Topical Area 7 – Waste Management and Decommissioning

Suitable Areas for a Long-Term Radioactive Waste Storage Facility in Portugal

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Abstract

Radioactive wastes in Portugal result mainly from the application of radioactive materials in medicine, research, industry and from U-ores mining and milling activities. Sealed and unsealed sources (including liquid effluents and NORM) classified as radioactive wastes have been collected, segregated, conditioned and stored in the Portuguese Radioactive Waste Interim Storage Facility (PRWISF) since the sixties. The Radiological Protection and Nuclear Safety Department (DPRSN) of the Nuclear and Technological Institute (ITN) is responsible for the RWISF management, located nearby Lisbon (Sacavém). Despite recent improvements performed at RWISF, the 300 m^3 storage capacity will be soon used up if current average store-rate remains unaltered. Being aware of the tendency for radioactive waste production increase in Portugal and of the international rules and recommendations on disposal sites for this kind of wastes, it becomes clear that the PRWISF must be updated.

In this work, a first evaluation of suitable areas to host a long-term radioactive waste storage facility was carried out using a Geographic Information System (GIS) base. Preference and exclusionary criteria were applied, keeping constant the map scale (1:1000000). After processing exclusionary criteria, remaining areas were scored by overlaying three preference criteria. A composite score was determined for each polygon (problem solution) by summing the three preference criteria scores. The highest scores resulted from the combination of these criteria correspond to 4% of the territory, spatially distributed in seven of the eighteen Portuguese mainland administrative districts.

Work in progress will use this area as reference for site selection, criss-crossing appropriate criteria for scales ranging from 1:50000 to 1:25000.

INTRODUCTION

Radioactive wastes represent a source of ionizing radiation. Therefore, they must be managed in a careful and responsible way in order to reduce the associated risks to acceptable levels. According to the IAEA safety standards this implies that a radioactive waste management system must be implemented along with a national system of radiological protection, thus ensuring the fulfilment of fundamental safety measures in what concerns human health and environment. Universal principles and international requirements in radiological protection and radioactive waste management should therefore be considered for the setup of any radwaste management system.

Radioactive waste suitable for disposal in a near surface repository is characterized for having short-lived radionuclides and low concentrations of long-lived radionuclides [1]. Near surface facilities have been used to dispose this type of wastes in many countries all over the world, showing that this isolation practice can be regarded as a safe method to achieve the needed protection. In this short paper, the first outcomes of studies recently initiated to setup a new waste repository facility in Portugal (following the new safety requirements and considering the expected increase of radwaste production in the Country) are presented.

The system adopted in Portugal for the classification of radioactive waste is the one recommended by the European Commission [2] and comprises three categories: transitory waste, low and medium activity (short- and long-lived) and high activity waste. This categorization is presently used only by experts and technical staff directly dealing with this type of waste and is not yet in the Portuguese legislation. Nonetheless a legal definition of radioactive waste exists: "*…any material which contains or is contaminated by radionuclides and for which no use is foreseen*" [3].

Radioactive wastes produced in Portugal result mainly from the application of radioactive materials in medicine, industry, research, and contaminated or irradiated scrap metal. Radioactive wastes that cannot be disposed of, incinerated or left to decay by the producers, are transported to the DPRSN (*Radiological Protection and Nuclear Safety Department*) at ITN (*Nuclear Technological Institute*), conditioned and stored at the *Portuguese Radioactive Waste Interim Storage Facility* (PRWISF). This facility is located at Sacavém, nearby Lisbon.

All the sealed sources used in the Country are imported and a few of them returned to the manufacturer when become spent or disused. If that procedure can not be implemented, the sealed sources are transported to PRWISF, being subsequently conditioned and stored. The wastes are incorporated in a cement matrix inside a concrete drum according to the characteristics of the waste itself and of the future waste disposal site; the drums are arranged in grids regarding the radionuclide half-period ($T_{1/2}$) and grouped as follows: (i) $T_{1/2}$ up to 30 years; (ii) $30< T_{1/2} <100$ years; (iii) $100< T_{1/2} <1000$ years; (iv) $T_{1/2}>1000$ years. In order to optimize protection according to the Principles of Radiological Protection and the Principles of Radioactive Waste Management, waste drums are arranged in grids that were optimized by using a Monte Carlo simulation, the MCNPX code [4]. Up to now and concerning the management of spent or disused sealed sources, 140 drums containing mainly ^{60}Co, ^{137}Cs, ^{226}Ra, and ^{241}Am are stored in PRWISF. It is clear that the existent radwaste facility is almost up to its full capacity and that new and more astringent safety requirements will imply a more adequate facility in a different surrounding area. According to the IAEA Safety Requirements [1], three operational phases are associated with the lifetime of a near surface repository: pre-operational, operational and post-closure phases. The pre-operational phase includes the necessary sitting and design studies as well as the period of construction of the repository. At this point and in what concerns the future radioactive waste repository site, this specific phase is still in its first steps with the analysis of the possible available areas in order to choose, in a near future, the suitable site(s).

