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TRGOVSKA GORA - HISTORY AND STATUS OF SITE SELECTION FOR RADIOACTIVE WASTE STORAGE

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Abstract:

Due to the need for secure and adequate storage/disposal of low and intermediate-level radioactive waste (LILRAW) from the Krško Nuclear Power Plant (KNPP) in Slovenia, a micro-location in Trgovska Gora, barracks Čerkezovac, has been selected. The complex designated for waste storage/disposal occupies an area of 60 hectares and is situated southwest, approximately 3 km in a straight line from the Municipality of Dvor, while being only about 600 meters away from the state border with Bosnia and Herzegovina, coinciding with the flow of the Una River. This paper provides an overview of the history and status of this process. Analytical methods of studying relevant documentation were used in the research, including analysis of strategic documents, state reports, scientific-expert elaborates and works, as well as reactions of the interested public. Data were collected from various sources to assess the situation and draw objective relevant conclusions. The results indicate that previous strategic environmental impact assessments have superficially addressed a series of impacts and incidents representing real risks of leakage of radioactive materials into the environment. When it comes to radioactive waste management, it is imperative to assess the risk of all possible incidents, disasters, and negative scenarios in their worst possible scenarios, as it involves a long-lasting and potentially highly dangerous form of pollution located in close proximity to the interstate border, Nature Park, and Una National Park.

Keywords: *radioactive waste, Krško Nuclear Power Plant, Trgovska Gora, disposal site, storage, Bosnia and Herzegovina, Republic of Croatia*

JEL Classification: Q53, Q48, R53, R58, K32

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INTRODUCTION

The history of selecting a location for the storage of LILRAW spans decades. During this period, various methods and criteria have been applied to find a suitable location that meets all safety standards and requirements for storing radioactive waste. The aim of this paper is to provide an overview of the history and current status of selecting a location for storage/disposal of LILRAW on Trgovska Gora, as well as an analysis of factors that have influenced the selection process.

The location of the military storage complex Čerkezovac is situated in the local community of Javornik, Municipality of Dvor, at 45°2'12.29" north geographic latitude and 16°19'24.06" east geographic longitude (EKONER, 2016). It is located on the southern slopes of Trgovska Gora, at an altitude of approximately 280 meters. The complex occupies an area of 0.6 km² (60 hectares) and is situated southwest, approximately 3 km in a straight line from the Municipality of Dvor, and only about 600 meters away from the state border with Bosnia and Herzegovina, coinciding with the flow of the Una River, while being 1.6 km away from the border crossing point in a straight line. The existing structure at the specified location is an oval (elliptical) concrete construction with a rectangular inner layout, measuring 12 m x 20 m, with a total area of 240 m² (DZZRNS, 2015).

According to the expert opinion of a group of authors from Bosnia and Herzegovina within the report titled "Deficiencies in the document 'Strategic Study for the National Program of Implementing the Strategy of Radioactive Waste Management, Used Sources, and Spent Nuclear Fuel (Program for the Period until 2025 with a Perspective until 2060) of the State Institute for Radiological and Nuclear Safety of the Republic of Croatia'" from 2016, the area is connected to three state roads leading to the municipal center of Dvor. Access to the location from Dvor is via a worn local road through the Una River valley to Javornik, then via a gravel forest road northwest to the gate of the facility. The distance from the gate of the military complex Čerkezovac to the protected area within the Natura 2000 Network is only 444 meters. Depending on where the radioactive waste disposal site (RAWDS) will be located within the barracks, its maximum distance from the protected area does not exceed 1000 meters, with a terrain gradient towards the protected area of the Una River and the direction of contaminant distribution by water, soil, and air towards the protected areas.

As Croatia is a co-owner of the Krško Nuclear Power Plant (KNPP), it has undertaken the obligation to manage half of the waste generated during the plant's operation, as well as half of the spent nuclear fuel after the plant's closure. In the Republic of Croatia, a location selection project for radioactive waste disposal (RAWDS) has been conducted, designating Trgovska Gora as the only remaining potential location. Although numerous studies through elimination and comparative criteria have shown that Trgovska Gora is neither suitable nor adequate, the Ministry of Economy and Sustainable Development of the Republic of Croatia maintains the stance that previous research and measurements at this location do not indicate possible negative consequences according to the environmental impact study. However, the final confirmation of the suitability of the Čerkezovac location for the Radioactive Waste Management Center is expected after the final analysis and interpretation of the conducted research within the study, the results of which will be publicly available. At the same time, the relevant Ministry of Spatial Planning, Construction, and Ecology of the Republic of Srpska is preparing a Declaration on Trgovska Gora, a document expressing the determination of all institutions of the Republic of Srpska, as well as the stance of all institutions in Bosnia and Herzegovina in general, not to allow the construction of a radioactive waste storage/disposal site at the location of Trgovska Gora, Municipality of Dvor.

The construction of the Radioactive Waste Management Center in the former barracks Čerkezovac is planned for 2025, with the center's operations commencing in 2026.

1. MATERIALS AND METHODS

Within the methodology of this work, analysis methods were used, where a complex analysis is divided into content elements and reproductive syntheses, i.e., simple collection and merging of facts, concepts, or knowledge into a whole. After researching and identifying adequate and relevant documentation and available literature, a database was created. Using the logical aspect of scientific research, this database was utilized to define the structure of the work, classify, and draw conclusions through referencing evidence. A review of available literature and relevant documentation was conducted to gain a comprehensive understanding of the research problem. Key information and data from selected titles formed the basis for systematization to identify similarities

and differences among the observed content and to extract relevant findings leading to final results.

