Journal of Environmental Radioactivity 99 (2008) 1216–1223

Contents lists available at ScienceDirect

Journal of Environmental Radioactivity

journal homepage: www.elsevier.com/locate/jenvrad

Study of pollution in the El Jadida-Safi Atlantic coastal zone (Morocco) by using PIXE and SSNTD methods

H. Erramli [a,*], H.D. Gogon [a], M.A. Misdaq [a], T. Sauvage [b], C. Ramboz [c]

[a] Nuclear Physics and Techniques Laboratory, Faculty of Sciences Semlalia, University Cadi Ayyad, Avenue de Prince My Abdellah, BP. 2390, Marrakech, Morocco
[b] CNRS/CEMHTI, site cyclotron, 3A, rue de la Férollerie, F 45071 Orléans Cedex 2, France
[c] Institut des Sciences de la Terre d'Orléans (ISTO), CNRS-1A, rue de la Férollerie, F 45071 Orléans Cedex 2, France

ARTICLE INFO

Article history:
Received 16 October 2007
Received in revised form 17 January 2008
Accepted 8 February 2008
Available online 1 April 2008

Keywords:
PIXE
Heavy and light elements
Van De Graaff accelerator
SSNTD
Pollution
Phosphate industry wastes

ABSTRACT

In this work, PIXE experiments were performed for measuring heavy and light elements' (ranging from aluminium to lead) concentrations inside various polluted and unpolluted soils as well as liquid samples collected from different phosphate factory sewers in the El Jadida-Safi Atlantic coastal region (Morocco). In addition, uranium (^{238}U) and thorium (^{232}Th) contents were evaluated in the same samples studied by using CR-39 and LR-115 type II solid state nuclear track detectors (SSNTDs). The influence of the phosphate industry wastes on the concentrations of both radioactive and non-radioactive elements of the samples studied was investigated.

1. Introduction

The Moroccan Office Chérifien des Phosphates (OCP) is a national company in load of all phosphate products. It is the second phosphate productive enterprise in the world, very little after American IMC Agrico Co. (Group Freeport McMoran). Mining is carried out on three main sites: Khouribga, Gantour and Boucraâ. The centres of transformation of phosphate into phosphoric acid are established in the littoral industrial park of Jorf Lasfar and Safi. The OCP is by far the first world exporter of rough phosphates and phosphoric acid and one of the largest international suppliers of fertilizers such as triple superphosphate (TSP) and diammonium phosphate (DAP).

Internationally, interest of pollution in urban and global environments has increased significantly over the last decade (Cohen, 1998; USEPA Report, 1999). Physicists, geologists, archaeologists, art conservators and others have utilized many analytical techniques for the determination of the compositions of polluted samples in environment, soil, rocks and minerals, and they continue to investigate emerging technologies for their utility. Their interest arises from the fact that a geologist can deduce information about the physical and chemical conditions under which a material was formed and through which the material has existed, from knowledge of soil, rocks and minerals composition. Specific materials are defined by their major elements, but it is the amount and distribution of the minor or trace elements that are more indicative of the materials geochemical environment. Thus analytical techniques, with more indicative limits, are of interest. Proton induced X-ray emission (PIXE) analysis used for more than 30 years is a powerful yet non-destructive elemental analysis technique and is a promising tool for the study of trace element behaviour in a wide variety of materials (geological, archaeological, biological, …). The combination of a reasonable resolution of a few microns combined with a detection power in the ppm (10^{-6} g g^{-1}) range offers possibilities for trace element mapping giving insight in trace element composition. PIXE method has been widely used for trace elemental analysis since Johansson et al. (1970) achieved mass detection limits in the region of 10^{-12} g. The extensive literature on the subject includes several excellent review articles (Johansson and Johansson, 1976; Owers and Shalgosky, 1974).

In the present work, the PIXE and SSNTD methods were employed to measure heavy and light elements in various material samples collected from different sites of the El Jadida-Safi Atlantic coastal region (Morocco).

2. Experimental methods

Six solid samples (S1–S6) were collected from different sites in the El Jadida-Safi Atlantic coastal region (Morocco) (Fig. 1),

* Corresponding author. Tel.: +212 24 43 46 49; fax: +212 24 43 74 10.
E-mail addresses: hassane@ucam.ac.ma, erramli@yahoo.com (H. Erramli).

0265-931X/$ – see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jenvrad.2008.02.003

