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Contribution for tier 1 of the ecological risk assessment of Cunha Baixa uranium mine (Central Portugal): I Soil chemical characterization

R. Pereira, S.C. Antunes, S.M. Marques, F. Gonçalves*

CESAM (Centro de Estudos do Ambiente e do Mar) & Departamento de Biologia, Universidade de Aveiro, Campus de Santiago, 3810-193 Aveiro, Portugal

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ABSTRACT

Within the tier 1 of a site specific risk assessment, the pseudo-total concentrations (extracted with *aqua regia*) and the potential mobile fractions of metals were determined to perform a preliminary evaluation of risks posed by contaminated soils from an abandoned uranium mine (Mangualde, Central Portugal). Considering the mobile fractions of metals, extracted with artificial rain water, aluminium and uranium were the most concerning elements, since their concentrations were above soil quality criteria values (SQGVs) established for both elements. However, according to the evaluation based on potential mobile fractions of elements, rather than on pseudo-total metal concentrations the risks were limited to sites within the exploitation area, where contamination derives mainly from past *in-situ* leaching activities of pore ore as well as from the deposition of sludge from the effluent pond. The exclusion of other sites under evaluation, from the risk assessment process, requires additional data provided by soil screening ecotoxicological assays.

1. Introduction

In the last century 4370 tons of U_3O_8, radio salts and about 13 millions tons of different kinds of wastes (e.g. uranium mill and mine tailings, sludge from effluent treatment ponds) were produced in Portugal, mainly in the Centre but also in the North and Alentejo regions (Nero et al., 2003). Underground and open pit mining were the main techniques used as well as in situ-leaching to recover uranium from the poorest ore (Nero et al., 2003). In all places where uranium mining has occurred extensive environmental impact resulted, being this exploitation the most problematic of all the mining activities since radiological impacts occur jointly with chemical ones (Vandenhove et al., 2007). Therefore, tons of tailings, sludge from effluent treatment ponds and acid mine drainage effluents yielded by the *in situ*-leaching process still persist in all of these areas even after the exploitation has ceased.

The metal and radioelement contaminated solid residues scattered in these areas contribute to an extensive contamination of the soil compartment (mainly with U and its daughter radionuclides and metals such as Pb, Cd, Zn, Cu and Mn) posing serious risks to humans that use surrounding areas for agriculture purposes as well as to edaphic communities which are extremely important for the future recovery of the area. The retention function of these soils (i.e. the ability to reduce mobility and the bioavailability of contaminants) is probably compromised and this can contribute to the contamination of surface and groundwater resources (Clevenger, 1990; Gupta et al., 1996). As Baykara and Doğru (2006) observed, uranium and its daughter radionuclides seemed to easily move

* *Corresponding author*. Tel.: +351 234 370 788; fax: +351 234 372 587.
E-mail address: ruthp@ua.pt (R. Pereira).

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from soils to water sources, since high concentrations of uranium where recorded in soil samples collected in the surrounds of water resources with radium and radon concentrations. However, this mobility may vary strongly depending on soil type and physical and chemical properties, which make imperative a very precise knowledge of the soil environment of each site to understand this variability (Echevarria et al., 2001).

Within these scenarios, concerns about the exposure of local populations and subsequent health effects posed by abandoned uranium mines have legally imposed reclamation actions and priorities were defined mainly supported by the following criteria: i) the extent of chemical and radioactive contamination; ii) the geological risks; iii) the main uses of the water and soil resources by local populations and, also iv) the impacts on the landscape around the mined areas (Nero et al., 2003; Santos Oliveira et al., 2002). However, regarding environmental impacts, no ecotoxicological evaluation was performed and no data exist about the risks to natural local communities. This information would be helpful to determine the extension of these areas that needs to be reclaimed, probably reducing the costs of actions required and to monitor risk mitigation in the future. Additionally, it is important to recognize that the protection of human health can not be attained without the protection of natural resources. The soil, in particular, provides several services and products such as fibre and food. Furthermore, due to its ability to retain and concentrate chemicals, it protects the quality of water resources and maintains local and global environmental quality (Beck et al., 2005; O'Halloran, 2006; Römbke et al., 2005).