2. RESULTS

2.1. KRŠKO NUCLEAR POWER PLANT (KNPP) - RAW AND SNF

According to the official KNPP website and available documents, KNPP has been commercially operating since 1983, and since April 19, 2003, it has been supplying produced electrical energy to the members of the society, GEN Energy, and Hrvatska Elektroprivreda (HEP). In accordance with the Agreement between the Government of the Republic of Slovenia and the Government of the Republic of Croatia on the regulation of status and other legal relations related to investment in KNPP, its utilization, and decommissioning, KNPP produces and supplies electrical energy exclusively for the benefit of partners who have the right and obligations to take over 50% of the total available capacity and electrical energy at the KNPP threshold. The raw material for nuclear fuel is the natural radioactive element uranium. Nuclear fuel is in the form of uranium dioxide tablets assembled into fuel rods in zirconium alloy tubes. There are 121 fuel elements in the reactor containing 50 tons of uranium, of which about 95% is uranium-238 isotope and 5% is uranium-235 isotope. Energy is released when uranium undergoes fission by neutrons.

During the production of electrical energy at KNPP, low- and intermediate-level radioactive waste (LILRAW) and spent nuclear fuel (SNF) are generated, and KNPP is responsible for safely and temporarily storing these materials in accordance with international standards. After the cessation of the nuclear power plant's operation, it is necessary to ensure its decommissioning, which involves a series of procedures and works required to bring the nuclear power plant to a state where it ceases to be a nuclear facility. The selection of a location for a permanent repository for LILRAW, its construction, and management in Slovenia fall under the jurisdiction of the Agency for Radioactive Waste (RAW), while in Croatia, it is the responsibility of the Fund for Financing the Decommissioning and Waste Management of LILRAW and SNF from KNPP. After the entry into force of the Agreement between the Government of the Republic of Slovenia and the Government of the Republic of Croatia on the regulation of status and other legal relations related to investment in KNPP, its utilization, and decommissioning

(NN - International Treaties, No. 9/02), the Slovenian RAW Agency and the Croatian Agency for Special Waste prepared the Decommissioning and Waste Management Program for LILRAW and SNF from KNPP in accordance with the Strategy for Radioactive Waste Management, Used Sources (US), and SNF (NN, No. 125/14), with the participation of experts from KNPP as well as other professional organizations from both countries.

The KNPP decommissioning program was first developed in 1996. The program envisages the course and scope of technological procedures for the decommissioning of the facility and for the disposal of SNF and LILRAW after the cessation of KNPP's operation, as well as the overall costs. Funds for decommissioning must be collected during the plant's operation and allocated to a dedicated fund. In Slovenia, the Fund for Financing the Decommissioning of KNPP and the Disposal of LILRAW from KNPP was established as early as 1994, while Croatia established the Fund for Financing the Decommissioning and Waste Management of LILRAW and SNF from KNPP only in 2008.

The specific case of joint Slovenian-Croatian responsibilities for waste from KNPP also takes into account EU Directive 2011/70/Euratom on the management of SNF and LILRAW, explicitly supporting the application of the International Treaty.

According to the National Program for the Implementation of the Strategy for Radioactive Waste Management, Spent Sources, and Spent Nuclear Fuel (Program for the Period until 2025 with a View to 2060), as of 2018, the expected quantities and activities of RAW and SNF from KNPP rounded to one decimal place, representing half of the total quantities generated in KNPP, are shown in the table below.

Source and classification of RAW		Expected quantities in 2023.	Expected activity Bq	Expected quantities in 2043.	Expected activity Bq
KNPP	Low RAW	1,430 m ³	1.2×10^{13}	1,780 m ³	1.6×10^{13}
Decommissioning of the KNPP	Low RAW	-	-	2,660 t	5.5×10^{12}
	High RAW	-	-	41 t	8.0×10^{15}
IN TOTAL	Low RAW	1,430 m ³	1.2×10^{13}	1,780 m ³ + 2,660 t	2.2×10^{13}
	High RAW	-	-	41 t	8.0×10^{15}

Tab. 1: Expected quantities and expected activities of RAW and SNF KNPP

It is essential to emphasize that besides the LILRAW from KNPP, institutional RAW from RH is also planned to be deposited at the location. According to the aforementioned National Program, the total existing quantities of short-lived and long-lived RAW for the year 2015 amounted to 11.5 m³, with expected quantities by 2060 of around 100 m³, which will double the activity of long-lived RAW (3.0x10¹² Bq).

3. CHRONOLOGICAL OVERVIEW OF THE SELECTION AND STATUS OF THE LOCATION FOR STORING LILRAW

Trgovska Gora emerged as a location drawing attention as a potential storage/depository site³ for radioactive waste as early as 1979. The results of a historical review and a chronological presentation of key events and turning points that shaped the status of Trgovska Gora as a potential location are provided in Table 2.

YEAR	EVENTS AND ACTIVITIES WITHIN THE SUBJECT LOCATION
1979.	During the time of the former Yugoslavia, when the construction of multiple nuclear power plants was planned, 13 preferred locations were chosen for the placement of repositories within the territory of the former Yugoslavia.
1987.	After abandoning the idea of a federal nuclear project, the Radioactive Waste Management Service was established at the Nuclear Power Plant to lead project activities, including coordinating the development of methodologies and procedures for selecting repository locations for radioactive waste in the territories of present-day Slovenia and Croatia.
1987.	The Radioactive Waste Management Service at the Nuclear Power Plant preliminarily proposed potential areas for further research in an internal document: Psunj massif, Moslavačka mountain, Trgovska mountain, Papuk-Krndija massif, Požeška mountain, Zrinska mountain, Petrova mountain, Lasinjsko hills, and Dilj.
1988.	The company INA has been entrusted with the project of evaluating the territory of Croatia for the location of hazardous waste disposal sites, while Electproject from Zagreb has been tasked with developing a proposal for a tunnel-type disposal site solution.

