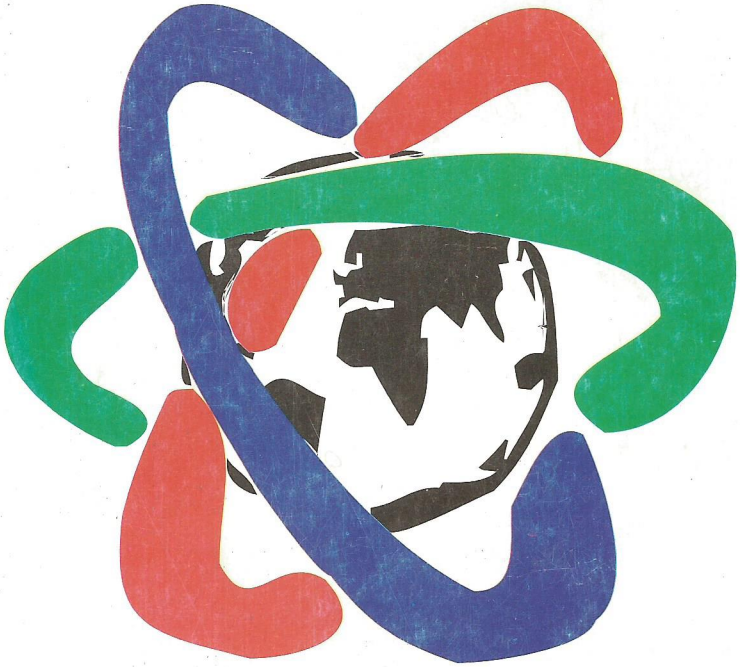

INTERNATIONAL YOUTH NUCLEAR CONGRESS 2000

April 9-14, 2000 Bratislava, Slovakia

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"KOZLODUY" NPP GEOLOGICAL ENVIRONMENT AS A BARRIER AGAINST RADIONUCLIDE MIGRATION

Dimitar Antonov

Geological Institute of the Bulgarian Academy of Sciences, "Acad. G. Bonchev" St., Bl. 24, 1113 Sofia, Bulgaria, dimia@geology.bas.bg

ABSTRACT

The aim of this report is to present an analysis of the geological settings along "Kozlodyu" NPP area from the viewpoint of a natural, protecting barrier against unacceptable radionuclides migration in the environment. Possible sources of such migration could be an eventual accident in active nuclear plant; radioactive releases either from decommissioned Power Units or from temporary or permanent radwaste repositories. The report is directed mainly to the last case and especially to the site selection for near surface short lived low (LLW) and intermediate level (ILW) radwaste repository. In Bulgaria a preliminary choice of prospective sites in different geological formations has been made. The terrains in the region of Kozloduy are among these sites since they offer advantages from the viewpoint of the local population reaction, the hazards related to RAW transport and the natural conditions. This region is calm in tectonic aspect. It is characterised by VII degree of seismic intensity according to the MSK scale and no active faults have been determined in it. Thick Neogene clays (more than 600 meters), some with sand layers, covered by Quaternary clays and loess have been deposited on the top of Jurassic and Cretaceous sediments. Beyond the range of the river Danube tributaries the relief has low segmentation. The low Danube terraces are covered by loess and the relief lowerings in the loess cover represent an interest in searching prospective sites. The positive and negative qualities of the geological environment as a host media for LLW and ILW disposal are evaluated. Special attention is paid to the properties of loess soils in which "Kozloduy" NPP is built up. The main conclusion of the geological settings assessment and the many years` monitoring is that the "Kozloduy" NPP area offers good possibilities for site selection of LLW and ILW repository.

INTRODUCTION

According to the recommended classification of the International Atomic Energy Agency IAEA (IAEA. 1994. Classification of Radioactive Waste, Safety series № 111-G-1.1) the radioactive wastes (RAW), subject to disposal, are separated into three groups:

- low- and intermediate level (short-lived) RAW (LLW and ILW)
- low- and intermediate level (long-lived) RAW
- high level RAW

In the present paper problems connected with disposal of the first kind of wastes are discussed. These wastes contain radionuclides with half-life of the radioisotops less than 30 years (including ^{137}Cs). By the whole time of the Kozloduy NPP operation (including an eventual new reactor), the quantity of such wastes, in a decommissioned form, is expected to reach almost 100 000 m^3. In most countries these kinds of wastes are disposed in shallow or near-shallow repositories. It is assumed that their harmful effect on the environment is going to last for 300 to 1000 years following their disposal.

