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Influence of environmental, economic and social factors on a site selection index methodology for a technological centre for radioactive waste management

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The design of a near-surface disposal facilities for low and intermediate level radioactive waste involves an important previous work for a suitable site selection. This paper falls within a huge study for the estimate of suitability indices, useful for the comparison of some areas which have passed a preliminary screening step. Since in a previous study geological and morphological factors had been mainly assessed, the focal aim of this paper concerns the evaluation of other important parameters relevant to the overall impact owing to the siting of a near-surface disposal facilities. The proposed methodology takes into account three impact index categories: the environmental, the economic and the social ones. The comparison between those impact index typologies has been developed throughout the use of the Analytical Hierarchy Process (AHP) elaborated by T. L. Saaty. As a matter of fact, this method allows the comparison between decision elements which are difficult to quantify, and it is used to prioritize alternatives. The weighting of each impact index typology derives from the analysis of the relative constituent parts. Finally, this new approach represents a useful, prompt and easy to use instrument for the evaluation of the suitability degree of areas under investigation.

1. Introduction

Low-level radioactive waste results from nuclear power plants and from the use of radioisotopes in medical, research and industrial applications. Even if nuclear energy has been banned in Italy with a referendum in 1987, nuclear power plants and associated fuel-cycle facilities entail significant quantities of radioactive waste produced over the past decades and that will arise from their decommissioning. The use of radioisotopes in medical, research and industrial applications results in the generation of 1200 m^3 of low-level waste per year. For all these reasons even in Italy it is necessary a near-surface site for disposal of radioactive waste. Several joint committees worked to identify potentially suitable sites for a national repository; the so called “Task Force Site” coordinated by ENEA and the “State/Region Commission” are worth to be mentioned. The first one aimed at preparing a list of potentially suitable sites; it selects about 200 areas after applying exclusion criteria; these areas have then been reduced to nearly 30 when the presence of human settlements and geomorphologic suitability

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requirements have also been taken into account. The second committee devoted its efforts in pointing out a possible roadmap in order to identify a final disposal site in the frame of a people consensus.

2. Methodological proposal for site selection

IAEA recommends that a suitable disposal site should be chosen in a short list, sorted out from an extended list of possible sites (IAEA, 1994). The proposed IAEA approach is based on the assignment of a "suitability index" to each selected area able to quantify the area's suitability in a simple and prompt way. According to IAEA recommendation, candidate sites, satisfying geological, tectonic, hydro-geological, geochemical and seismic requirements (technical criteria), must comply with environmental, economic and social criteria in order to define an overall impact index given by:

$$I = a\ I_{env} + b\ I_{eco} + c\ I_{soc} \quad (1)$$

The values of I_{env}, I_{eco} and I_{soc} will be calculated taking into account the parameters described in the following paragraphs and will be correlated with the peculiar characteristics of each area under investigation.
In order to select the best site, the coefficients a, b, and c will be calculated by means of Analytical Hierarchy Process (AHP) developed by T.L. Saaty (Saaty, 1980). The core of Saaty's method is an ordinal pair-wise comparison of all criteria. By means of these comparisons the method will define the relative position of one criterion in relation to all other criteria making use of a 9 point scale (Table 1) for the assignment of priority values.

Table 1: Saaty scale

Value	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Intermediate values

2.1 Environmental impact index

The environmental impact index takes into account the environment of the areas, considering all the surrounding ecological and landscape characteristics which could be damaged or altered by the disposal facilities.
Since the Italian Peninsula has been the cradle of some of the highest expressions of human culture of all time, our country profits by an invaluable historical, cultural and landscape heritage of thousands of years of civilisation. Moreover, due to its central position in the Mediterranean sea, with a huge latitude extension and many phytoclimate types, Italy is one of the nations with a higher number of threatened, endemic and rare species, and an high biodiversity value (Blasi et al, 2008). Consequently, it is now increasingly crucial that the biological, natural and landscape

resources of our country be preserved, (inverting the preceding mentality by which progress was always deemed positive, with damage to the environment an insignificant collateral effect).