³ The terms “storage” and “disposal site” are used throughout the text in accordance with the literature and documentation referenced.

1987. - 1994.	The location selection process involves four steps using elimination and comparative criteria ⁴ : 1. Selection of 12 potential areas (100 – 200 km ²) through elimination criteria. 2. Selection of 34 potential locations (2 – 20 km ²) using comparative criteria. 3. Selection of 4 locations: Trgovska gora (8 km ² , 2 micro-locations), Moslavačka gora (20 km ² , 3 micro-locations), Psunj (14 km ² , 4 micro-locations), and Papuk (8 km ² , 2 micro-locations). 4. The process concluded with the publication of the “Final Report of Phase I”, which served as the basis for the development of the Spatial Planning Strategy and Program in 1997 and 1999.
1997.	It was envisaged that all preferred locations would be included in the Spatial Planning Program of Croatia for further detailed investigation. However, during the debate in the Parliamentary Assembly, the locations of Psunj and Papuk were removed by an amendment proposed by a group of representatives, without valid arguments. As a result, only the remaining two preferred locations, Moslavačka gora and Trgovska gora, were included in the Spatial Planning Strategy.
1999.	During the debate in the Croatian Parliament when adopting the Croatian program, once again, without any expert justification, the location of Moslavačka gora was eliminated. Consequently, the area of Trgovska gora was designated for the construction of hazardous waste disposal sites.
1999. - 2004.	Through the development of a series of studies on Trgovska gora, specifically Milinkovac, Veliko brdo, and Pavlovo brdo (which constitute the Majdan micro-location), they were proposed as the most favorable micro-locations for the hazardous waste disposal site on Trgovska gora.
2001.	In the process of adopting the Spatial Plan of Sisak-Moslavina County (SMC), the county councilors unanimously adopted an amendment to remove provisions related to the disposal of hazardous waste (space for the construction of a hazardous waste disposal site) on the territory of SMC – Trgovska gora, from both the textual part and the cartographic representations of the Plan.
2013.	For the purpose of storing hazardous waste, the location Čerkezovac was considered, defined as the “non-perspective logistic complex of the Croatian Army,” situated “10 - 15 km southeast in relation to the Majdan micro-location.”

4 During the procedure, the Conclusion on Establishing Criteria for Selecting Locations for Thermal Power Plants and Nuclear Facilities, Narodne novine No. 78/92, was utilized. The regulation, adopted in 2008 by the former State Institute for Nuclear Safety (SINS), was titled “Regulation on Conditions of Nuclear Safety and Protection for the Siting, Design, Construction, Use, and Decommissioning of Facilities Engaged in Nuclear Activities,” NN No. 71/08. With the establishment of the State Directorate for Radiation and Nuclear Safety (SDRNS) in 2010, the regulation ceased to be valid, as the radioactive waste disposal site was no longer categorized as a nuclear facility

2015. - 2016.	<p>A Strategic Study was conducted, in which, through the application of the same elimination and comparative criteria, the location Čerkezovac was confirmed for the storage of hazardous waste. The conclusion stated: “By a consistent scoring system based on comparative criteria, the total value of the Čerkezovac location was evaluated at 406.0 points, while the total value of the Majdan location was evaluated at 410.8 points. The established difference of 4.8 points in favor of the Majdan location is not considered significant because both locations are within the same morphostructural complex of the Trgovska gora massif.” (EKONERG, 2016).</p> <p>The Parliamentary Assembly of Bosnia and Herzegovina adopted a Resolution rejecting the construction of storage and disposal facilities for radioactive waste on Trgovska gora, as did the National Assembly of Republika Srpska, which adopted a Resolution opposing activities related to the construction of a hazardous waste disposal site in the Municipality of Dvor.</p>
2017.	<p>In the Amendments and Additions to the Spatial Plan of Sisak-Moslavina County, in section 1.3.5. Special Purpose, the possibility of repurposing existing buildings for defense needs is mentioned, but with the consent of relevant state and local authorities and in accordance with applicable laws and regulations. Among the locations of significance for defense, the military warehouse Čerkezovac in the Municipality of Dvor is listed.</p> <p>A “Green Club” has been established, consisting of a group of representatives from all levels of government in Bosnia and Herzegovina, with the aim of enhancing public dialogue in the field of energy, renewable energy issues, climate change, energy efficiency, and environmental protection. They have also announced the possibility of arbitration before the International Court of Justice.</p>
2018.	<p>According to the Spatial Development Plan of the Municipality of Dvor, Second Amendments and Additions, Trgovska gora is not designated as an area for the construction of hazardous waste disposal sites. However, the location of the military storage complex Čerkezovac has been identified as an area of special purpose with I and II construction restriction zones.</p>
2018.	<p>The National Program for the Management of Radioactive and Nuclear Waste (Program for the Period up to 2025 with a View to 2060, hereinafter referred to as the Program) has been published, foreseeing the establishment on Trgovska gora, at the preferred location of Čerkezovac:</p> <ul style="list-style-type: none">- A central repository for institutional radioactive and nuclear waste (2019 – 2060),- A long-term (40-year) repository for radioactive and nuclear waste excluding spent nuclear fuel (LILRAW) until 2023, and- Subsequently, the disposal of LILRAW on Trgovska gora (2060 – 2065) with a preferred surface disposal type.
2019.	<p>Protests are organized in the municipality of Novi Grad under the banner “No Trading Lives” opposing the disposal of nuclear waste on Trgovska gora.</p>