The choice of suitable places for disposal of treated and conditioned NPP radionuclide wastes in Bulgaria has a twenty years' old history, dating back to the beginning of the 70's. It was for this purpose that in 1979 a joint committee had been founded, which, having analysed the data obtained, offers a further investigations in the loess terrains along Kozloduy and Smolyanovtsi abandoned uranium mine.

In 1986 the following sites (seeming suitable for the time) were investigated from the viewpoint of a low- and intermediate level radioactive wastes repository construction:

- The high loess terrace, located south of Kozloduy
- The loess hills, east of Ostrov villige – (Oriahovo District)
- Kochava gypsum mine – (Vidin District)
- Abandoned gallaries of Chiprovtsi mine

After several years of suspension, the work of site selection for permanent RAW repository was activated in 1991 with the Government Council Ordinance №7 assigning to the Bulgarian Academy of Sciences to "organize the working out of a Concept for National Repository for RAW". In the course of the investigations connected with the elaboration of the Concept, the guidance of the IAEA and the Commission of the European Union have been taken into consideration for the first time.

About twenty potential sites and areas have been distinguished by the method of the consecutive

elimination. A preliminary investigation has been made thereof. The above-mentioned two loess sites near Kozloduy NPP are included in them.

The methodology used and the results recieved in connection with developing the Concept became known to Bulgarian general public and abroad by a series of publications, (Evstatiev, 1995), (Evstatiev, 1997).

In 1997 a group of West-European and Bulgarian specialists finished a large project for RAW Management in Bulgaria, financed by Phare (Radioactive waste management.....1997). In this project a preliminary choice of suitable sites for LLW and ILW disposal is accepted and a methodology for further limitation of the site number is proposed.

The compilation of this paper follows the completion of another project funded by the Committee on the Use of Atomic Energy for Peaceful Purposes: "Investigations and researches for site diminution, suitable for low- and intermediate level radioactive, NPP waste disposal". There are two main aims of this project: developing a methodology for site diminution and localizing additional sites along Kozloduy NPP region.

As it is seen from the presentation up to here, in all investigations for suitable site choice, the region along Kozloduy NPP has always been included. The main reasons determining this action are the expected more favourable local population`s reaction, who are well acquainted with the real and imaginary risks of nuclear reactors operation. Besides, the expenses and the risks connected with the RAW transportation are less.

The aim of this report is to present, as briefly as possible, the geological settings along Kozloduy NPP area in their capacity of a natural barrier, which is the third part of the multi-component protecting system: waste form, repository construction and geological media. The last one is expected to provide the long-term safety of the repository. To clarify all aspects of the geological settings: the geodynamic development, tectonic, seismic, litostratigraphical, geomorphologic, hydrogeological and engineering geological conditions, they are presented in their development during the latest periods of the geological history as well as in their present state.

GEODYNAMIC DEVELOPMENT, TECTONIC STRUCTURE AND SEISMITY

The Kozloduy NPP region is situated in the north-eastern part of the Lom Depression – the main tectonic unit of the Moesian platform. The Depression is developed during the Neogene and has been inherited from a geosynclinal structure, which was formed at this place during the Paleozoic (590 – 250 Ma) and existed as an uncompenced edge lowering during the Mesozoic and Paleogene (250 – 24.5 Ma), (Yovchev, 1971). During the Neogene (24.5 – 1.64 Ma), in result of repeated regressions and transgressions of the Fore-Carpathian Basin, the Lom Depression was gradually filled up with sediments (mainly clays, with local sand intercalations) and the process of its formation as an independent tectonic structure finished therewith. At the beginning of the Pleistocene (0.78 Ma) the Danube river "penetrates" through the Panonian Basin (located mainly at the place of present Hungaria) and flows through the "wet" lowerings, made by lakes with fresh sedimentation, remains from the former Pliocene Basins. During the Quaternary the main event, which took place in the region under research, are glacial and interglacial periods. Under their impact six loess terraces and two floodplane-terraces are formed along the Danube river valley.

