CHAPTER 7

SITE SELECTION OF LOW AND INTERMEDIATE LEVEL RADIOACTIVE WASTE REPOSITORY IN THE REPUBLIC OF CROATIA

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Abstract. The radioactive waste repository site-selection program in Croatia consists of two stages. The first, the site survey stage, consists of: an exclusionary screening of the national territory, an internal evaluation of selected potential areas, and an identification of potential sites, as well as the selection of a few preferred (candidate) sites which would be suitable for further detailed investigations. The second, the site evaluation stage, consists of all necessary field investigations and additional site-characterisation tasks at previously selected preferred sites. Eight potential areas containing 42 potential sites have been selected in Croatia so far. Selection of 3-4 preferred sites is under way. Site selection methodology, including a description of applied exclusionary and comparative criteria, is also presented in the paper. The report is completed with basic information on current Croatian legislation and organisation of a regulatory body in the field, as well as with a brief characterisation of a few more perspective potential sites.

7.1 INTRODUCTION: SOURCES OF RADIOACTIVE WASTE

The necessity of constructing a low and intermediate level radioactive waste (LLW/ILW) repository in Croatia has developed from the fact that there are two main sources of radioactive waste materials. The first group of sources is waste generated in the Republic of Croatia itself, and the second, includes radioactive waste originating from the operation of the Krsko Nuclear Power Plant (NPP). Although the plant is situated in the neighbouring Republic of Slovenia, it represents a joint venture facility of both Slovenia and Croatia. Therefore, Croatia is obliged to find an appropriate solution to dispose of half of all radioactive waste generated during the lifetime of the NPP.

Radioactive waste in Croatia is derived mostly from various nuclear applications: medicine, industry, agriculture and scientific research. In addition to this, there are about 50,000 ionising smoke detectors distributed in 950 buildings and some 500 ionising lightning arresters (protectors) installed on 320 buildings in the country. However, the total amount of radioactive waste which has been generated in Croatia so far is not more than 80 m^3, and its estimated gross activity is 2.3×10^{12} Bq. The waste is composed of radionuclides like ^{152,154}Eu, used in ionising lightning arresters; ^{241}Am, installed in ionising smoke detectors; ^{192}Ir, ^{90}Sr, ^{85}Kr and some others, used in measurement and processing techniques in industry; ^{137}Cs and ^{60}Co, used in numerous diagnostic and therapeutic methods in medicine, etc.

Basically, there are three radioactive waste disposal approaches being practised in Croatia. The first, which refers to hospitals and research laboratories, is an adequate storage of waste until its activity falls to the background level, and after that it is treated as common waste. The second approach is related to waste types containing long-lived radionuclides, which are being properly stored in two temporary storage facilities at scientific institutes “Ruder Boskovic” and the Institute for Medical Research and Occupational Health (both are situated in Zagreb, the capital of Croatia). According to available data, there are some 500 institutions including more than 5,000 persons that are professionally in direct or indirect contact with radiation sources in Croatia.

The Krsko NPP is obviously the greatest producer of all radioactive waste expected to be disposed of in Croatia. Since the plant started operation in 1982, some 2,000 m^3 of LLW/ILW with a total activity of about 3.6×10^{13} Bq have been generated so far. However, it is realistic to expect some 8,500 m^3 of LLW/ILW to be generated in the lifetime of the NPP. The total activity generated during the plant lifetime, could reach an estimated 1.5×10^{14} Bq. In addition, roughly 11,000-12,000 m^3 of decommissioned waste is expected to be produced in the

plant by the end of its operation. This type of waste is supposed to be composed of 53% LLW, 36% ILW and 11% high-level waste. The prevailing radionuclide is ^{60}Co, which is responsible for about 90% of the total activity of the waste. It is expected that Croatia will be responsible for final disposal of some 10,000 m^3 of LLW/ILW, i.e. one half of the total LLW/ILW generated during the lifetime of Krsko NPP.

7.2 ESSENTIAL STRATEGIC ISSUES IN RADWASTE MANAGEMENT IN CROATIA

The strategy on radioactive waste management in Croatia was originally drafted by the APO - Hazardous Waste Management Agency in 1992. It was recognised then that only a systematic and well-organised program, which would be based on responsible treatment with radioactive materials and tightly related to regulatory bodies and current legislation, can provide an acceptable approach to safe operation of nuclear facilities and radiation sources in different nuclear applications.

Basically, the strategy as developed in Croatia, includes the following topics, i.e. tasks to be regularly and continuously practised:

- identify all sources and precise quantities of radioactive waste in Croatia, as well as create and maintain an inventory of radiation sources and radioactive waste materials;
- define a legal framework, i.e. the system of responsibilities;
- establish the financing of a national radioactive waste program;
- introduce and, if necessary, improve existing legislation and regulations in the field of radioactive waste disposal;
- develop the LLW/ILW repository, including all necessary activities like site selection, technical design, safety analysis etc.;
- foster public relations; and
- give support to other radiation safety related actions and programs.

The strategy has been rearranged according to existing IAEAdocuments, and is expected to be modified in the future according to forthcoming requirements and recommendations of this international agency.

7.3 LEGISLATION AND REGULATORY FRAMEWORK

Regulations concerning radioactive waste management, which are temporarilyy implemented in the Republic of Croatia, have been partly taken over from the ex-Yugoslav legislation. In general, these regulations have been established according to world-wide practice and support other regulations concerned with environmental protection or the management of other wastes. The basic regulation is the, “Law on Ionising Radiation Protection and Special Safety Actions in Nuclear Energy Implementation”, issued in 1984. From this law, 17 regulations and codes of practice have been subsequently derived. The new Croatian law on radiation protection and nuclear safety is expected to be approved by the end of 1996.