2020.	<p>The Fund for Financing the Decommissioning and Management of Radioactive and Nuclear Waste has taken over the former military storage site Čerkezovac in the Municipality of Dvor from the Ministry of Environmental Protection and Energy of the Republic of Croatia for use. Fund KNPP plans to commence the construction of the Center in 2023 and complete it by 2024.</p> <p>The Coordination Body of Bosnia and Herzegovina for the Issues of Radioactive and Nuclear Waste Disposal at the Trgovska gora site, at its first session held on June 3 in Banja Luka, decided to form an expert team consisting of 21 members.</p>
2021.	<p>The Legal Team has been formed, as announced in the Službeni glasnik of Bosnia and Herzegovina, issue number 3/21.</p>
2022.	<p>The Strategy for Legal Protection of Interests of Bosnia and Herzegovina Regarding the Disposal of Radioactive and Nuclear Waste at the Trgovska gora Site has been adopted. KNPP Fund - Determination of Radioactivity at Ground Zero, Seismic Hazard Assessment of the Area, and Accessibility Road Studies were completed by the end of 2022⁵.</p>
2023.	<p>In early 2023, the KNPP Fund completed geological, hydrogeological, hydrological, and geophysical research, as well as demining of part of this former military site.</p> <p>The conclusion of the intergovernmental commission between Croatia and Slovenia (held on October 2 in Slovenia) is that neither Croatia nor Slovenia have the capabilities or capacities to take over the LILRAW by the end of 2025. Therefore, the decision was made to postpone this obligation until 2028, meaning that by then, Croatia would need to have a storage facility built on Trgovska gora.</p>

Tab. 2: Chronological presentation of the status of the Trgovska Gora location as a potential location for LILRAW

According to Delić et al. (2016), among a series of scientific and professional publications dealing with the storage and disposal of radioactive waste in Croatia, particularly significant are the studies by A. Schaller presented in 1997 in the publication “Selection of Sites for Low and Intermediate-Level Radioactive Waste Disposal in the Republic of Croatia.” This author objectively analyzes the locations that were under consideration at that time, narrowing down the number of favorable locations to four: Papuk, Psunj, Moslavačka gora, and Trgovska gora based on a comparative analysis. Schaller concludes that, based on the suitability criteria, Moslavačka gora is the most favorable location with 74.25 points, particularly standing out in criteria such as lowest altitude, favorable lithological composition, low rock porosity, slope stability, maximum and minimum relief height, and precipitation quantity.

⁵ The studies carried out by the NEK Fund in 2022 and 2023 are not accessible to the public for review, and they are only referenced within reports from specific media sources or officials.

Trgovska gora, with 44.34 points according to this criterion, is the least favorable location. Particularly unfavorable aspects include lithological composition, rock porosity, slope stability, slope gradient, relief height difference, and distance from faults.

The issue of managing Croatian nuclear waste at the Trgovska gora site has become a primary concern addressed by legal professionals regarding the legal possibilities of implementing the Croatian plan, applying international legal standards in this area, and the legal options available to Bosnia and Herzegovina to protect its interests and mechanisms to deter Croatia from disposing or storing nuclear waste. This topic has sparked significant reactions from both the general public and experts and represents a complex political issue (Popović, 2021).

4. DISCUSSION

In this section of the work, we will address part of the assessment of potential risks, possible accidents, disasters, unfavorable terrain characteristics, and environmental risks in their worst-case scenarios because it involves a long-lasting and potentially highly hazardous form of contamination.

Climate Change – According to the document “Environmental Protection Program of Sisak-Moslavina County (SMC) 2018 – 2021 Zagreb, the climate status for the period 1971 - 2000 (reference period) and climate changes for future time periods 2011 - 2040 and 2041 - 2070 were analyzed in the territory of the Republic of Croatia based on the results of numerical integrations with the regional climate model (RCM) RegCM. According to the results of climate modeling in the Sisak-Moslavina County area, a temperature increase between 1.5 °C and 2 °C is expected by 2040. The precipitation projection for the Sisak-Moslavina County area until 2040 predicts a very slight increase of up to 30 mm, while a slight decrease in precipitation is expected in the further future (until 2070).

According to ENSEMBLES simulations, by the end of the 21st century, increasingly larger parts of Croatia will be affected by more pronounced changes in precipitation. This primarily concerns the dynamics of flood occurrences, which, in the case of increased dynamics, can act as complicating factors in the use of planned infrastructure objects in the county during floods. There is also a possibility of an increase in the overall flood area beyond the current affected areas.

Since the radioactive waste disposal site must be functional and under supervision for a long period (several hundred years), the impact of climate change (if it occurs as predicted) on the integrity of the radioactive waste disposal site must be considered. This primarily refers to the vulnerability to flooding, erosion, landslides, etc. Since it involves radionuclides, the analysis should consider worst-case scenarios rather than averages.

Floods - The entire Una River basin is characterized by strong surface and subsurface erosion processes and flash floods. The result of erosion processes in the basin is the degradation of arable surfaces in the hilly area and the filling of streambeds with sediment in the lowland area, causing the rise of groundwater levels and flooding of lowland areas along the watercourses. The Una River floodplain area near Dvor is exposed to flooding from the Una River and its tributary, the Žirovac River (Regional Forum for Environmental Security and Cooperation, group of authors, 2016).