In tectonic attitude, the main structure in the Kozloduy NPP region, is the already mentioned Lom Depression. It had been filled up with deposits and in practice it had quitted its sinking at the end of the Neogene, i. e. 1640 thousand years ago. The following structures are also formed during the Neogene-Quaternary stage: Kozloduy-Glojenska geosynclinal; Upper Tsiber, Kozloduy, Zlatia and Oriahovo flat positive structures. At present the region is calm in tectonic aspect, as the nearest fault with proved activation is Iskur one. According to the seismic zonation of Bulgaria over a period of 1000 years (Bulgarian Building Code ... 1987), the region has seismic intensity Io of VII degree on the MSK-64 scale, which is less than the maximum admissible IX degree for LLW and ILW repository construction. The seismic constant Kc is 0.10.

LITOSTRATIGRAFHICAL STRUCTURE

Triassic, Jurassic, Cretaceous, Neogene and Quaternary sediments are determined from the data obtained by depth oil and natural gas borehole investigations. Mesosoic and Paleogene deposits are not so important from the viewpoint of the problem discussed. The Quaternary alluvial, eolian and eolian-alluvial deposits as well as the Neogene clayey and sandy sediments have a direct bearing to the problem. The Neogene sediments are separated in several formations, (Filipov, 1992).

Along Kozloduy NPP region the total thickness of these sediments exceeds 550 m. In the uppermost part of the litological cross-section, they are formed by deposits of Dacian and Romanian age. These sediments build up the bedrock of the Quaternary deposits. The cross-section of the Dacian litostratigraphic formations begins with lignitic coals, of thickness up to 10 meters, followed by sandy clays, occasionaly fatty. The upper part of the Dacian continues with gray-bluish sandy clays and sands. The Romanian sediments (overlying the Dacian ones, without sedimental washout) are represented, in their major part, by yellowish, dense greasy clays with calcareous kernels, sandy in some parts, with clayey sand intercalations. The Quaternary deposits are genetically bound to the river terraces. The typical terrace litological cross-section in its lowermost part consists of deposits with lacustrine-alluvial origin represented by gravel deposits, turning upwards into sands, admixed with gravel

and intercalated by clays. Upwards follows eolian loess horizons, alternating with so-called "fossil soils" jointly forming "loess complex", (Minkov,1968). The earlier the terrace is formed, the bigger loess horizons number it possesses. The terrace with the absolute height "carries" six loess horizons and five fossil soils, while the lowest terrace possesses only one horizon and a fossile soil is absent. Eolian-alluvial deposits (represented by reddish calcareous-sandy clays) lying between the coarse grained alluvial materials and the loess complex are also determined in the older terraces. Because of their wide spreading (from the first Danube terrace in the north to the Fore-Balkan to the south) and their continuous thickness (up to 40 m in the region under research) special attention has to be paid to the loess deposits. The loess soil is a special beige-yellowish, clayey-aleurolity, porous sediment. Its engineering properties from the viewpoint of the problem discussed will be considered further in the report. The litostratigraphic structure discribed offers good possibilities for investigation of the suitable site for LLW and ILW repository construction. The thick Neogene clay layers presence would impede the migration of the radionuclides in depth.The loess sediments are a suitable barrier in this connection as they have silty-sandy compose and a large thickness.

