Available online at www.sciencedirect.com
SCIENCE DIRECT®
Marine Environmental Research 60 (2005) 35–49
MARINE ENVIRONMENTAL RESEARCH
www.elsevier.com/locate/marenvrev

Measuring and modelling temporal trends of ^{226}Ra in waters of a Spanish estuary affected by the phosphate industry

R. Periáñez *

Dpto. Física Aplicada 1. EUITA, Universidad de Sevilla, Ctra Utrera km 1, 41013-Sevilla, Spain

Received in revised form 27 July 2004; accepted 16 August 2004

Abstract

The presence and temporal evolution (1990–2001) of ^{226}Ra in a tidal estuary affected by the phosphate industry has been investigated. Water samples collected in the course of four separate sampling campaigns were analysed for ^{226}Ra content using a gas flow proportional counter following Ba coprecipitation. Two ^{226}Ra sources have been identified: direct discharges from the industrial complex and run-off from a phosphogypsum pile. Although activity levels are similar, or even higher, than those found in other environments affected by the phosphate industry, there has been a general decrease in contamination since direct discharges ceased in 1998 due to new regulations from the EU. However, sediments are now acting as a source of Ra to the water column due to redissolution processes. A numerical model of the estuary has been developed to describe quantitatively the experimental results. The model solves the hydrodynamics and the dispersion equation of ^{226}Ra including interactions with sediments. Model results are, in general, in good agreement with observations.

Keywords: Radium; Odiel-Tinto estuary; Phosphogypsum; Numerical modelling; Hydrodynamic; Sediment

* Tel.: +34 954486474; fax: +34 954486436.
E-mail address: rperianez@us.es.

0141-1136/$ - see front matter © 2004 Elsevier Ltd. All rights reserved.
doi:10.1016/j.marenvres.2004.08.003

1. Introduction

The Odiel and Tinto rivers, in the southwest of Spain, form a fully mixed tidal estuary which surrounds the town of Huelva (Fig. 1). Both rivers join at the Punta del Sebo. From this point, they flow together to the Atlantic Ocean.

An industrial complex, containing a plant dedicated to the production of phosphoric acid and phosphate fertilizers, is located by the Odiel river. It is well known that the phosphate rock used as a raw material by this industry contains significant amounts of natural radionuclides, mostly U, Th and Ra. The industrial processing of the phosphate rock leads to a redistribution of radioactivity. For instance, during the wet process for phosphoric acid production, 86% of U and 70% of Th present in the rock are transferred to the phosphoric acid itself, while 80% of the Ra content follows the so-called phosphogypsum path (Guimond & Hardin, 1989). This is a form

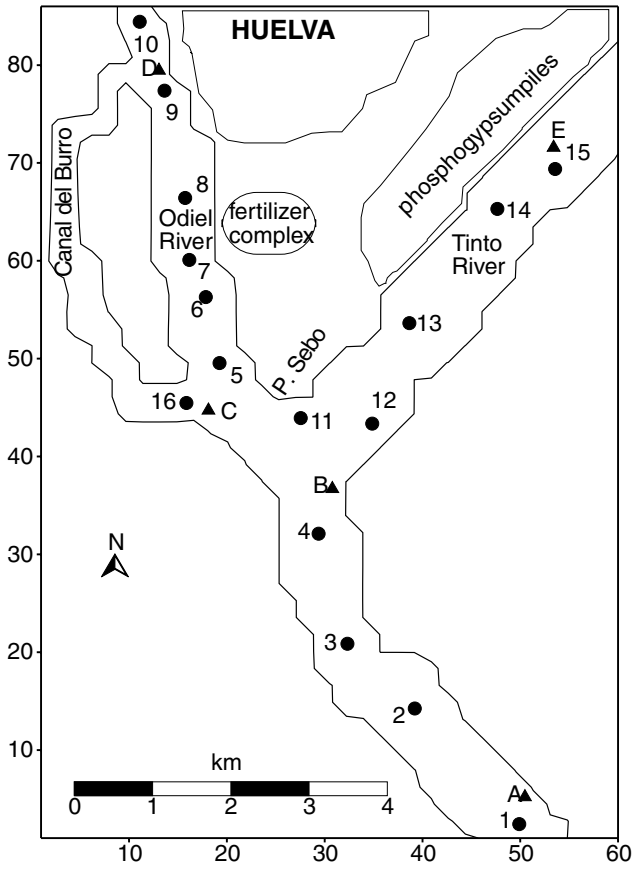

Fig. 1. Map of the area of the estuary covered by the model. Numbered circles indicate the points where water samples were collected. Lettered triangles indicate the points where currents measurements were available. Units on the axes give the grid cell number. The sea is approximately 1 km to the south of point 1.