According to the Urban Planning Document for the Settlement of Dvor, flooding of the lowest areas along the Una River begins with the arrival of a water wave of 800 m³/s, and floods have often been catastrophic, causing the inundation of roads and surrounding agricultural land during high water levels of the river.

One of the major floods recorded in Croatia over the past century includes the flooding of the Una River in 1974. Flooding in Pounje was also recorded in 2009, 2010, and notably in 2013, when extreme rainfall from January to April contributed to the formation of numerous large water waves, and in 2014, in October, when new extreme precipitation resulted in large water waves on the Una River. In May 2023, some border crossings on the Una River were closed due to floods. Considering that the main roads providing access to the proposed location are traced along these rivers (the roads from Croatia Kostajnica – Dvor - Javor and the road from Glina - Donji Žirovac - Dvor), occasional floods could significantly impede access, specifically the transportation of radioactive and nuclear waste to the location. In the Disaster Risk Assessment Study of the Republic of Croatia, Chapter 6, Scenario, Subsection 6.6 - Floods Caused by Overflow of Inland Water Bodies, the entire territory of the municipality is characterized as a high-risk area.

The Suspected Hazardous Area (SHA) - According to the Development Strategy of the Sisak-Moslavina County 2017-2020, through Appendix 2: Situation Analysis, a total of 92 km² is considered a suspected hazardous area in the Sisak-Moslavina County. Specifically, the Municipality of

Dvor, where mine-uncleared areas occupy a total of 22.5% of the SHA of the county, with a 4.1% share of the SHA of its total area, is identified as the most endangered local self-government unit (LSU) within the county.

According to data from the Croatian Mine Action Centre, in the immediate vicinity of the military location Čerkezovac, there are mined suspicious areas (MSA) that are scheduled for demining. These areas extend along the peripheral zone of the entire military storage complex, i.e., along the complex fence from the lower entrance to the vicinity of the command facility on the ridge.

Seismic movements - Earthquakes in the Sisak-Moslavina County (SMC) area are relatively frequent. The epicentral area of Kupa is located in the space between Glina, Sisak, and the mouth of the Glina River (Spatial Plan of SMC, 2017).

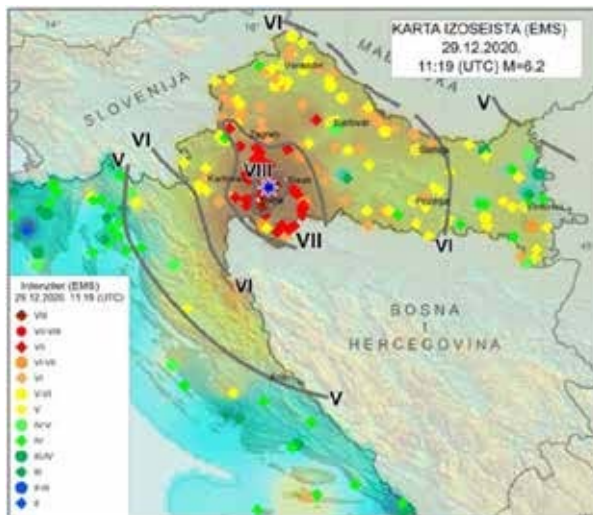


Fig 1: Iseismic map of the earthquake on December 29, 2020. Source: https://www.pmf.unizg.hr/geof/seizmoloska_sluzba/potresi_kod_petrinje/2020-2021

In the area of the city of Sisak (47 km aerial distance from Trgovska gora), earthquakes could cause damage to around 15,000 objects and threaten 50,000 people, even though the area is not within a unique seismic zone. According to the seismic map, certain parts fall into zones 6 - 7 of seismic areas, with an earthquake zone intensity of 7° - 9° on the MSC scale (Control Bureau, 2018).

According to the Spatial Plan of the Municipality of Dvor from 2006, the area of Trgovska Gora is characterized by very complex tectonic

relations with layers disturbed by numerous faults of different intensities and ages. Lower-order faults have been identified, which have broken layers differently, as well as transverse faults and displacements that extend up to several tens of kilometers, along which there have been intense movements of blocks. The Municipality of Dvor is located in VI and VII zones of maximum earthquake intensities and lies on seismically active or potentially active sections in zones along longitudinal faults and sections along transverse and diagonal faults with horizontal block displacements and structures.

On December 29, 2020, the area around Petrinja was struck by a devastating earthquake with a magnitude of 6.2 on the Richter scale and an intensity of VIII degrees on the EMS scale at the epicenter. Seven people were killed, and significant material damage occurred in Petrinja, Sisak, Glina, and surrounding areas. Many residential and commercial buildings throughout the Sisak-Moslavina, Zagreb, and Karlovac counties were damaged. Numerous coseismic ground ruptures occurred in the broader epicentral area, mainly landslides, sand boils, collapsing sinkholes, and cracks on roads.

Ekonerg states that north of the area of the Čerkizovac location (3.5 km to 4.0 km), there is the fault line of Glina – Prijedor (the zone of the Žirovac fault), which is part of the Dinaric extension, partly with transpressive features and right horizontal displacement. Taking into account the intensity of the earthquake in Petrinja in 2020 and the intensity in the surrounding area, Figure 1 clearly shows that the area of Trgovska gora is located in intensity zone VII.

