Characterization Plan for L/ILW Repository Candidate Sites in Croatia

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ABSTRACT. There have been four preferred sites for L/ILW repository selected in the siting program in Croatia so far. According to the accepted and verified site selection procedure, these sites are suitable for a more detailed characterization, including also site specific field investigations. The aim of these investigations is to measure and calculate all needed site specific parameters important for performance of safety assessment, aiming eventually with selection of the final disposal site. Both Croatian and IAEA regulations referring to radwaste repository siting procedure have been briefly discussed. Detailed site investigations foreseen to be done in order to perform a successful site characterization, refer to the following main topics: geomorphology, lithostratigraphy, tectonics, seismicity, rock mechanics, surface-water hydrology, aquifer features and groundwater hydrology, rock and groundwater chemistry, and radionuclide transport modeling. All these issues are listed in suggested site characterization format.

INTRODUCTION

Characterisation plan of preferred sites for low- and intermediate level radioactive waste (L/ILW) repository in Croatia is one of immediate actions to be carried out in further progress of national radwaste disposal facility programme. The sensitive stage of the plan performance and its application to preliminary safety assessment report is the next step in the repository programme development.

Since there have been already four preferred site selected (two of them are expected to be included into the Physical plan of Croatia), it is necessary to define and elaborate a consistent and complete characterisation plan convenient for subsequent implementation into safety assessment activities.

A briefly presented review of domestic and IAEA regulations is related to methodology and structure of siting procedure as well as to their functional and logic links and interrelations with safety assessment activities. Finally, after an overview of performed stages of siting programme in Croatia, it is suggested the plan of site characterisation to be applied in the forthcoming stage of siting activities.

SITE CHARACTERIZATION IN CURRENT CROATIAN REGULATIONS

The basic act that is currently applied in Croatia in the field of radioactive waste disposal, is "Law on ionizing radiation protection and special safety measures related to use in nuclear energy" [1], issued in 1984. From this law 17 regulations and codes of practice have been subsequently derived. Preparation of a new Croatian law on radiation protection and nuclear safety is under way.

Two regulations relevant for radwaste disposal practice in Croatia are "Code of practice on conditions of locating, construction, start-up and operation of nuclear facilities" [2] and "Code of practice on standard format of safety report and other documentation needed for safety of nuclear facilities" [3]. The law and both codes of practice mentioned went into effect in independent Croatia according to the "Law on taking over the federal laws in the field of health protection, applying in the Republic of Croatia as republic laws" [4].

With respect to radwaste disposal siting, the *"Law on ionizing radiation protection and special safety measures related to use in nuclear energy"* [1] prescribes that construction of a nuclear facility may be allowed only if the site had been previously denoted for the purpose by the Physical plan (article 28).

"Code of practice on conditions of locating, construction, start-up and operation of nuclear facilities" [2] obligates the investor of disposal facility to ensure the facility to meet all safety related site requirements (article 8). These requirements, as they are listed in the article 10, are expected to be met through elaboration of the following kinds of explorations: (1) geological, seismologic, seismotectonic and geotechnical investigations; (2) hydrologic investigations; (3) meteorological surveys; (4) extreme impacts of human activities on the site; (5) demographic and socio-economic characteristics; (6) land use and water utilization on the site; (7) other phenomena and parameters relevant for the site safety. Besides these objectives, given in somewhat wide and (particularly in point 7) imprecise form, there follow additional site requirements (article 15): (1) (water)impermeability of soils; (2) sufficient distance of a waste disposing rock layer to the water-table; (3) safety against flooding; (4) absence of springs in the hydrogeologic formation wherein the disposal facility is sited. In addition, all these requirements should be met during a 300-years long period of time since the start of repository operation (i.e. until all radionuclides are decayed and radioactivity of waste falls to the background level).