The characteristics of the repository to be developed depend, among other factors, on the radwastes characteristics. In the Portuguese case, the wastes of concern have short-lived radionuclides with low concentrations of long-lived radionuclides, NORM wastes from dismantling of non-nuclear industries, contaminated or irradiated scrap metal, spent and disused sealed sources. The disposal of radioactive wastes in a near surface repository is part of a practice as defined by ICRP and the Basic Safety Standards (BSS) [6]. Radiation protection considerations are based on the principles justification, optimisation and dose limitation and are fully applicable throughout the lifetime of the repository. The long-term safety of the repository is achieved through the combination of site characteristics, engineered design features, forms and content of the wastes, operating procedures and institutional controls. The primary objective of the repository is, basically, the isolation of the waste from the accessible environment. Other objectives such as the control of the radionuclides releases and the mitigation of the consequences of any acceptable releases should also be considered.

Safety assessment procedures, compliance with safety and quality assurance requirements for a near surface repository should be developed and analysed by an appropriate regulatory body in view of the potential radiological effects on human health and the environment during operation and in the post-closure phase. Waste acceptance requirements for the new facility should be generically specified by the regulatory body or developed by the operator (based on factors such as radiological criteria, the conditions of operation, the planned length of active institutional controls and the characteristics of natural and engineered systems) and then reviewed by the regulatory body. Characteristics of acceptable sites should provide for the isolation of waste and strong restriction of potential radionuclide release, technically ensuring that any possible effects for the biosphere that might arise from radwaste repository are within acceptable limits, thus fulfilling the overall safety objective.

METHODOLOGY

The IAEA recommendations [7] were followed in delimiting regions that include potential suitable areas for a near surface repository to receive low and intermediate radioactive wastes. A preliminary set of general criteria for site selection was considered (including geological, geophysical, biological (eco-systems distribution) and socio-economic parameters), integrating the available digital spatial databases for the Portugal mainland territory. In this context, a multi-step approach was developed making use of the Geographic Information System (GIS – ArcMap 9.1 from ESRI®):

1) Exclusion of areas that correspond to protected lands (one national park, twelve nature parks, nine nature reserves and other small areas) [8];
2) Exclusion of areas that correspond to major aquifers, forming the main source of water supply to a significant number of population [9];
3) Exclusion of areas that correspond to buffer zones of 2 km around active (neotectonic) fault zones, most of them showing instrumental and historical seismic record [10].

After these territory subtractions, the remaining areas were ranked on the basis of the following preference criteria:

1) Average annual rainfall [11];
2) Maximum seismic intensity [12];
3) Population density [13].

Scenarios were drawn considering these three criteria (without introducing any particular weighting factor) and attributing a qualitative score ranging from 1 (worst-case) to 7 (best-case). The correlation between ranges and rating (scores) is shown in Table 1.

Table 1 - Ranges and rating of the three preference criteria.

Scenario	Score	*Average Annual Rainfall (mm)*	*Maximum seismic intensity*	*Population density (Inhabitants/km^2)*
Worst-case	1	> 2400	10	571.4-71169.6
	2	1600-2400	9	222.9-571.3
	3	1200-1600	8	114.5-222.8
	4	800-1200	7	60.2-114.4
	5	600-800	6	29.6-60.1
Best-case	6	500-600	5	14.7-29.5
	7	<500	4	1.4-14.6

In this approach (that may be refined in future assessments through the use of adequate weighting factors) the composite score for each polygon (problem solution) results simply from the sum of the three individual scores. The polygons emerge from the spatial intersection of criteria, keeping all the source information.

