θ_c are the critical angles of etching for the LR-115 type-II and CR-39 are respectively given by:

$$\cos\theta'_c = \frac{1}{1+\exp(-0.27R'_D + 3)} \quad (3)$$

and

$$\cos\theta_c = \frac{1}{11.6R_D^{-0.464}} \quad (4)$$

where: R'_D, R_D are the ranges of α-particles in LR-115-II and CR-39 SSNTD in μm. $\Delta R_S = R_{max}(E_{max}) - R_{min}(E_{min})$, R_{max} and R_{min} are the ranges of α-particles in the sample which corresponds to the energy windows E_{max} and E_{min} at the upper and lower ends, both of which are functions of the detector and critical angle.

Combining Eqs. (1) and (2), we obtain the following relationship between uranium-to-thorium ratios and track densities:

$$\frac{A_c(^{238}U)}{A_c(^{232}Th)} = \frac{\gamma\sum_{i=1}^{7} k_i R_{i\alpha} - 6\beta\Delta R_s}{8\beta\Delta R_s - \gamma\sum_{i=1}^{8} k_i R_{i\alpha}} \quad (5)$$

where: $\gamma = \frac{\cos^2\theta_c}{\cos^2\theta'_c}$ and $\beta = \frac{D_G(CR)}{D_G(LR)}$

From where one obtains the uranium activity given by:

$$A_c(^{238}U) = \frac{2D_G(LR)}{\Delta R_s d_s \cos^2\theta'_c\left[4 + 3\frac{A_c(^{232}Th)}{A_c(^{238}U)}\right]} \quad (6)$$

and therefore, we determine the thorium activity.

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