Documents to be emphasized here, due to their particular importance in the field of site selection and radioactive waste repository construction and operation, are “Code of Practice on Conditions of Locating, Construction, Start-up and Operation of Nuclear Facilities”, “Code of Practice on Standard Format of Safety Report and Other Documentation Needed for Safety of Nuclear Facilities”, as well as “Code of Practice on Methods of Collecting, Account, Processing, Storing, Final Disposal and Release of Radioactive Waste Substances in the Environment. (all of them were issued in the period 1986-88). These regulations went into effect according to the “Law on Taking Over the Federal Laws in the Field of Health Protection, Applied in the Republic of Croatia as Republic Laws”.

A national regulatory body organising and controlling radioactive waste management, as well as radiation protection issues, has not been established in Croatia as a single institution covering all related issues. It consists of sections of three separated governmental entities: the Ministry of Health, the Ministry of Economy, and the State Directorate for Environmental Protection. Unfortunately, there is no permanent body in Croatia which would co-ordinate activities of these ministries in the field. The Sanitary Inspectorate, as a section of the Ministry of Health, is the competent national authority for radiation protection. The Ministry of Economy, i.e. Department of Nuclear Safety, is the competent national authority for siting, construction, start-up, operation and closure of nuclear facilities. The competence of the State Directorate for Environmental Protection is directed to issues related to environmental clean-up actions of contaminated sites, hazardous waste management, etc. It should be added that a few other ministries (Transport, Finances, Interior, etc.) are responsible for licensing particular activities, which are incorporated in

radioactive waste management and cover the transportation, import-export, release of effluents and some other issues.

7.4 SITE SELECTION METHODOLOGY: STRUCTURE OF SITE SELECTION PROGRAM

7.4.1 Concept Description

The global concept of the Radioactive Waste Repository Project in Croatia consists of several interrelated main task groups. Besides site selection, it also comprises licensing, technology & design development, safety assessment, economic evaluation, transportation analysis and waste characterisation. The whole project is supported by particular activities related to development of legislation and regulatory body organisation. Since there is an urgent economic need to ensure additional energy sources in Croatia, the site selection of thermoelectric- and nuclear power plants is encompassed by the same program as well.

The site selection includes two stages: the first, site survey stage (Fig. 7.1), terminating with the inclusion of candidate sites into the Physical Plan of Croatia; and the second, site evaluation stage, aimed at defining the final repository site through field investigations and other necessary actions.

The first part of site selection, i.e. the site survey stage, is currently under way. It includes the actions that are extremely sensitive since defining site selection methodology and criteria, as well as achieving political and public acceptance for repository siting, have to be completed before preferred (i.e. candidate sites) will be identified and included in the Physical Plan of Croatia and, thus, become available for further field investigations. The planned activities are projected to be performed in two phases: (1) regional analysis and selection of potential areas; and (2) selection of preferred sites (Fig. 7.1).

In other words, the philosophy of site selection is, at first, to define exclusionary criteria for the global reconnaissance of Croatia in order to find potential areas. After comparative and additional exclusionary criteria are defined, potential areas will be subjected to more detailed evaluation designed to identify a number of potential sites. Through a comparison of potential sites and their internal characterisation, a few preferred sites will be evident. These, preferred (or candidate) sites are finally supposed to be included in the Physical Plan of

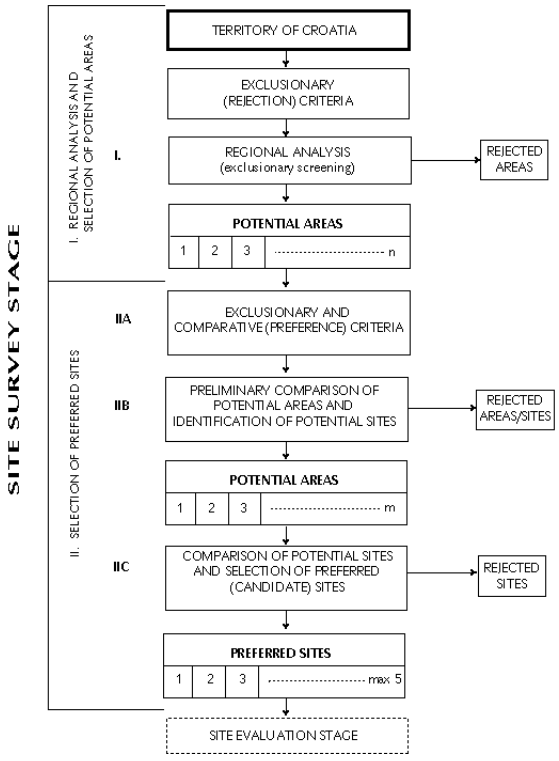

Figure 7.1. Site selection procedure as applied in site survey stage.

Croatia. In the second stage, detailed site investigations will be worked out at two or three preferred sites, which will result with the identification of the final repository site.

In accordance with the above mentioned, it is necessary to clarify terminology involved in referring to selected areas i.e. sites: *potential areas* represent larger areas (100-600 km^2), characterised by acceptable isolation properties; *potential sites* are smaller homogeneous areas (5-20 km^2), derived from potential areas, which are favourable for siting a radioactive waste repository, and finally, *preferred sites* are small areas (2-20 km^2), highly acceptable for the repository siting and convenient for inclusion in the Physical Plan of Croatia[1].

As shown schematically in Figure 7.1, the site survey stage consists of two phases. It could be described in more detail as follows:

- *Regional analysis*, terminating with selection of potential sites, represents the first phase of the site survey stage. It is based on an assessment of the whole territory of Croatia using selected exclusion-

ary criteria ("exclusionary screening"). Areas which do not meet the requirements, defined by at least one of these criteria, are eliminated. Remaining areas are designed as potential areas for further analyses. Regional analysis is based on appropriate information derived from topographic and other thematic maps of Croatia on the scale 1:300,000.