In the Petrinja earthquake series, according to the descriptive classification based on the estimated maximum earthquake intensity in the epicentral area, the following earthquakes with magnitudes greater than 2.0 occurred (until December 15, 2021)⁶:

1. One devastating earthquake (the main earthquake that occurred on December 29, magnitude M6.2, with an intensity of VIII-IX degrees on the EMS scale)
2. Ten strong earthquakes (from VI to VII degrees on the EMS scale)
3. Twenty-two fairly strong earthquakes (from V to VI degrees on the EMS scale)
4. Eighty moderate earthquakes (from IV to V degrees on the EMS scale)

6 https://www.pmf.unizg.hr/geof/seizmoloska_sluzba/potresi_kod_petrinje/2020-2021

5. One thousand two hundred fifty-nine weak earthquakes (with intensities from III to IV degrees on the EMS scale)

In the National Program in Appendix IX (Description of the Preferred Location of Čerkizovac), it is stated that the maximum expected earthquake intensity (I_{\max}) at the location is not greater than 8° MCS. Looking at the Mercalli intensity scale, it can be seen that an earthquake intensity of 8°, as stated by the authors, is described as destructive with effects such as chimney collapses and building damage. An intensity of 8° MCS cannot be considered a situation without significant seismic activity, whether it is indigenous or a consequence of earthquakes outside the zones.

Damage to the ground – erosion and landslides - According to the classification of ground damage, erosion and landslides belong to the third degree of heavily non-renewable (irreversible) damage. Erosive processes refer to the migration of surface soil materials under the influence of water or wind and occur in three stages: detachment of soil particles from the mass of soil, transport by wind or water, and deposition. The intensity of erosion depends on the slope of the terrain, the amount of precipitation, the terrain cover, wind speed and frequency, and soil characteristics (Bašić, 1995).

By examining the maps of potential and actual risk of water erosion created according to the CORONE method, which represents a qualitative cartographic method for assessing the risk of water erosion, the territory of the Dvor Municipality and the micro-location Čerkizovac are characterized as areas of moderate and high class of actual risk of water erosion. Based on a complex multicriteria analysis, a total of nine environmentally (and structurally) relevant relief (slope) bonity categories are distinguished - from very unsuitable (category 1) to most valuable (category 9). Slopes in the vicinity of the Čerkizovac location are classified into the category of mostly unsuitable slopes (category 3, subcategory b). The main reasons are relatively high slope gradients of the slopes (12° - 32°) and shallower soil depth (50 cm - 80 cm). Slopes of this category may experience the development of sliding and gully erosion processes, as well as occasional slippage and collapses. The average relief energy, which expresses the measure of maximum vertical relief dissection (in meters) per unit area (km²) for the Čerkizovac area, is about 140 m/km² (National Program of Strategy for the Management of Hazardous Waste).

Forest land - Stormy weather, fires, floods, and erosion cause habitat fragmentation, resulting in the direct consequence of damage and loss of forest and forest land, which can lead to edge effect where microclimatic conditions (humidity, light intensity, wind speed) are different than in the interior, thus leading to increased intensity of the primary causes of damage (increased susceptibility to forest fires at the forest edges due to reduced humidity, intensified erosion, etc.). We are talking about a potential loss of stability of forest ecosystems and a reduction in the overall beneficial functions of forests such as: soil protection from water and wind erosion, prevention of floods and high water waves, and mitigation of greenhouse gas effects by carbon sequestration and enrichment of the environment with oxygen. The hydrological function of forests is reflected in the increase in precipitation and water content in the soil, slowing down water runoff, and retaining and properly distributing snowfall.

Fires - According to available data, about 1/4 of the total number of forest fires occur in continental Croatia, making the Sisak-Moslavina County, besides Karlovac County, the most endangered by fires with a high risk. In extremely hot and dry years, an above-average number of wildfires have been recorded throughout the territory of Croatia. Due to climate change, fires are increasingly prevalent even in the inland areas of Croatia. The lack of forest roads, clearings, and other physical barriers favors the rapid development and spread of fires in open areas, both forested and agricultural land.

The Dvor Municipality, as well as the macro-location of Trgovska Gora, namely the micro-location Čerkizovac, is located in the territory of Croatia, which, according to the document "Risk Assessment of Disasters for the Republic of Croatia," is defined as an area with a high potential for wildfires. Parts of agricultural land are neglected and uncultivated, and due to overgrowth and lack of maintenance of field roads, they represent a potential danger for the occurrence and spread of fires. During the burning of waste in dry periods and the failure to take basic protective measures, fires can break out and spread over neglected agricultural and forested areas. In this regard, it is necessary to mention the neglect of parts of forested areas in private ownership for which there are no management programs, and due to the age of the owners or other reasons, the forests are not maintained in accordance with professional standards.

According to the Environmental Protection Program of the Sisak-Moslavina County for the period 2018-2021, there are four illegal waste dumpsites in the area of the Dvor Municipality, and fires are a

characteristic phenomenon for such dumpsites. These fires pollute the atmosphere with toxic by-products of incomplete combustion and cause significant environmental pollution in the form of smoke and airborne pollutants. Additionally, there is an additional risk of fire spreading to surrounding vegetation.

A review of the assessment of fire and technological explosion hazards in the Sisak-Moslavina County from 2018 emphasizes that part of the hydrant network for firefighting in the area is not in functional condition in terms of the quantity of above-ground hydrants, pressure, and water quantity in the network in most settlements or parts of settlements. In some settlements, the external hydrant network has not been installed. Through expert opinions within the framework of the Regional Forum for Environmental Security and Cooperation, a group of authors noted that at least nine minefields are located in the forest belt around the Cherkizovac location. In the event of forest fires, these terrains are inaccessible, or they cannot be extinguished from the ground due to the risk of unexploded ordnance. Moreover, due to the distance from the Adriatic Sea, it is very difficult to ensure firefighting with aircraft in case of fire.

