Available online at www.sciencedirect.com
SCIENCE DIRECT
ELSEVIER
Journal of Environmental Radioactivity 82 (2005) 371–381
JOURNAL OF ENVIRONMENTAL RADIOACTIVITY
www.elsevier.com/locate/jenvrad

Distribution of uranium and radium isotopes in an aquifer of a semi-arid region (Manouba-Essijoumi, Northern Tunisia)

A. Added[a,*], A. Ben Mammou[a], F. Fernex[b], S. Rezzoug[c], M. Bernat[b]

[a]*Département de Géologie, Faculté des Sciences de Tunis, Campus Universitaire, 1088 Tunis, Tunisia*
[b]*Département des Sciences de la Terre, Université de Nice, Valrose, F – 06108 – Nice Cedex 02, France*
[c]*Laboratoire de Radiochimie, Chimie analytique et Environnement, Université de Nice, Valrose, F – 06108 – Nice Cedex 02, France*

Received 6 July 2004; received in revised form 3 January 2005; accepted 3 February 2005

Abstract

Groundwaters from the Sebkhet Essijoumi drainage basin, situated in northern Tunisia, West of the city of Tunis, were sampled and analyzed for uranium and radium isotopes. Low $^{234}U/^{238}U$ activity ratios coupled with relatively high ^{228}Ra and ^{238}U concentrations were found in the Manouba plain phreatic aquifer, at the northern part of the basin, where remote sensing has indicated that this plain corresponds to the main humid zone of the area. Low $^{234}U/^{238}U$ ratios probably reflected short residence time for waters in the Manouba plain, and high ratios longer residence time in the south, where water reaching the phreatic aquifer seems to have previously circulated in rocks constituting the southern hills. Assuming that, in the Manouba plain aquifer, the groundwater flows downstream from the Oued Lill pass area to the South-West of the Sebkha, the difference in the $^{228}Ra/^{226}Ra$ activity ratio suggests that the residence time of water has been 2.8 years longer near the Sebkha than upstream.

Keywords: Uranium; Radium; Isotope ratios; Water residence time; Manouba aquifer; Northern Tunisia

* Corresponding author. Tel.: +216 885 408.

0265-931X/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jenvrad.2005.02.010

1. Introduction

Radionuclides of the U decay series in groundwaters received attention on the one hand in order to verify whether the resulting radioactivity may pose any hazard (ChruScielewsky and Kamit'lsky, 1999; Pietrzak-Flis et al., 2001; Hakam et al., 2001; Zhuo et al., 2001). On the other hand, several studies tried to describe the behavior of groundwater or detect the sources, using in particular the $^{234}U/^{238}U$ activity ratio, which has been found frequently to depart from secular equilibrium (Miekeley et al., 1992; Osmond and Cowart, 1992). As already documented by several authors, the relative contribution of mixing groundwater could be obtained by measuring the U concentrations and $^{234}U/^{238}U$ activity ratios, without need the knowledge of the flows of the contributors (Kronfeld and Adams, 1974; Osmond et al., 1974; Osmond and Cowart, 1992). In several cases, the ratio variations were not clearly related to residence time or environmental conditions. However, Osmond and Cowart (1992) and Ivanovich et al. (1991) explained that in deep aquifers, there is a redox front before which (in oxidizing conditions) water becomes more and more enriched with U and the $^{234}U/^{238}U$ ratio increases. Beyond the redox front, U concentration lowers, as well as the U activity ratio because of the ^{234}U excess decay. Fröhlich and Gellermann (1987) presented a model for the U isotopic composition along flow-paths, but, as they explained, groundwater dating requires homogeneous aquifers, and U residence times not much shorter than the ^{234}U half-life.

As regards to the Ra isotopes, only few works have focused on their significance as useful parameters to trace the groundwater Ra isotope behavior in groundwaters. Sturchio et al. (1993) used the $^{224}Ra/^{226}Ra$ ratios in their study of thermal waters at Yellowstone. Therefore, the short ^{224}Ra half-life (3.5 d) allowed the authors to evaluate to about 2 days, the time elapsed during travel from aquifer to spring. In the same way, Rihs and Condomines (2002), have measured high radium activities, in particular ^{226}Ra, up to 2300 Bq/l, in thermal waters from the Massive Central – France. Such a result clearly demonstrates that CO_2-rich waters enhance the Ra solubility.

In the present work, we focused our study on the distribution of ^{234}U, ^{238}U, ^{226}Ra and ^{228}Ra in water-wells from the Sebkha Essijoumi watershed (Fig. 1). On the basis of these data we intend to describe the behavior of waters in the phreatic aquifer.

2. Sampling and methods

2.1. Area of investigation

Manouba-Essijoumi watershed is located in Northeastern Tunisia, and in West of the city of Tunis. It covers a surface of 230 km^2 including Sebkhet Essijoumi (30–50 km^2) which constitutes the only natural discharge system for the basin and for the studied aquifer. In this zone, the watershed is bordered, eastward by a set of hills constituting the so-called «barrier of Tunis», northward by the crest line of two mountains (Jebel Ammar and Jebel Ennahli), westward by the crest line of Aïn El Krima mountain and southward by a mountain range including Jebel Sidi Salah, Jebel Nadhour and Jebel Mohsen.