- In the second phase - *selection of preferred sites* - all previously selected potential areas are checked by the exclusionary criteria, and then evaluated on the basis of more detailed data and large scale maps (1:100,000). Comparative criteria are applied to both potential areas and potential sites in order to identify potential sites and preferred sites, respectively. This task is divided into three sub-phases as follows.

7.4.1.1 Selection of Parameters and Criteria.

Proposed parameters and criteria, applied in the identification, selection and comparison of potential sites, are defined by a special team of experts, composed of specialists from different fields of interest (from geology to sociology). Both exclusionary and comparative criteria were officially published in the Croatian official gazette "Narodne novine", No. 78/92. Comparative criteria are generally presented as requirements for achieving a certain goal or a desired state. These goals can be defined as desirable conditions, and if a desirable condition can not be achieved, the criteria should describe the degree of acceptability (i.e. to what extent does the solution approach desirable conditions). The following four groups of comparative criteria have been formed in accordance with basic aspects or dominant characteristics of the criteria involved:

A. *Engineering aspects*. Criteria comprised by this group show whether the engineering requirements for acceptable radioactive waste disposal are met. Emphasis is placed on the economic issues of facility construction and operation. Preference is given to site characteristics which enable simpler and, thus, economically more acceptable solutions. Characteristics of the site can also affect, to a lesser extent, certain safety aspects of the facility, but these can be successfully compensated by engineering interventions. Regarding this comparative criteria group, sites requiring simple and less expensive engineering solutions are preferred.

B. *Safety-related aspects.* In this group are collected criteria needed to determine whether the safety requirements for construction and/or operation of the facility are met. Concordance with safety requirements is checked during all phases of the site selection program, and is very much evident in the licensing procedure of the facility. Emphasis is placed on evaluating the physical properties of an area that could have negative effects on facility safety. However, some site characteristics could have an impact on the choice of additional needed engineering solutions that can influence on cost-benefit issues of construction and operation. Regarding this group of comparative criteria, preferred sites are those where facility safety is derived from more convenient physical (natural) characteristics of the site, requiring a minimum of engineering intervention.

C. *Environmental impact and acceptability in the immediate site area.* This group includes comparative criteria showing whether the safety requirements, concerning the impact of the facility on the immediate environment, are met. Emphasis is placed on the environmental impact of the facility during its regular operation as well as in cases of possible accidents. Site characteristics can also have an impact on the degree of social acceptance. Concordance with safety requirements must be confirmed throughout all phases of site selection, and it will be evident in corresponding documentation (e.g. study on environmental impact assessment, safety reports, site permits etc.). Preference is given to those physical (natural) site characteristics which provide less impact on the environment, as well as to existing and planned land use types which could act positively on the safety and acceptability of the site.

D. *Acceptability of the facility site in the broader area.* This group consists of comparative criteria that assess the possible impact of the radioactive waste disposal facility on the broader area. Emphasis is placed on an analysis of present and planned land use types, as well as on the degree of social acceptance regarding possible changes in the value of the area. Preference is given to present and planned land use types causing less conflict and therefore having a greater social acceptability, as well as to physical characteristics that provide milder environmental effects resulting from the facility operation.

Comparison of potential sites: method of weighted criteria

In this phase, it is necessary to choose the most appropriate method of site evaluation and comparison. There

are several techniques and methods in world practice. On the basis of experience acquired in Croatia and Slovenia in the field during the last few years, a multiple criteria analysis has been chosen as the most effective. In particular, the method PROMETHEE (i.e. "Preference Ranking Organisation Method for Enrichment Evaluations"), created by J.P. Brans and P. Vincke, has been applied in our case. The method represents a computerised analysis of a multiple criteria technique and decision-making methods. Thus, objectivity in site selection and assessment has been successfully achieved. The method is based on the application of numerous criteria in order to express interrelations among alternatives, indicating a group of "better" solutions.

The relative significance of each criterion is expressed by assigning to it a corresponding weighting factor. The values of the weighting factors are defined by applying the rating method, and are based on decisions of the experts. After discussion, members of the expert team propose weighting factors for all comparative criteria. As result, a special co-ordinating group adopts the final list of weighting factors (as is presented in Table 7.1; see the section "Comparative Criteria"). It is obvious from the Table that the expert team concluded that criteria group C ("Environmental impact and acceptability in the immediate site area") is the most important with a total weighting factor for this group of 52.5% . This is followed by the group B ("Safety related aspects") with a 30.0%. share. The acceptability of broader site area (group D) is expressed by a total weighting factor of 9.5%, since it is assumed that LLW/ILW repository will have almost no impact on the broader site area. Finally, the importance of engineering aspects is estimated to be only 8% because it is expected that the repository would not require considerable civil-engineering interventions.

7.4.1.2 Assessment and Comparison of Potential Areas and Identification of Potential Sites

In order to get more precise information, the first task in this sub-phase is to check on the exclusionary criteria application which would be based on more detailed maps (on the scale of 1:100,000). Geologic characteristics, i.e. engineering/geologic properties - including lithological and geomorphologic, tectonic and seismic, as well as hydrogeological characteristics of the selected sites, are of special interest.

7.4.1.3 Assessment and Comparison of PotentialSites Followed by Selection of Preferred (Candidate) Sites.

In this sub-phase, more detailed data on sites, previously chosen in sub-phase 7.4.1.2, are collected in order to perform a comparative assessment of their acceptability. The on-site investigation of all potential sites should be carried out, and the exclusionary criteria are supposed to be checked once again. In the field of potential sites, the previously determined reference points should be re-evaluated. With regard to basic safety site characteristics (lithology, hydrogeology, risk of flooding), a certain number of potential sites is expected to be excluded due to their lower quality, by comparison with the others. It has already been decided that not more than 3-5 preferred (candidate) sites will finally be proposed for further detailed on-site investigations.