2.1.1. Landscape impact

According to the European Landscape Convention (ELC, 2000), landscape means an area whose character is the result of the action and interaction of natural and human factors. In the light of this, the assessment of I_{env} foresees a preliminary focus on the particular landscape and anthropical characteristics of each analyzed area, trying to evaluate the entity and the probability of possible damages owing to the settling of a near-surface disposal facilities for radioactive waste. This step of the study can be developed throughout the use of standardized evidences like the presence of neighbouring zones subject to archaeological or landscaping constraints, and throughout the analysis of possible alterations to the land use, considering also the loss of agricultural or farming areas. This analysis should be made by means of CORINE (*Coordination of Information on the Environment*) Land Cover digital maps, established by the European Community, in order to compare the land use of different areas by means of the same standardized methodology and classification.

2.1.2. Ecological impact

Ecosystem health and integrity is central to the management of land, water and living resources, and can be achieved by means of strategies promoting conservation and sustainable use in a fair way. The first kind of ecological impact is the one associated with atmospheric, water and soil pollution due to the possible presence of a technological centre for radioactive waste management. The radioactive pollution is evaluated, considering the potential damages due to the introduction in the environment of radioactive isotopes. It is important to analyze the possible trophic chains in the surrounding environments and the probable interactions with food plants and animals that could involve serious damages to human health. The second kind of ecological impact is correlated with the biodiversity loss and the conservation of rare or threatened habitats; these two aspects are jointly considered, since they are tightly connected. As a matter of fact, according to the Convention on Biological Diversion (CBD, 2000), nowadays the first cause of biodiversity loss is the habitat fragmentation. Although during the preliminary screening step all the Natural Protected Areas have been excluded, it is very important to highlight all the sites where the building of the repository for radioactive waste could generate a relevant impact on the surrounding habitats and ecosystems, giving particular priority to the ones included in the Red List drawn up by the IUCN (*International Union for the Conservation of Nature*). Furthermore, also the ecological corridors should be considered and preserved by possible impacts; as a matter of fact they represent significant areas for the conservation of the interspecific and intraspecific biodiversity, and unfortunately they are often difficult to circumscribe. All the ecological networks, meant as the whole systems of ecological components and their interconnections must be considered and then weighted; at the same time, environmental impact parameters can be used for the implementation of a GIS (Geographical Information System) database, (able to give useful information through the interrogation of these digital maps).

2.2 Economic impact index

The building of a near-surface repository for radioactive waste entails an alteration of local economic equilibrium. Consequently the economic impact index aims at assessing the extent and the features of these alterations, correlating them with an economic quantification. In order to evaluate the economic impact, it should be taken into account the near-surface repository cost along its life cycle (Guidi et al, 2008).

From a macroeconomic point of view, the accomplishment of a repository involves the management of the so-called negative environmental externalities. Negative externalities occur when an individual or firm making a decision does not have to pay the full cost of the decision. If a good, service or plant has a negative externality, then the cost to society is greater than the cost consumer or citizens have to pay for it. A gap between private and social costs and between private and social benefits will exist. In order to narrow this gap, taxes and ecological subsidies will be used to internalize environmental damage. Main economic impacts linked to the repository construction are the overall cost of it, the real estate assessment change and the loss of image for the area. The overall cost of the repository is referred to the cost of each phase, namely planning and siting, review and approval, construction, operation, closure and post-closure (IAEA, 2002). The presence of new employees and their families in the area may place demand on available housing stock, both for rental and ownership, possibly resulting in higher housing costs and increased property values. On the other hand, the concern regarding radioactive waste could adversely affect housing market activity and depress property values. The construction of a repository for radioactive waste may remove lands from agriculture use. This impact can potentially affect local agriculture business, decreasing crop revenues and number of farm workers employed. Another business activity in the local and regional area such as tourism, may experience adverse impacts resulting from public concerns associated with radioactive waste. The concern regarding radioactive waste in the repository could affect local image of the area, potentially reducing the sale of certain agriculture products and the number of tourists. The aforementioned economic impacts are all negative but there are also positive economic impacts coupled with a radioactive waste repository such as local job creation and new business development. Repository development generally goes together with employment opportunities which may be seen as a local benefit. Employment needs may rise and fall by far during different repository life cycle phases. Different skills and work force numbers are typically involved in the construction and operation phases while employment needs diminish considerably during closure. A repository project involves direct purchase of materials, supplies, buildings, equipment and trade services. This purchasing may stand for an opportunity for local and regional suppliers and could also result in new business development.