From the perspective of risk management regarding natural and anthropogenic fires, this location is extremely unfavorable because it lacks any infrastructure for firefighting and control and is communicationally distant from centers that can react promptly in case of a fire.

The infrastructure - The infrastructure review from 2018 encompassed, in part, the transportation infrastructure, including main routes and lower-order roads. Lower-order roads are generally in poor condition and have a low level of technical standards and safety. The characteristics of these roads lag behind the rapid development of vehicles, and speed limits and road profiles are limiting factors in smooth traffic flow. Additionally, the width of roads in settlements is not satisfactory, especially in old urban cores where there are problems with accessibility. Main traffic routes can be considered safer and well-marked, while feeder roads connected to these routes pose an increased risk due to the number of intersections, bends, signaling, and traffic density.

The transportation of hazardous materials requires greater precautions than those during packaging and storage. There are additional risks in transportation, such as the effects of variable forces, climate changes, and potential traffic accidents that can cause real catastrophes due to the release and action of hazardous materials. By decision on the determination of roads for motor vehicles transporting hazardous materials and determining places for packing motor vehicles with

hazardous materials, it has been specified that the transport of hazardous materials on the roads in the county is allowed for transportation from the port and Sisak Refinery DC 37 Sisak (DC 36) - Popovaca (A3). The transport of hazardous materials on other county roads is not allowed, except in cases of supplying economic entities, gas stations, and residents.

In the Strategic Study, it is stated: "For the transportation of half of the NSRAO from KNPP, quantities that will arise until 2043, it will require 400 to 500 transports, and by 2060, another approximately 350 transports for the LILRAW from the decommissioning of KNPP. These are approximate estimates," and they add, "Related to transportation, a study on transportation optimization and security will be conducted." In the event of a traffic accident, the consequences for the population, material goods, and the environment would be lasting and immeasurable. The road where a traffic accident occurs would have to be closed to traffic for the time needed by the competent services to address the consequences, which in this case would also mean closing the border crossing.

Cross-border impact - the first and key remark from the Expert Opinion document from 2016 is that within the Strategic Study for the national program implementation of the strategy for the management of radioactive waste, used sources, and spent nuclear fuel (Program for the period until 2025 with a perspective until 2060), cross-border impact was not analyzed, thus violating Croatian and international legislation provisions on cross-border impact.

The storage of nuclear waste planned by the Republic of Croatia on Trgovska Gora, which is located on the border with Bosnia and Herzegovina in its northern part, raises controversies and entails possible far-reaching consequences for the population, plant and animal life, and the environment itself. Competent institutions at all levels of authority in Bosnia and Herzegovina have a unanimous stance on the unacceptability of disposing of radioactive waste in the immediate vicinity of the border, as it would endanger the environment and the health of residents in 13 municipalities in the Una River basin in Bosnia and Herzegovina.

Given that the criterion of political power is not grounded either in Croatia or in international legislation, it can be noted that activities are being carried out contrary to international standards. The opposition of the local population and neighboring Bosnia and Herzegovina is increasing, and there is no doubt that it will strengthen. If Croatia persists in its intention, it will lead to jeopardizing the bilateral relations between the two countries, as well as regional security. The population and expert

public generally understand the essence of the problem well enough to realize that it involves imposing a location that is least suitable according to suitability criteria but is most desirable according to political power criteria (Delić, et al., 2016).

Popović and Jović (2022), in their work “The Case of Nuclear Waste Disposal on Trgovska Gora in the Republic of Croatia” clearly emphasize that Bosnia and Herzegovina has committed to finding a solution through diplomatic means with Croatia to protect its interests and mechanisms to deter Croatia from implementing the disposal of nuclear waste at that location. By the decision of the Council of Ministers of Bosnia and Herzegovina (Službeni glasnik of BiH, No. 3/21), a legal team was formed to develop a strategy for the legal protection of the interests of Bosnia and Herzegovina related to the issues of disposing of radioactive waste and spent nuclear fuel at the location of Trgovska Gora. The Council of Ministers of Bosnia and Herzegovina, upon the proposal of the Ministry of Foreign Trade and Economic Relations, unanimously adopted the Strategy for the Legal Protection of the Interests of Bosnia and Herzegovina regarding the issues of disposing of radioactive waste and spent nuclear fuel at the location of Trgovska Gora in October 2022. According to the statement from the Council of Ministers⁷, the Strategy contains a comprehensive legal analysis within the context of the national and international legal framework, which provides a legal basis for the conclusion that Croatia has violated, among others, the ESPO Convention and the SEA Protocol from 2003, and the Aarhus Convention from 1998 on access to information, public participation in decision-making, and access to justice in environmental matters.

While the finalization of a new environmental study is expected from the Croatian side by the end of 2023, a Declaration on Trgovska Gora is being prepared in Bosnia and Herzegovina, a document expressing the determination of all institutions of Republika Srpska, as well as the stance of all institutions in Bosnia and Herzegovina in general, not to allow the construction of a radioactive waste repository at the location of Trgovska Gora, in the Municipality of Dvor. Until the publication period of this paper, the contents of the studies carried out neither by the Croatian side nor the studies by the expert commissions of Bosnia and Herzegovina are not available to the public.