The final comparison of potential sites, as well as the final selection and proposal of preferred sites, will be performed after validation of both criteria and weighting factors by a competent governmental/parliamentary body. Comments on the involved criteria that would probably result from public debate and discussions with experts will be thoroughly re-examined afterwards by members of the expert team. If agreement is reached, these comments will be accepted. In that case, the main sections of the site survey procedure will be reanalysed.

7.5 SITE SELECTIONAS A MULTIPLE CRITERIA ANALYSIS

7.5.1 Some Basic Facts about Croatia

The Republic of Croatia (56,538 km^2) is situated in the southern part of central Europe. It includes three major physical-geographical regions: Pannonian basin, Dinaric Alps and the Adriatic coast. As part of former Yugoslavia, it proclaimed its independence in June 1991. There are about five million inhabitants living in Croatia, with an average population density of 80 inhabitants per square kilometre. Due to its unusual shape, the total length of the Croatian border is very long - 2,100 km. The neighbouring countries to Croatia are Slovenia, Hungary, Serbia, Bosnia-Herzegovina and Montenegro, as well as Italy (the border with Italy runs along the Adriatic sea). The major Croatian cities are Zagreb, the capital (900,000 inhabitants), Split (250,000), Rijeka (200,000), Osijek (120,000), Zadar (80,000) and Pula (70,000) (Fig. 7.2). Farming, forestry, fishery, industry, shipbuilding and tourism are the main economic activities. Industry, including mining and

Table 7.1. List of comparative criteria and their weighting factors.

Group: Percent:	A 8.0%	B 30.0%	C 52.5%	D 9.5%	TOTAL 100%
1. Transportation					3.7%
1.1 *Transportation or radioactive waste*			C.1.1. - 3.7		
2. Meteorology and hydrology					14.3 %
2.1 *Hydrological issues*		B.2.1 - 7.5	C.2.1 - 3.2		
2.2 *Meteorological issues*		B.2.2 - 2.8	C.2.2 - 0.8		
3. Geology and seismology					35.8%
3.1 *Seismotectonics and seismics*	A.3.1 - 4.0	B.3.1- 5.9			
3.2 *Soil mechanics and slope stability*	A.3.2 - 4.0	B.3.2 - 9.8			
3.3 *Hydrogeology*			C.3.3 - 12.1		
4. Demography					5.4%
4.1 *Population density*			C.4.0. - 5.4		
5. Present and planned land use types					22.2%
5.1 *Settlements*			C.5.1 - 4.4	D.5.1 - 3.5.	
5.2 *Tourism*			C.5.2 - 3.3	D.5.2 - 2.5	
5.3 *Agriculture*			C.5.5 - 2.6		
5.4 *Forestry*			C.5.4 - 2.2		
5.5 *Industry and mining*			C.5.5 - 1.1		
5.6 *Infrastructure*			C.5.6 - 1.5		
5.7 *Special purposes*			C.5.7 - 1.1		
6. Environmental protection					18.6%
6.1 *Protection of natural heritage*			C.6.1 - 3.0	D.6.1 - 2.5	
6.2 *Protection of cultural heritage*			C.6.2 - 1.6	D.6.2 - 1.0	
6.3 *Soil properties*		B.6.3 - 4.0	C.6.3 - 2.4		
6.4 *Bio-ecological values of the site*			C.6.4 - 2.5		
6.5 *Radiological aspects*			C.6.5 - 1.6		

energy production, produces 44% of the national gross income.

7.5.2 Geological Background

Sedimentary rocks prevail in the geologic structure of Croatia, occupying 95% of its surface lithology. Moreover, it should be emphasized that the distribution of Mesozoic carbonate rocks, like limestone and dolomite, is the leading rock type throughout the southern part of the country (i.e. south from Karlovac.) The morphology of this area is characterised by karst (Fig. 7.3), occurring in two basic varieties: shallow karst, covered by soil in the interior parts, and thick, exposed karst stretching along the Adriatic coast. An irregular hydrogeology and very sensitive mechanisms have a remarkable impact on the quality of surface- and ground-water and control some specific bio-lithological processes (e.g. formation of travertine). Consequently, a lot of human activities being practised in the area eventually leads to considerable environmental pollution.

In the northern part of the country in the Pannonian basin, fluvial, erosional and aeolian clastic sediments are dominant, particularly in the lowlands along the rivers Sava and Drava, as well as in the east Croatian plain. The central Slavonic massifs (Papuk, Krndija, Psunj, Pozeska gora), in the heart of northeastern Croatia (known as Slavonia), are mainly composed of old Paleozoic igneous (granite, basalt, etc.) and meta-