2.3 Social impact index

Recent experiences demonstrate that social acceptability is one of the main areas of concern about a radioactive waste repository siting. A national information and awareness campaign about radioactive waste should be promoted in order to gain public acceptance. Siting of a waste management repository should take into account the social context. The social impact index should consider the repository social acceptability, the demography, the social structure, the community character and the community health (IAEA, 2002). Increase in population may occur in the local community due to incoming workers and family members, especially if the initial settlement of the host community is relatively small. These changes may have an effect on housing, community social services and infrastructure demands and community character. The impacts will vary along the repository life cycle phases: they are greatest during construction and operation phases, will diminish during closure phase and will be minimal during post-closure. If the income levels and educational background of the incoming workers vary considerably from the existing social structure in the local community, changes could result. During siting, impacts in the local community and neighboring areas may occur based on varying opinions about the proposed repository. The involvement of interested parties from outside the local community may enhance these impacts. Community opinions may range from perceptions of an undesirable image and related social tensions to support for economic development and job creation benefits. If the repository is located near communities with low income levels, environmental justice issues may arise during the repository planning and siting and review and approval phases. During the construction phase, impacts may result in community character from tensions between workers and their families and the established community. Vehicle traffic levels greater than before, high noise levels and new light sources can affect people's enjoyment of property, local lifestyle and other aspects of community character. The character of the facility to be built may cause anxieties and fears in some individuals and groups that may result in potential human health impacts, particularly during the early phases of the repository development process.

3. Results

A scientific group of experts with different fields of specializations was asked to compare pair-wise the relative importance of each impact criterion, namely environmental, economic and social, according to Saaty scale. A judgmental matrix was created for each expert. It was used for computing the priorities and the consistency index was then carried out (Saaty, 1987). The priorities expressed by experts have been combined using the arithmetic mean. The results are shown in Table 2.

Table 2 Comparison matrix

	Environmental	Economic	Social	Geometric mean	Weight	K eigenvalues
Environmental	1.00	6.60	4.60	3.12	0.72	0.99
Economic	0.16	1.00	0.42	0.40	0.09	0.94
Social	0.23	2.6	1.00	0.84	0.19	1.16
TOTAL	1.39	10.29	6.02	4.36	1.00	3.09

Each weight value is obtained by dividing the geometric mean of each line by the total sum of the geometric means. K eigenvalues are deduced by multiplying each weight, calculated for environmental, economic and social, by the corresponding total.
The consistency index (CI) will be calculate using the following relation:

$$CI = (K_{tot} - n)/(n - 1) \quad (2)$$

where n is the number of components (Table 4). Then, the consistence ratio (CR) is calculated by the ratio of the consistency index to the random consistency index (RI). RI is the random index representing the consistency of a randomly generated pair-wise comparison matrix and is obtained as average random consistency index calculated from a sample of 500 of randomly generated matrices based on the AHP scale. In our case (3 components), RI has 0.58 value.

Table 4: Index values

N° of components	Consistency index	RI	CR
3	0.05	0.58	0.08

The expert group gave the highest weight (0.72) to environmental criterion, followed by social one (0.19) and the less important was judged to be the economic criterion (0.09).

4. Conclusions and further developments

Saaty method allowed to calculate the values of a, b, c coefficients to be inserted in the formula (1) in order to assess the overall impact index. Naturally this index will be assessed after the calculation of I_{env}, I_{eco} and I_{soc}. This will be done taking into account the parameters defined in the previous paragraphs. In a further development a method will be presented in order to calculate I_{env}, I_{eco} and I_{soc}.

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