⁷ https://www.glassrpske.com/cir/novosti/vijesti_dana/usvojena-pravna-strategija-za-trgovsku-goru/440397 accessed November 29, 2023, at 3 P. M.

CONCLUSION

Through the available analyzed literature and documentation presented in the study, the entire process of selecting the location has been shown to be forced, unprofessional, inadequate, and scientifically weak. The data and research presented clearly confirm the fact that the Trgovska Gora location does not meet either the physical-geographical or the socio-demographic criteria for managing radioactive waste.

The macro-location of Trgovska Gora remains the only location for storage/disposal of radioactive waste, as the Psunj, Papuk, and Moslavačka Gora locations were excluded from further consideration without objective analysis and solely based on political will. The multi-criteria analysis used in the 2014 study for selecting the storage/disposal site was based on elimination and comparative (weighting) criteria selected by the Regulation that ceased to be valid in 2010.

In the introductory and concluding parts of the study, the terms storage and disposal of radioactive waste are intentionally used together because the presented study, nor other strategic documents, make a clear distinction between them, particularly failing to specify additional measures related to permanent disposal and requirements that are significantly stricter than storage. By using both terms in certain parts of the analyzed study, the question remains open whether this signifies the ultimate intention for Trgovska Gora to be a permanent disposal site rather than a radioactive waste storage facility.

There is no mechanism by which storage is automatically converted into a disposal site, considering that they are physically different facilities with different security and other requirements.

When it comes to managing radioactive waste, it is an absolute imperative to conduct a risk assessment of all possible accidents, disasters, and negative scenarios in their worst possible outcomes because it involves a long-lasting and potentially highly hazardous form of contamination. A more detailed assessment of meteorological factors and climate change is necessary. The danger of anthropogenic and natural fires was not analyzed in previous studies, and new ones are not publicly available. Seismic activity analyses are incomplete, especially considering earthquakes that have occurred in this area in the last 3 years. In the event of forest fires, these terrains are inaccessible, or they cannot be extinguished from the ground due to the danger of unexploded ordnance, and because of the distance from the Adriatic Sea, it is very difficult to secure firefighting with water bombers. The risk assessment of floods is based on older

data, and the response to them is mentioned as organizing radioactive waste transport outside flood seasons. The infrastructure of the disposal facility, as described in available documents, is characterized by roads in poor condition. In the event of a traffic accident, the consequences for the population, material goods, and the environment would be long-lasting and unforeseeable.

New research conducted by the Decommissioning and Radioactive Waste Management Fund of the Krško Nuclear Power Plant through 2022 and 2023, preceding the final environmental study, is not accessible to the public as of the submission of this work, thus continuing to violate the transparency of the process and the involvement of the interested public. All available research so far has been done without any data beyond the administrative border of the Republic of Croatia, and it is evident that two-thirds of the potentially most endangered area around the location are located precisely on the side of Bosnia and Herzegovina, which would inevitably lead to the disruption of relations between the two countries and the initiation of international arbitration due to violations of provisions governing conditions for the disposal of radioactive waste and provisions of the Aarhus and Espoo conventions.

Considering all the aforementioned points, it is necessary for relevant institutions and decision-makers to carefully consider alternative locations for managing radioactive waste, taking into account not only political and technical criteria but also geographical and social ones.

An acceptable solution implies the annulment of the decision regarding the selection of the location and the initiation of a new procedure for selection based on valid and newly selected applicable elimination and comparative criteria, as well as the direct involvement of the interested public in the process. Additionally, one of the solutions could be to store the Croatian portion of radioactive waste together with the Slovenian portion, which already has a certain adequate location for waste disposal.

ТРГОВСКА ГОРА - ИСТОРИЈАТ И СТАТУС ОДАБИРА ЛОКАЦИЈЕ ЗА СКЛАДИШТЕЊЕ РАДИОАКТИВНОГ ОТПАДА

Јелена Згоњанин
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Сажетак:

Због потребе за сигурним и адекватним складиштењем/одлагањем ниско и средње радиоактивног отпада (НСРАО) из нуклеарне електране Кршко (НЕК) у Словенији одабрана је микролокација на Трговској гори, касарна Черкезовац. Комплекс предвиђен за складиштење/одлагање отпада заузима површину од 60 ha и смјештен је југозападно, на удаљености око 3 km ваздушне линије од Општине Двор док је од државне границе са БиХ, која се подудара са током ријеке Уне, удаљен свега око 600 метара. Рад доноси преглед историјата и статуса овог процеса. У истраживању је кориштена аналитичка метода проучавања релевантне документације, односно, анализа стратешких докумената, државних извјештаја, научно - стручних елабората и радова, те реакција заинтересоване јавности. Кориштени подаци су прикупљени из различитих извора како би се сагледала ситуација и донијели објективни релевантни закључци. Резултати показују да су досадашње стратешке процјене утицаја захвата на околину сасвим површно обрађивале низ утицаја и акцидената који представљају реалне ризике цурења радиоактивних материја у животну средину. Када је у питању збрињавање РАО, апсолутни је императив да се изврши процјена ризика свих могућих акцидената, непогода, и негативних варијанти у њиховим најгорим могућим сценаријима јер је у питању дугоживући и потенцијално високо опасан облик загађења који се налази у непосредној близини међудржавне границе, Парка природе и Националног парка Уна.

Кључне ријечи: радиоактивни отпад, Нуклеарна електрана Кршко, Трговска гора, одлагалиште, складиштење, Босна и Херцеговина, Република Хрватска

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