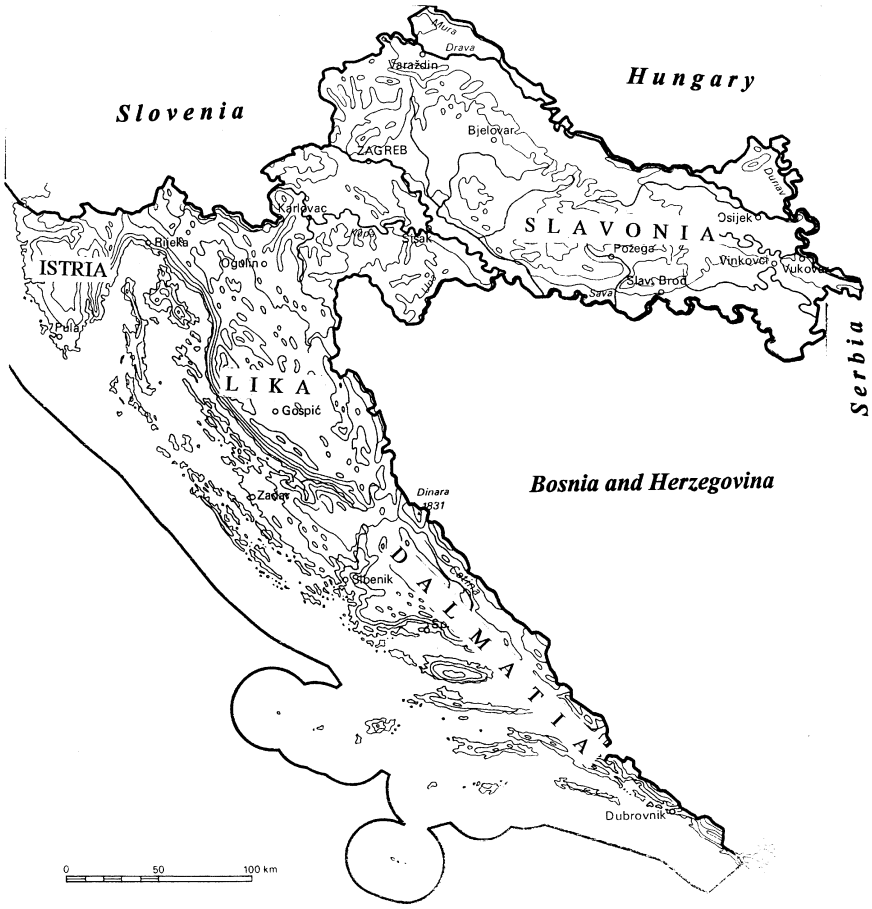

Figure 7.2. Croatia with its major cities.

morphic rocks (crystalline schists, gneiss, etc.) (Fig. 7.3).

The territory of Croatia is an unstable area from the standpoints of both tectonics and seismicity. Several major longitudinal faults run in a NW-SE direction, in both the northern and southern parts of the country. Where they intersect, transverse faults are in many cases characterised by geothermal springs. Earthquakes as intensive as VIII-X MCS can be expected in most of the Adriatic coast region (southern Dalmatia, in particular), but they can also occur in some areas of northwestern Croatia.

During site selection for a radioactive waste repository, attention should be paid to both repository design options and available rock types. The leading principle in both cases is to ensure environmental safety, and not to save money.Almost half of Croatia is not convenient for a repository siting due to the prevailing carbonate lithology, karst morphology and the consequent irregular circulation of groundwater. Since the remaining flatlands are generally unsuitable because of major infiltration with high water-tables (along the rivers Sava, Drava and Danube), the areas of interest are the previously mentioned mountains of the country's interior, Papuk, Krndija, Psunj and part of Bilogora as well as Moslavacka gora, that is situated somewhat to the west. All these mountains, except Bilogora, are horst-structures composed to a great extent of granite, gneiss and schist[2].

7.5.3 Site Acceptability Assessment

In the site selection process, it would be insufficient to locate only a host-rock capable of providing waste containment, i.e., to keep water away from the waste. According to the accepted approach, it is recognized that the entire system, i.e. waste form and package, host-rock, geological formations of the broader area, and environment of the region, should provide waste containment. In keeping with this philosophy, the applied criteria should address all site characteristics that contribute to waste containment and insulation. These characteristics