GEOMORPHOLOGIC CONDITIONS

The type of the relief in this area is a direct result of the main events that took place during the last geological period – the Quaternary, namely glacial and interglacial stages and loess soil accumulation by eolian way connected therewith. Great influence has been exerted by the erosional-accumulative activity of the following rivers running through the region: the Danube river (at first place) and its tributaries the Ogosta river; the Tsibritsa river; and some other smaller rivers. Taking into account all these natural proceses, they have brought about a very specific relief. First, the erosianal terraces must be mentioned. Other important geomorphologic elements are the loess plateaus situated amidst the tributary-valley Danube river system, where the loess complex reaches its greatest width; slopes that build up the zones between the terraces, where the loess soils are eroded and redeposited and their properties are modified; loess plates inheriting older existing lowerings, with varied physical and mechanical properties as well as dry valleys inherited as dried up Pliocene river valleys; etc. It is necessary to mention the loess hills blown during the Pleistocene and reaching, in some particular cases, hundreds of meters. In general, beyond the range of the Danube river tributaries, the relief has low segmentation. The conclusion about the geomorphological conditions is that they enable to localize suitable potential sites for further investigation. In this respect the most prospective sites are the Danube low terraces and the valley-like lowerings inherited from the Pliocene, where clayey deposits are very near the surface.

HYDROGEOLOGICAL CONDITIONS

There are three main hydrogeological units that may be differentiated in the region under research:

- Alluvial aquifer mainly formed in the floodplain and in the first terrace of the Danube river. It is formed by the gravels and sands and it possesses a direct hydralic connection with the river.
- Pliocene complex-built up by mighty Pliocene clays intercalated by fine-grained and clayey sands. This complex is a part of the north-eastern bord of the Lom Depression. The main lowering of the layers is to north-western direction with an angle of $2\text{-}5^0$. The task of further researches will be to clarify the hydrolic connection among the separated aquiferes, formed in the sand intercalations as well as the extent these aquiferes can spatially sustain. The exact hydrodynamical parameters are not clarified as yet. Till now, on the basic of the litostratiphical structure, it may be concluded that they occur in a large depth, and are isolated by impermeable clays and this will not be a serious obstacle in the region general assessment from the viewpoint of the task considered.
- Loess complex spreads out widespread to south all along the line south of the Danube river floodplain. It is permeable (Kf=0.5-2.5 m/25 h) with anisotropy of the filtration properties and higher values in vertical direction. The permeability varies, but in general it decreases both in depth and from north to south. Although the loess soils have relatively good sorbing capacities, as a whole they attain high values of permeability and the loess in its natural condition cannot be considered as a sufficient and reliable barrier against the eventual radionuclide migration. If the repository is built into loess soils there must be done a compaction and stabilization in advance.

ENGINEERING GEOLOGICAL CONDITIONS

The main geological risk processes in the prospective region are: loess deposits collapsibility and saturated sands liquefaction (inspired by seismic energy). As it has already been mentioned, the thickness of the silty-sandy loess in the region reaches up to 40 m. The loess complex shows not only vertical heterogeneity but also horizontal one (the percentage clay content rises from north to south). Depending on the thickness, composition and structure of the loess, the collapsibility may be developed under the geological pressure and/or under the additional load. The total deformation which could be expected under geological pressure is up to 50 cm. The colapsibility reaches its greatest values in the loess plateaus and decreases to the low Danube terraces. Our country has

considerable experience in loess improvement. The Kozloduy NPP is buit up on a soil-cement cushon. This cushon is impermeable and improves the properties of the natural loess ground as a barrier against radionuclide migration, which could take place in the process of the NPP work or after its decomissioning. The experience with Kozloduy NPP foundation may serve to the LLW and ILW repository construction. The liquefaction of the sands can also be resolved geotechnically. It was eliminated for the construction of the new big cooling canals using compact gravel columns.

CONCLUSIONS

The selection of a suitable site for LLW and ILW repository in Bulgaria is a problem under development. The general conclusion of the geological settings assessment and the many years` monitoring is that there is a possibility to search sites, in the vicinity of the Kozloduy NPP, having good protective barriers against eventual radionuclide migration. The litostratigraphical structure and the tectonic conditions in the region under research are favourable. Although there are some unclear points about the hydrogeological conditions, the data obtained show that a radionuclide migration pattern could be made. The construction of a repository in the loess complex offers great advantages provided the problems with loess collapsibility are solved. Finally, it has to be said that detailed investigations of the local geological settings properties of each site should be carried out in the next stages of the development of this problem.

ACKNOWLEDGEMENTS

The author expresses his special gratitute to Prof. Dimcho Evstatiev for his scientic support in the course of this study. The author highly appreciates the IAEA financial support, without which this paper could not have been existed.

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