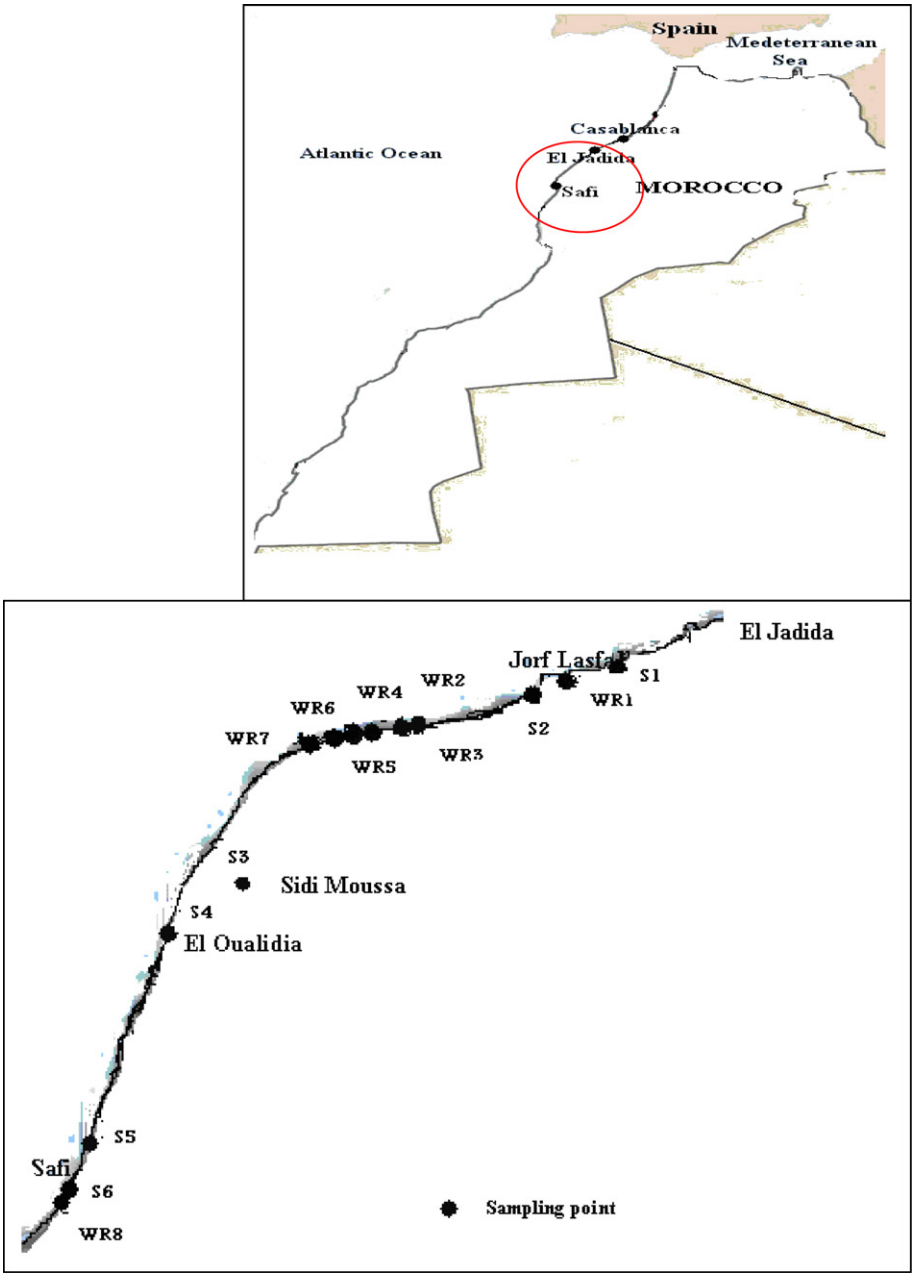

Fig. 1. The geographical situation of the study area.

pounded and homogenized. S1 was collected from a deposit of raw sulphur material in the Jorf Lasfar port, S2 and S6 were directly collected from two dumps of recent phosphate wastes resulting from the phosphate industrial activities in the study area, S3 and S4 were collected from the El Oualidia and Sidi Moussa agricultural zones and S5 was collected from the beach of the Safi city. Eight water samples were directly collected from the sewers of the phosphate factories situated in the same study area (Fig. 1) and filtered. The resulting residues "foams": WR1–WR8 were dried.

Almost 2 g of each soil and water residue sample were compacted in a pellet of 1.5 cm diameter and few mm thickness using a mechanical press. The obtained pellets were stuck on an aluminium disc. The prepared soil and water residue samples were then analysed by PIXE method. The PIXE experiments were performed at the CNRS/CEMHTI, Orléans, using a 3.5 MV HVEC Van De Graaff accelerator. The miniprobe focuses a 2.5 MeV proton beam to a target placed under vacuum (from 5×10^{-5} to 10^{-6} mbar). Detail descriptions have been reported previously by Zine et al. (1990) and Choï (1996). The X-ray Si(Li) detector (Oxford instruments) is installed at a 135° angle with respect to the beam axis and is 2.4 cm distant from the sample. This detector is characterized by a 30 mm^2 nominal surface area, a 3 mm nominal Si-crystal thickness and 7.5 μm-thick Be window. Its energy resolution at 5.9 keV is 148 eV. The dead time of the Si(Li) detector is of 25 μs. A 135 μm-thick Be-filter is placed in front of the detector to prevent interactions with scattered protons. A 200 μm thick Al-funny filters and bored of a hole of 0.77 mm are superimposed on the Be-filter in order to attenuate the characteristic X-rays from major elements, which would disturb the electronic detection, increase pulse pile-up on the spectra and obliterate X-rays of trace elements. A mirror, placed in front of the target, reflects the image of the beam impact on the target to endoscopes, which magnifies at 200× (Gama et al.,