There are two sections referring to characterization of possible repository site(s) in the standard format:

1.	REPOSITORY SAFETY APPROACH	
1.3.	Safety criteria and standards	
1.3.1.	Repository site	geomorphology, hydrology, geology, hydrogeology, meteorology and climate, radionuclide migration into environment, use of disposal facility after end of operation
2.	DESCRIPTION AND ANALYSIS OF REPOSITORY SITE	
2.1.	Site description, demography and topography	
2.2.	Meteorology	
2.3.	Hydrology	
2.4.	Geology	
2.5.	Seismicity	
2.6.	Ecology	

It is finally worth mentioning to give a rough explanation of a criteria approach applied in the performed stage of radwaste repository siting process in Croatia. Due to absence of both strict methodological concept of the siting procedure and definition of site selection criteria (requirements), they had both to be established at the very beginning of the radwaste repository siting process in 1988. Thus, the criteria were defined by a special Croatian expert team in 1989 (and were confirmed by IAEA WAMAP experts in 1991), but were not approved by Croatian authorities before 1992 [5]. In complete, there were 10 exclusionary and 28 comparative criteria involved. Exclusionary criteria referred to hydrology (risk of

flooding), seismicity (earthquake capability), neotectonics (distance to active faults), lithology (type of rocks), geomorphology (slope dynamics), hydrogeology (circulation of groundwater), demography (population density and distribution), mining and ore exploitation, preservation of nature, and protection of cultural heritage. Comparative (weighted) criteria applied were classified into six subject groups: (1) transport of radioactive waste, (2) meteorology and hydrology, (3) geology and seismology, (4) demography, (5) land use and utilization, and (6) environmental protection issues.

SITE CHARACTERIZATION IN IAEA DOCUMENTS

There is a series of documents issued by the International Atomic Energy Agency (IAEA) considering site characterization as a part of radioactive waste disposal practice. They have been published in a few groups of editions: (a) safety fundamentals, (b) safety standards, (c) recommendations, (d) safety guides, (e) procedures and data, (f) technical reports, and (g) technical documents. All of them, being prepared from diverse viewpoints and at different obligatory levels, provide useful information on particular ways of actions in the field. They cover several specific thematic entities: (a) radwaste disposal planning, (b) pre-disposal activities, (c) near surface disposal, (d) disposal in deep geological formations, (e) mining and uranium- thorium treatment, and (f) disposal facility decommissioning and environmental recovery.

The IAEA safety standards define the characterization of candidate site(s) for radwaste disposal facility as a stage of the siting process, that includes all relevant actions needed for selection of a suitable disposal site [6]. The basic objective of the siting process is to select a suitable site for radwaste disposal and to demonstrate that the selected site, in conjunction with the repository design and waste package, has properties which proved adequate isolation of radionuclides from the accessible environment for desired period of time [7].

The appropriate siting process, as defined by IAEA safety guidelines, consists of four stages: (1) concept and planning stage; (2) area survey stage; (3) site characterization stage; and (4) site confirmation stage.

Site characterization itself should incorporate detailed on-site and subsurface investigations as well as related laboratory analyses necessary to provide reliable information on relevant site characteristics: geomorphology, lithostratigraphy, hydrogeology, tectonics, seismicity, hydrology, geochemistry, meteorology and impact of human activities.

Some of essential site characterization principles are:

- the geological environment (geosphere) must guarantee the necessary long-term safety without surveillance measures;
- the geosphere is treated conservatively in safety assessments; it acts primarily as hydrogeological barrier;
- the aim of site characterization is to identify a suitable site that fulfils the requirements imposed by the authorities; and
- a successful site characterization study is a prerequisite for the application for a general repository license.

There follows a few remarks regarding the role of site characterization [8]:

- the information to be acquired during site characterization depends on the needs of the repository design process and the performance assessment necessary for licensing;
- full characterization of at least one site will be essential; and
- as the site investigations progress, they will move from surface based testing and remote sensing to *in situ* testing in exploratory excavations (trenches, galleries, shafts).

CURRENT STATUS OF SITING PROCESS IN CROATIA

As it was already mentioned, the siting process in Croatia began in 1988. It started on the initiative of Croatian government. The project leading company was Croatian Electricity Utility, whilst the coordinating institution was Urban Institute of Croatia in first stage, and Hazardous Waste Management Agency (APO) in the later.