Hence, following the tiered approached of the U.K. framework for the Ecological Risk Assessment of contaminated sites (Weeks and Comber, 2005) this work is part of the tier 1 and it was undertaken to attain the following objectives: i) to perform a first evaluation of the chemical contamination and of the radioactivity of soils from the Cunha Baixa uranium mine (Mangualde, Central Portugal), one of the Portuguese uranium mining areas classified as requiring priority intervention; ii) to evaluate the influence of different soil chemical extractions on the assessment of risks of contaminated soils and, iii) to assess the potential mobility and bioavailability of soil chemical contaminants mediated by climatic factors such as rainfall.

The U.K. framework for ecological risk assessment of contaminated sites comprises a tiered scheme whose tier 1 includes a preliminary evaluation of risks based on the concentrations of contaminants of concern, recorded in the soil compartment (Weeks and Comber, 2005). These concentrations are compared with Soil Quality Guideline Values (SQGV) and potential risks are considered when these values are surpassed. However, it is always advisable, to reduce uncertainties, reinforce the evaluation based on chemical data with time and cost-effective ecotoxicological assays (Weeks and Comber, 2005).

2. Material and methods

2.1. *Study site*

Cunha Baixa uranium mine, located in the Centre of Portugal (Mangualde, Viseu district), in the watershed of the Rio Castelo (affluent of the Mondego River) (Fig. 1), exploited one of the main Portuguese uranium deposits between 1967 and 1993. Nowadays, the mining company, enforced by law, is mainly engaged in the neutralization of the acid mine effluent, that is still being produced as result of the *in situ* leaching of the ore, performed in the past, within the mine pit (Pedrosa and Martins, 1999; Machado, 1998; Santos Oliveira and Ávila, 1998). This acidic and heavy metal-contaminated effluent still contributes for the contamination of superficial waters and groundwater (Antunes et al., 2007a,b; Machado, 1998; Pedrosa and Martins, 1999; Santos Oliveira and Ávila, 1998). Sludge from the treatment pond is frequently spread in the mining area, which was also filled with pore ore in the past. Both residues still contribute for the contamination of local soils with a complex mixture of metals, mainly U, Zn and Cu (Santos Oliveira and Ávila, 1998).

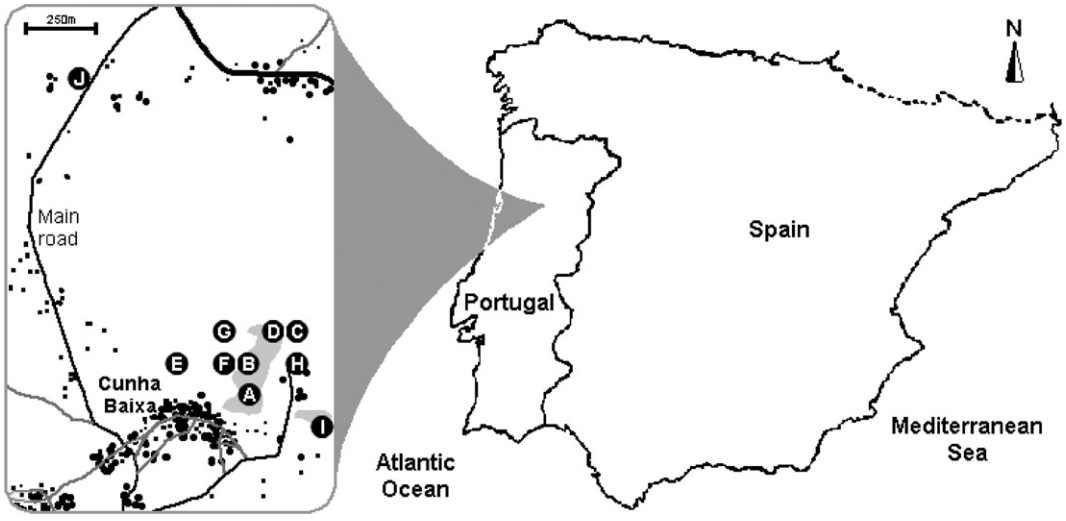

Fig. 1 – Cunha Baixa uranium mine geographical location and sampling sites distribution within the area under environmental risk assessment.