Finally, a graphical output was constructed in the form of a preliminary thematic map (scale 1: 1 000 000) showing areas with different ranks of potential suitability to host a near surface repository.

RESULTS

Table 2 summarizes the area reduction in function of the criterion used independently, considering the Portuguese mainland territory at a 1: 1 000 000 scale.

Table 2 – Preference criteria spatial distribution (percentage in area of the territory)

Scenario	Score	*Average Annual Rainfall*	*Maximum seismic intensity*	*Population density*
		Percentage of the territory (%)		
Worst-case	1	0.6	0.3	3.0
	2	6.0	0.7	5.1
	3	13.5	3.8	8.6
	4	22.7	25.8	12.0
	5	38.4	36.0	14.5
Best-case	6	13.0	20.1	20.8
	7	5.8	13.4	36.0
Total area (%)		100.0	100.1	100.0

Exclusion of protected lands, aquifer systems and areas adjoining active fault zones led to a 52% reduction of the area to study in more detail during the present selection step (Figure 1, Map A).

The analysis of the spatial distribution of the preference criterion *"average annual rainfall"* highlights the less suitableness of the Northwest region of the Country, as well as its central, hilly domain for the aforementioned purpose; the most favourable regions occur mainly at the South and Northeast parts of the Country.

Concerning the criterion *"maximum seismic intensity"*, the Northern region of the Country (the most distant of the plate tectonic boundary Eurasian – African) is favoured, regardless of the local importance of intra-plate seismic activity related to some major active fault zones. Considering the "seismic factor", the less favourable region corresponds to the Northeast neighbourhood of Lisbon [12].

Overlaying the *"average annual rainfall"* and *"maximum seismic intensity"* criteria in the 42490 km^2 remaining territory, a widespread location of regions with potential suitableness areas for host a near surface repository is obtained. They occur from North to South, mainly in the Eastern part of the Country, fulfilling the three highest scores and corresponding to about 6% of the territory (Figure 1, Map B).

The criterion *"population density"* reflects an increasing (and problematic) tendency to people concentrate around consolidated urban areas, mainly along the seashore; indeed, half of the resident population occupies roughly 8% of the territory. The addition of this criterion to the previous ones puts in evidence an outstanding asymmetry between most of the seaside and countryside regions, clearly confirming the suitableness of the areas formerly indicated.

As shown in Figure 1, map C, the three highest scores (19, 20 and 21) resulting from the combination of the three criteria correspond now to only 4% of the territory, spatially distributed in seven of the eighteen Portuguese mainland administrative districts. This percentage means that for each criterion the highest scores correspond to relevant areas (shadow areas in Table 2).

From the geological point of view, the resulting target (4% of the Portuguese territory) is essentially made of Palaeozoic meta-sedimentary sequences (sometimes with inter-bedded meta-volcanic rocks) intruded by different igneous bodies (mostly of granitic composition and Upper Palaeozoic age). Note, however, that Cainozoic clastic sedimentary rocks cover a significant part of one of the regions included in that 4% of territory.

FINAL STATEMENT

1 – The leading goal of the site selection process carried out is to ensure that, independently of the facilities to be considered in the future, the picked areas will be intrinsically suitableness by virtue of their natural features and land-use settings (therefore guaranteeing the fulfilment of the basic protection requirements). The identification of these highly favourable regions and areas therein will be confirmed through refining of the aforementioned criteria together with consideration of other decisive factors adequate for different scales of concern.

2 – At this point, a conservative approach was followed, combining the exclusion of all national protected lands with the elimination of the surface areas corresponding to aquifer systems that represent the main drinking water supply for a significant amount (37%) of Portuguese population. [14]. The choice of a 2 km buffer belt around active fault zones is also reasonable for a first approach, although further work might determine the use of a more appropriate value for a detailed scale of analysis.

3 – The non-consideration of hard geological criteria in this initial step of screening is basically due to the large variability of outcropping rock types in the Portuguese mainland territory. These and other related geological criteria (such as geochemical homogeneity, fracture network properties, geomorphic features, thickness of

weathering profiles, soil type, *etc.*) will be considered whenever appropriate in function of the map scale and the intrinsic geological characteristics displayed by the selected region or area.