The applied siting process was conceived as two-stage procedure consisting of (1) *site survey stage* terminating with 1-3 preferred or candidate sites for further detailed on-site investigations, and (2) site evaluation stage, aiming through on-site and laboratory investigations, to define the final repository site. The first siting stage has been completed so far: starting from the entire national territory there were chosen seven potential areas, and thereafter 34 potential sites within them. Finally, four potential sites were promoted into preferred sites, and two of them have been expected to be included definitely into Physical plan of Croatia and then subjected to site investigations.

Our efforts are presently directed toward: (a) elaboration of a more applicable safety assessment as it is defined by regulations, and (2) preparation of all known data on preferred sites, preferable disposal facility design, waste characteristics and other needed elements required for the safety assessment report. Synchronously, the elaboration of applicable program of on-site investigations to be carried out in the final site characterization, i.e. site confirmation stage, is under way. Thus, the study of geoecological characteristics on two preferred sites, according to all available (site specific) data, is expected to be completed before summer 1998. In the same level of completion is the study on bio-ecological characteristics of the sites. Both documents are supposed to be very useful inputs for expecting preliminary safety assessment. In addition, a completion of the sites related database, applied also in the "Geographical Information System" (GIS) will enable an overview, application and updating of available data in any moment, as well as establishing useful simulations for environmental monitoring.

OUTLINE OF SITE CHARACTERIZATION PLAN

A successfully performed site characterization is expected to give inputs for safety assessment in terms of elaboration of the following issues:

- <u>population density and distribution</u>
  - for definition of pathway scenarios by air, soil, surface- and groundwater, plant uptake, food chains, exhumation by burrowing animals
    - provide reasonable assurance that exposure to humans will not exceed performance objectives
  - for prevention over-exposure of population
  - for prevention of contamination in case of hypothetical intrusions
- <u>groundwater</u>
  - for site specific analyses (radionuclide migration by groundwater)

- <u>rock types, slope stability, tectonics</u>
  - long-term stability of the repository (erosion, faulting, earthquakes, landsliding, surface drainage, etc.)
    - provide reasonable assurance that there will be no need for on-going active maintenance after closure

The suggested outline of the site characterization format is trying to follow the mentioned principles and safety related requirements. It includes: (1) siting criteria, (2) site investigations, (3) site investigation methods, and (4) site investigation basic techniques. All issues included are presented in the form of a list and are not elaborated in details:

1. Siting criteria

- Long term stability (integrity) of geological barrier
  - tectonics
  - hydrology
  - hydrogeology
  - erosion/uplifting
- Low water fluxes through repository
  - low permeability of host rock
  - low hydraulic gradients
  - favorable hydrochemistry
  - reducing conditions
  - pH neutral to alkaline
  - salinity low to moderate
- Dilution in the discharge area
- Radionuclide retardation in geosphere
- Low risk of incidental intrusion (e.g. mining)
- Explorability
  - demonstration of suitability is achievable with reasonable economic effort
- Acceptability and international consensus

2. Site investigations

- Geomorphology
  - vertical and horizontal dissection of relief
  - slope inclination
  - geomorphic units (distribution and analysis)
  - geomorphic processes
    - erosion capability (erosion, accumulation)
- Lithology and stratigraphy
  - distribution and thickness of lithological units
  - petrographic composition of lithological units
  - characterization of lithofacies
- Structure and tectonics
  - analysis of structural-tectonic features
  - identification of folds, faults, thrusts, etc.
  - analysis of faults (position, aging, activity, etc.)
  - distribution of fissures
- Seismicity
  - inventory of earthquakes occurred
  - microseismic analysis
  - dynamics of seismic waves (vibrations, ground-accelerations, etc.)
  - attenuation analysis

- calculation of earthquake return periods (incl. maximum expected earthquake magnitudes and ground-accelerations)
- hypocenters distribution analysis (incl. revision of existing data)
- seismic regionalization (positions and depth of hypocenters, magnitudes and intensity of earthquakes occurred, etc.)