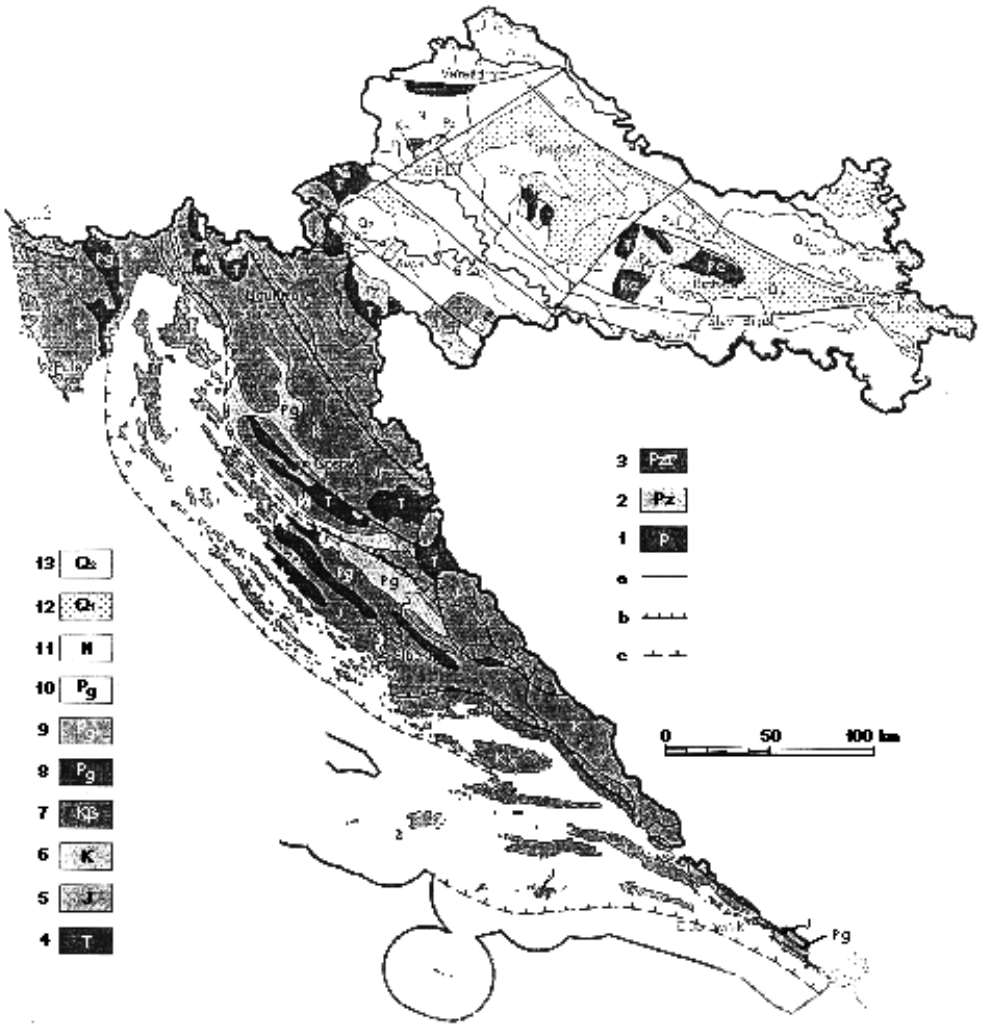

Figure 7.3. Geologic map of Croatia:. 1- Precambrian (metamorphic rocks); 2 - Paleozoic (clastites, additionally carbonates); 3 - Paleozoic (igneous rocks: granite); 4 - Triassic (carbonates, add. clastites); 5 - Jurassic (carbonates, add. igneous clastites); 6 - Cretaceous (carbonates, add. clastites/flysch); 7 - Cretaceous (igneous rocks: basalt); 8 - Paleogene (limestones); 9 - Paleogene (clastites, flysch) 10 - Paleogene (limestone clastites, limestones); 11 - Neogene (clastites, limestones); 12 - Pleistocene (clastites/mostly non-cemented); 13 - Holocene (clastites/mostly non-cemented.) Tectonics: a - normal faults; b - reverse faults and thrusts; c - reverse faults and thrusts (submarine).

include geotechnical and socio-economic concerns. In the application of these criteria, greater consideration should be given to those factors that directly influence the safety of the repository than to those criteria which affect only repository cost and timeliness.

In the final analysis, repository licensing and operation can not be performed until it is demonstrated that the total waste disposal system, including the waste form and its packaging, design of engineered facilities and barriers, as well as the multiple natural barriers, will adequately protect public health and safety and preserve the quality of the environment[3].

7.5.4 Exclusionary Criteria

There are ten exclusionary criteria to be applied in the first phase of the site selection process, i.e., in a regional analysis of the whole territory of Croatia, where the aim is to reject all areas that do not meet requirements of these criteria. The exclusionary criteria are divided, similarly to the previously discussed classification of comparative criteria, into four groups: A - Engineering aspects; B - Site safety related aspects; C - Site accept-

ability; and D - Facility safety. These four aspects involve three basic principles for repository siting: cost-benefit ratio, acceptability and safety. The following is a brief description of each criteria with examples of the excluded areas that result when the territory of Croatia is analyzed.

1. Meteorological and hydrological criteria: Flooding (Group D)

All natural floodplain areas excluded (assuming repeat periods at 1,000 year intervals), regardless of whether they are protected or not.

Comment: The LLW/ILW repository must be situated beyond the reach of floods. Hence, all natural floodplains, as well as those areas where accumulations of water are planned, are excluded. Areas, where it is not likely to prove a low risk of flooding by additional investigations, are also excluded. The risk of flooding is supposed to be studied throughout the site selection program.

Excluded areas: Large lowland zones along the major Croatian rivers of Sava and Drava, as well as the Danube in Baranja region; and numerous sinks in karst regions, which are characterised by seasonal flooding.

2. Geology and seismology: Seismotectonics (Group A)

Areas with maximum potential earthquake intensity equal to or higher than IX MCS, are excluded.

Comment: Elimination of areas that are potentially affected by strong earthquakes is also safety related and should be thoroughly evaluated in further investigations. From technical and economic viewpoints, the cost of facility construction increases exponentially as the expected earthquake intensity increases; therefore, the expected maximum intensity IX MCS has been taken as the highest acceptable value.

Excluded areas: Most of southern Croatia (Dalmatia), including the coastal zone, Kvarner bay in the north Adriatic, as well as the so-called "Balaton morpho-lineament", i.e., the mountains of Medvednica and Kalnik in northwest Croatia. Some locations in northeast Croatia (Slavonia) are also excluded by this criterion.

3. Geology and seismology: Neotectonics (Group A)

Zones characterised by known active faults are excluded.

Comment: It is known that in neotectonically active areas, as well as in the vicinity of regional and even local active faults, dislocations and rock cracking are possible. These events could cause damage to a waste disposal facility. This safety related criterion is also supposed to be applied (or re-checked) in subsequent phases of the site selection program. In addition it should be mentioned that the term "active fault", as used here, is related to a zone that is a few kilometres in width and includes two or more parallel faults. Earthquakes with magnitudes 5.5 - 7.0 can occur along these faults.

Excluded areas: Southern Croatia, including the coastal zone, Kvarner bay, parts of northwest Croatia, as well as some spots in northeast Croatia - Slavonia.

4. Geology and seismology: Lithology and geomorphology (Group A)

Option 1: Shallow ground disposal: *Areas characterised by an increased erosion rate due to lithology (prevailing rock types) and/or relief dynamics, as well as areas composed of rocks which are unstable under natural conditions (e.g. which are not resistant to weathering etc.) after the completion of civil-engineering works, are excluded.*

Option 2: Tunnel-type disposal: *Areas characterised by land slides and rock falls are excluded if it is thought that these processes could pose a hazard to repository structures.*

Comment: Lithologic, geomorphologic and geotechnic characteristics, along with hydrogeological properties of an area, are considered the most important criteria related to the siting of an LLW/ILW repository. The upper Pliocene and Quaternary clays and Neogene marls (lower Pontic "Abichi" sediments, in particular) are considered the most suitable for a shallow-ground facility siting in Croatia. For the tunnel-type repository, areas composed of granites and some other igneous rocks are most suitable. Some metamorphic rocks like gneiss and some types of schists could also be used for this purpose. Areas which do not meet these requirements are excluded.