4 – Considering the scale used in this work (1:1 000 000) the GIS software proves to be a very useful tool in providing reliable data treatment, allowing gathering the information needed to build a coherent starting point for further work.

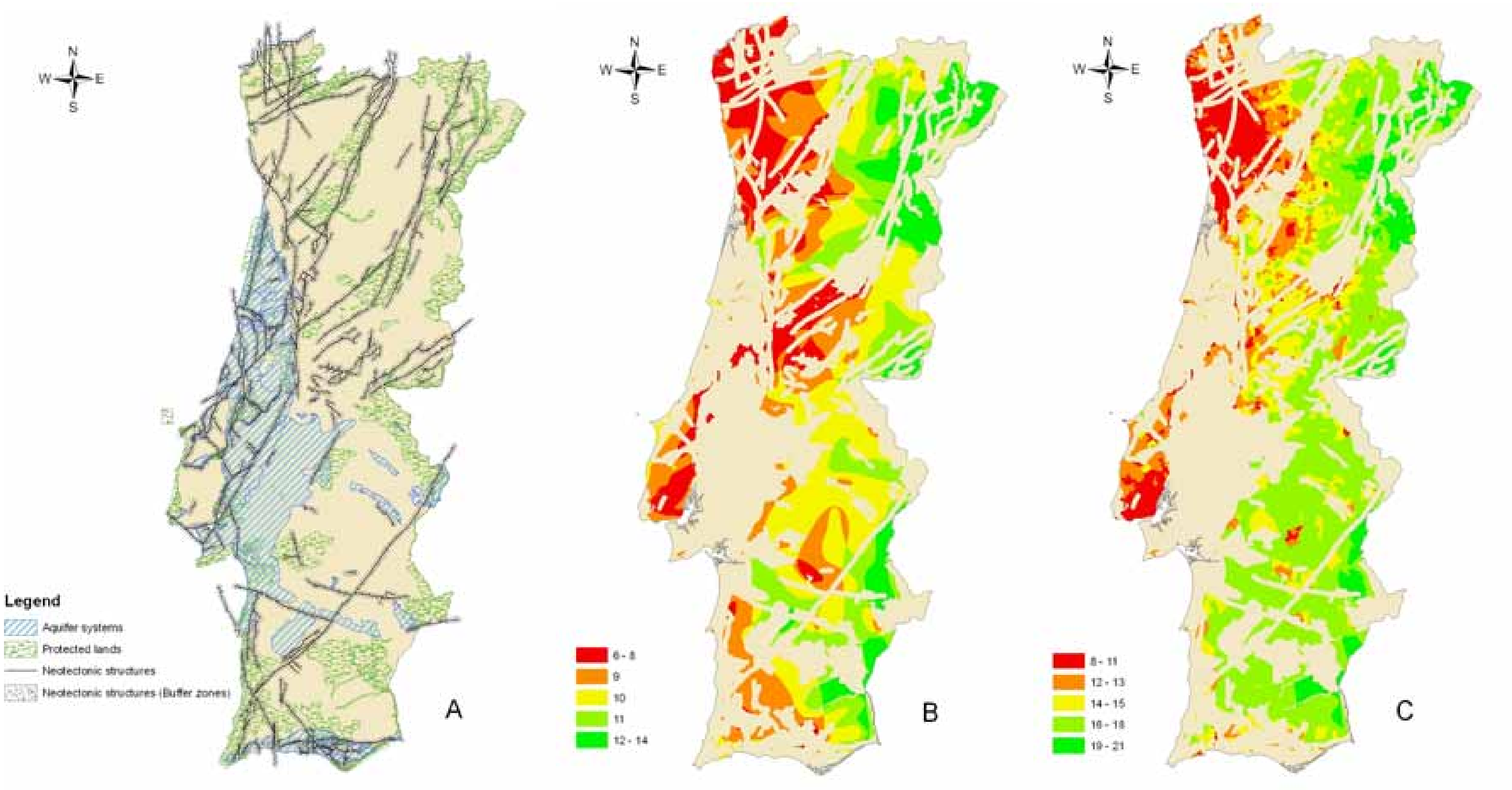

Figure 1 – Layout of the excluded areas (A); Average Annual Rainfall and Maximum Seismic Intensity criteria overlay (B); Average Annual Rainfall, Maximum Seismic Intensity and Population Density criteria overlay (C).

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