- Regional stability
- Rock mechanics (geo-engineering)
  - identification of physical features of rocks
    - porosity (cavernosity, compactness, compatibility)
    - permeability
    - capilarity
    - distention (bulging)
    - *thermal conductivity*
    - electrical conductivity
    - magnetic properties
    - natural radioactivity (background)
- Surface water hydrology
  - identification of streams, lakes, ponds, springs, wells, etc.)
  - discharge areas
  - maximum expected water levels (1000-years, 500-years floods)
  - analysis of basic hydrologic parameters of streams (Q, q, etc.)
  - identification and analysis of torrents
- Aquifer features and groundwater hydrology
  - Rock features of non-saturated zone
    - pressure head
    - density: total (wet) density, dry (bulk) density, particle density
    - porosity (effective, bulk)
      - moisture content
      - saturation degree
      - saturated hydraulic conductivity
      - vertical hydraulic gradient
      - thickness of non-saturated zone
      - distribution coefficient (K_d)
      - longitudinal dispersivity
  - Rock features of saturated zone
    - groundwater temperature
    - density: total (wet) density, dry (bulk) density, particle density
    - porosity (effective, bulk)
    - moisture content
    - hydraulic conductivity
    - vertical and horizontal hydraulic gradient
    - groundwater velocity
    - aquifer thickness and depth of water-table
    - distribution coefficient (K_d)
    - longitudinal, transversal and vertical dispersivity
  - Groundwater hydrology
    - aquifer capability
    - groundwater dynamics (water-table fluctuation, filtration coefficients)
    - distribution of regional hydrochemical zones

- Geochemistry (rock and groundwater chemistry)
  - chemical composition (organic, inorganic, colloids)
  - ionization capability of groundwater
  - groundwater retention rate (aging)
  - pH of rock and groundwater
  - oxygen solubility rate and redox properties of groundwater
  - gas composition of groundwater
  - sorption-desorption isotherms of rock
  - chemical substitution
  - pore diffusion
  - retardation factors
  - radionuclide exchange
  - radionuclide solubility
- Radionuclide transport modeling

3. Methods of investigations

- Regional geophysical survey
  - reflection & refraction seismics
  - gravimetry, aeromagnetic survey
- Surface based studies
  - geological mapping
  - neotectonic studies, micro-seismicity
  - long-term evolution
- Geoelectrical survey
- Deep drilling program & *in situ* testing
  - hydrogeological testing
  - borehole logging
  - hydrochemical sampling
  - long-term monitoring system
- Laboratory testing
- Hydrogeological modeling
  - assessment & prediction models
- Project synthesis and conclusion

4. Site investigation basic techniques

- Regional surface work
  - geological mapping
  - remote sensing - aerial geology (interpretation of satellite imagery and aero-photogrametry)
  - sample collection
  - data review
- Correlation techniques
  - geochemical
  - geophysical
  - mineralogical
  - lithological

- Regional subsurface work
  - drilling
  - deep well studies
  - coring
  - age dating

CONCLUSIONS

Finally, according to the experience obtained in Croatia in the field of radwaste repository siting, the following remarks should be underlined:

- Croatian legislation related to radwaste disposal facility siting is not quite consistent and complete, and requires to be considerably revised and adjusted to modern international regulations;
- a few IAEA expert missions to Croatia regarding radwaste disposal facility project, that have been organized so far, gave a big impetus to the project performance, assisting to be achieved remarkable improvements;
- experience of countries having an operating repository points out hydrogeology to be the most important site acceptability related issue that will have an extraordinary importance in subsequent performance of safety analyses;
- prior to on-site investigations (drilling, geophysical surveying, etc.) start, all indirect methods - from evaluation of respective data available in bibliography up to remote sensing methods like satellite imagery and aerial photography - should be utilized in as complete extent as possible;
- relations to the public should be open, honest and complete, so that public - particularly local communities - through education and full information will be able to accept a properly performed radwaste disposal as a relevant safety related activity that will remarkably improve our care to preserve environment and protect human health.

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