Excluded areas: Lowlands along the Sava and Drava rivers in the interior of Croatia, due to possible liquefaction caused by earthquakes; hills which surround the mountains of Zumberacka gora, Medvednica, Kalnik and Ivanscica in northwest Croatia and are composed of Neogene and Quaternary sands, clays and marls; flysch

belts in the Istrian peninsula (west Croatia), parts of alluvial zone of the Sava river and its tributaries, and some sections of river valleys in Istria and Dalmatia and few other spots in the karst regions.

5. Hydrogeology: Protection of water-bearing layers (Group B)

Areas containing protected sources of drinking water are excluded. In order to preserve groundwater from possible radioactive pollution, a disposal facility can not be situated in an area containing significant water-bearing layers of any type.

Comment: Hydrogeologic properties of any potential site significantly influence the selection of repository design, and also represent specific mechanisms for the assessment of possible environmental pollution. Therefore, areas of high risk for groundwater pollution are excluded at the very beginning of the site selection program. In the case of a tunnel-type repository, suitable areas are those which are composed of solid, primarily impermeable rocks having no secondary porosity. For shallow-ground disposal, the more preferable areas are composed of thick clays and marls without major aquifers. The possible impact on springs and wells, in addition to the necessary protection measures, are examined in all further site specific investigations.

Excluded areas: Parts of the country characterised by major aquifers where groundwater is not protected by near-surface layers or by formations of high porosity. This means almost all of the lowlands along the rivers of Mura, Drava and Danube, the extreme upstream and downstream sectors of the Sava river zone, as well as practically the entire karst area, which represents in fact the southern half of the country.

6. Demography: Population density (Group C)

Areas characterised by a population density of 80 inhabitants per square kilometre (i.e., the average value for Croatia) or more, within a 20 km radius around the facility site, are excluded.

Comment: One of the preferred factors in lowering the risks of nuclear facilities to human health and environmental preservation is to have as low a population density as possible. For that reason the more densely populated areas of Croatia are excluded. The population density in the vicinity of a facility will be re-evaluated in subsequent phases of the site selection program.

Excluded area: Broad areas around major Croatian cities and the towns of Zagreb, Split, Rijeka, Osijek, Zadar, Pula, Dubrovnik, Karlovac, Sisak, Varazdin and Sibenik, which are all characterised by population densities higher than 80 inhabitants/km^2.

7. Present and planned land use types: Special purposes (Group B)

Areas designated for special purposes, including their protected zones, are excluded.
Comment: Certain areas are of special interest for national defence. All areas which are, or could be, in conflict with this criterion are excluded.

8. Present and planned land use: Mining exploration of ores and minerals (Group B)

Areas in zones of present or planned mining including exploration of minerals, gas, oil, coal etc., are excluded.

Comment: Exploration of ores and minerals could have an impact on the LLW/ILW disposal facility safety, and in this way make the potential site economically unfavourable. Some limited areas along the Sava and Drava rivers have been excluded by this criterion due to existing or perspective exploration of oil and gas.

9. Environmental protection: Protection of natural heritage (Group B)

National parks, natural parks and other specific natural areas of common interest, are excluded.

Comment: In early phases of the site selection program, it is necessary to identify areas that are protected as a natural heritage and are therefore not suitable for siting a LLW/ILW disposal facility. This criterion is closely related to the requirements defined in the Natural Protection Law, which mentions specific, ecologically sensitive areas that should be continuously protected.

Excluded area: National parks (Brijuni islands, Risnjak mountain, Plitvicka jezera lakes, Velebit mountain, Kornati islands, Krka river and part of Mljet island), natural parks (parts of some mountains, rivers, swamps, islands, etc.) and other significant natural reservations (landscapes, forests, etc.)

10. Environmental protection: Protection of cultural heritage (Group B)

Areas containing monuments of cultural heritage which

are registered in the List of World Cultural and Natural Heritage, as well as those that are of an extraordinary national importance, are excluded.

Comment: It is necessary at the very beginning of the site selection process to define areas which are protected as monuments of cultural heritage, since they have to be avoided as potential sites for the LLW/ILW disposal facility. The term "cultural heritage", as used here, is applied not only to an object of interest itself, but also to the surrounding area.

Excluded area: Monuments of cultural heritage presented on the List of World Cultural and Natural Heritage (e.g. Diocletian's Palace in Split and the old town of Dubrovnik), larger areas known by their specific landscape, as well as culturally, historically and aesthetically valuable locations.

7.5.5 Comparative Criteria

After potential sites are identified by the process of exclusionary screening (including re-checking of preliminary chosen sites by the same exclusionary criteria, but applied now on more detailed maps), they have to be subjected to a comparative analysis, i.e. an evaluation based on an application of comparative criteria. As already mentioned, these criteria were defined by the expert team members and divided into four aspect groups: A - Engineering, B - Safety, C - Environmental impact and acceptability in the immediate site area, and D - Acceptability of the site, i.e. the facility in the broader area. The criteria were then classified into six thematic groups, and, according to their importance, were given corresponding weighting factors, also defined by the expert team. A total of 28 comparative criteria (see Table 7.1) were applied in the site selection program. Table 7.2 provides a list of topics to which the comparative criteria in Table 7.1 were applied.

Table 7.2. Application of comparative criteria.

Identification Number	Comparative Criterion to be applied to:
A.3.1.	Seismic Activity
A.3.2.	Soil mechanics
B.2.1.	Risk of flooding
B.2.2.	Extreme meteorological phenomena
B.3.1.	Neotectonic activity
B.3.2	Lithology and geomorphology
B.6.3.	Chemical aggressiveness of soils
C.1.1.	Transport of radwaste
C.2.1.	Distance to surface waterways
C.2.2.	Dispersion in atmosphere
C.3.3.	Presence of infiltration
C.4.0.	Population density
C.5.1.	Settlements
C.5.2.	Tourism
C.5.3.	Agriculture
C.5.4.	Forestry
C.5.5.	Industry and mining
C.5.6	Infrastructure
C.5.7.	Special purposes
C.6.1.	Natural heritage protection
C.6.2.	Cultural heritage protection
C.6.3.	Plant production (soils)
C.6.4.	Bioecological issues
C.6.5.	Radiological issues
D.5.1.	Settlements
D.5.2.	Tourism
D.6.1.	Natural heritage protection
D.6.2.	Cultural heritage protection

7.6 DESCRIPTION OF COMPLETED ACTIVITIES

The activities on radwaste repository site selection in Croatia began in 1988. Until 1991, Slovenia and Croatia had not been proclaimed as independent states, and the preliminary activities on repository site selection in both republics (i.e. states) were managed by the Inter-republic Coordination Commission in order to harmonise the site selection procedures in both countries. In Croatia, the Ministries of Energy and Physical Planning, through the Croatian Electricity Management Board, were committed to the Institute for Urban Planning of Croatia to perform the study "Site Screening, Investigation and Assessment of Site Suitability of Fossil Fuel Power Plants and Nuclear Facilities in the Territory of the Republic of Croatia". The goal of the study was the identification of preferred sites for thermal and nuclear power plants, as well as a radioactive waste repository, which might later be nominated for this purpose in the Physical Plan of Croatia. The Institute for Urban Planning created a special team of experts, to define and assess selection criteria, as well as to act decisively in identifying potential areas, potential sites and preferred (candidate) sites. The set of exclusionary criteria was defined by July 1989, and validation of criteria was carried out by the Croatian Government.

Using the method of exclusionary screening for the whole territory of Croatia (Fig. 7.1), the resulting map showing areas which "survived" exclusion of inconve-

Figure 7.4. Locations of eight potential site areas for a LLW/ILW repository.

nient regions was obtained, and eight potential areas (Petrova gora, Trgovska gora, Zrinska gora, Bilogora, Moslavcka gora, Papuk-Krndija-Psunj, Pozeska gora, Dilj) were finally identified in autumn 1990 (Fig. 7.4). Collecting additional data on potential areas and defining comparative criteria were the main project activities being worked out during the rest of 1990 up to August 1991. Site selection methodology and criteria were examined by the IAEARadioactive Waste Management Advisory Programme (WAMAP) in the spring of 1991, and were assessed as high-grade. Since autumn 1991, i.e. after the fall of former Yugoslavia, the newly established APO - Hazardous Waste Management Agency started to manage the remaining part of site selection program in Croatia. On the basis of previously performed actions, it was possible in autumn 1994 to identify 42 potential sites, which are dispersed within the above mentioned eight potential areas (Fig. 7.4). Consequently, the only task remaining in the second phase of the site survey stage is to select 3-5 preferred sites, which will be suitable for further detailed on-site investigations. This task should be done by the end of 1996.

7.7 CONCLUSIONS

The siting of a radioactive waste repository in Croatia has been adjusted to the requirements derived from physical (regional) planning documentation. The site selection program is composed of two stages: (1) a site survey, terminating with the inclusion of preferred (candidate) sites in the Physical Plan of Croatia; and (2), site evaluation to define the final repository site through field investigations and other necessary activities. There has been very slow progress in carrying out this program due to certain circumstances in the country and the

entire region, and the preferred sites will not be defined before the end of 1996.

The system approach includes a simultaneous preparation of the repository technical design, performance assessment and some additional activities. Furthermore, it would be preferable to find a site that would be convenient for a combined disposal facility, not only for radioactive waste, but also for other types of hazardous wastes. An interdisciplinary approach is applied in the site selection, where all relevant topics from geology to sociology are involved in the program. A standard site screening technique has been applied in this process. The stepwise approach to the site selection is based on validation of every single step (starting from the entire state territory), and is supposed to be terminated with the selection of few preferred sites. The program is based on the implementation of both exclusionary and comparative criteria that have been selected by a special team of experts.

The selection of a radioactive waste repository site is considered as a process leading to an optimisation of land use policy of the country in the light of attaining an optimum method of exploitation of the national resources. In addition, the site selection is conceived as an action supposed to be internationally verified, aiming to strengthen our proclamation that, "We are doing just the same as other countries". It is also worth mentioning that the radioactive waste repository site selection is part of a useful project directed to site selection of nuclear-, coal- and gas-fired power plants. Anyhow, a regularly performed site selection process could be assessed as a prerequisite for possible future nuclear energy program in Croatia.

Considerable effort is being given to a program of providing full, complete, continuous and honest information to the public. Necessary preparations for involvement of local communities into the site selection process have already been completed. Hence, democratisation in the siting process of a radioactive waste repository, as a controversial facility, could be achieved in the best possible way. It also includes the determination of incentives needed by communities living in the vicinity of the repository. In addition, being concerned of their possible NIMTOO ("Not in my Term of Office") behaviour, we are also very careful, and are doing our best to prevent "premature" exposure of politicians to the consequences of the expected NIMBY effect.

Finally, we are facing the specific problem of some malicious attempts, done mostly by certain politicians, or "experts," to explain the radioactive repository site selection program in Croatia as an action based, above all, on an ethnic criterion. It must be emphasised that in spite of arguments derived from an extremely irrational approach, these accusations could attain the end, which is not, in fact, to stop or aggravate the site selection process itself, but to deteriorate the very sensitive political and military situation in the broader region.

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