Use of underground excavated space for disposal of low radioactive mining waste resulted from uranium ore exploitation. Study case

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Abstract. The article presents the actual situation of the Avram Iancu uranium mine, located in Romania; where important quantities of radioactive waste rock from the uranium mining industry accumulated and become a major risk for the environment. The result of the analysis of the particular conditions of this mining perimeter was that the relocation of the contaminated material in the abandoned mines pits is the most advantageous solution regarding the long term protection against radiation and the costs.

Introduction

The increasing quantities of radioactive waste resulted from the geological research and extraction of the uranium ore raises serious ecological and economical problems. The past development of the uranium extraction industry in a manner insufficiently controlled regarding the environmental problems seriously affects the ecological balance in the area of the uranium ore extraction. The radioactive waste resulted from the uranium mining industry was deposited in waste rock piles with surfaces of thousands or tens of thousands hectares. The management of these waste rock piles, mainly formed out of radioactive waste with low uranium content, is actually a serious problem regarding the contamination of the environment.

Under these circumstances, the main objective of the long term treatment of the low radioactive uranium waste rock is to eliminate the risk of contamination by storing it in secured underground locations, preferably in abandoned mine pits resulted from the exploration or exploitation of the uranium resources.

The most favorable solution for the application of this procedure is in the case of the mines still operated but scheduled for closure, where the technical situation and the layout of the pits and adits is known and the machinery to be used for the relocation of the waste is available.

Even in the situation of a non-radioactive mining waste, that does not raises the radioactive contamination risk, the relocation of the waste rock in the abandoned mining pits and adits is in most cases the only suitable solution, technically and economically, for the ecological rehabilitation of the abandoned mining areas.

The case study presented here is an example of the use of the abandoned mining pits for the disposal of the radioactive waste rock generated within the perimeter of Avram Iancu uranium mining facility, which is actually under a program of closure and ecological rehabilitation.

The solution decided after the feasibility study prepared for the Avram Iancu mining facility, taking into consideration the complex geological and geo-morphological conditions of the area was the relocation of the radioactive waste into the abandoned mining pits.

The mining facility Avram Iancu

The Avram Iancu uranium delf was developed as one of the most important production centers for uranium ore, exploited for a long period of time. The place is situated in the southern part of the Bihor mountains, in a region that is the cut-water between the hydrographic basin of Ariesul Mic and Crisul Negru rivers

The region is a high mountain area with altitudes between 720m and 1840m, where the geological structure is formed of crystalline slates belonging to the Unit of Biharia. The geological complex is formed out chlorite slates with albite porphyryblasts, quartzy-chlorite-albite slates, chlorite mica-schist, crystalline limestone and magma products metamorphosed with granodiorite intrusions.

The hydro-thermal activity led to the establishment of some economical areas in the region, some of these being based on the uranium extraction - one at the Avram Iancu mine and another one at the Baita open pit.

The uranium mine was exploited through the horizontal adits.

The economy in the region of Avram Iancu mine is based on forestry, lumber industry, farming, exploitation of polymetalic sulphides and molybdenum and tourism in the nearby areas, which generated the demand for programs of environmental protection.

The risk assessments made in the area revealed as main sources of surface and underground pollution the waste water of the mines and the waste rock piles where the low-radioactive uranium waste rock was deposited.

The production center Avram Iancu was closed due to the exhaust of the ore reserves and due to the reorganization of the mining activity at national scale.

Starting with 1952, the year when the mine was opened, important quantities of uranium waste rock with low radioactivity were generated and deposited in differ-

ent dump-sites, positioned on the valleys of Ariesul Mic, Crisul Negru and Dedes rivers, on terrains with slopes of more than 20^0.

All this waste rock piles must be ecologically rehabilitated in such a way that the limits of the maximum admissible concentration of the pollutants, established through the national and European legislation are not exceeded.

The characteristics of the waste rock piles

The waste resulted from the mining activity was generally disposed in waste rock piles placed nearby the mine entrances and represent the major risk regarding the quantities, the radioactivity and the radius of impact - high due to the transport agent - the water.

The waste rock piles in the area of the Avram Iancu mine have many similarities:

- they are placed in woody areas
- they are placed on terrains with inclinations of more than 20^0
- they are situated in the immediate vicinity of water courses
- they have only one level of up to 30 meters
- the slopes of the waste rock piles have inclinations between 30 and 45^0

The analysis of the radiological risk revealed areas of the waste rock piles with external gamma radiation of more than 0,3μSv/h (table 1).

The closure procedure decided for the ecological rehabilitation of the Avram Iancu mine, was the relocation of the waste rock and contaminated material in the abandoned pits.

This option was taken because it was the most advantageous for the specific conditions of the mining area Avram Iancu, easy to realize and with the lowest costs compared with other solutions.

Table 1. Characteristics of the waste rock piles.

Dump site	Contaminated area (m^2)	Volume (m^3)	Level of external radiation (μSv/h)	
			0.3-0.45	over 0.45
Gal. XIV – XVI	2000	4400	x	-
Gal. X – X bis 2	1600 / 350	3400 / 700	x	x
Gal. 1, 2, 4	80	100	x	-
Gal. XII	10	20	x	-
Gal. 6	100	75	x	-
Gal. XI vechi şi XI nou	75	100	x	-
Gal. XVI bis	2100	2000	x	-
"A", "B","C","D"	500	250	x	-

The identification and evaluation of the underground location for the relocation of the waste rock

The following aspects were examined before the relocation of the waste rock in abandoned pits was started:

- The actual state of the mining works
- The geological suitability of the relocation area
- The conformity with the requirements concerning the Environment, health and safety compliance

The actual state of the mining works

Along the conservation period, the horizontal mining works were preserved in good shape. Best conserved were those located on the transport and circulation track (adits XXIII, Noroc Bun, XVI bis and blind pit no. 2)

The blind pit no. 1 is no more operational and the connections with the mining works network were closed, so its actual state is no more known.

The ventilation stations Dibarz, gal. XVI Vest, Izvorul Bihorului and Valea Vacii-Valea Leucii are out of order; the only one remained functional being at gallery XVI bis (eastern area).

It is necessary to execute remedy works on the underground access to west and south-west areas, on the galleries XIV, XVI west, and Dibarz 902, as the access to these areas is only possible from underground, till the surface access is re-established.

The Geology and the Hydrogeology of the underground environment

The decision to relocate the waste rock in the abandoned pits was decided after a complex geological, geochemical, geotechnical and hydrological evaluation.

From the geological point of view, there are no incompatibilities between the host rocks and the waste rock, as both are part of the same delf an equilibrium was established during the geological evolution. There are low chances of chemical interaction between the mineral components of the two systems, which can create new pollutants.

The geological environment is characterized by a natural fissuration of the rocks, but the mining activity generated supplementary breakdowns in the rock massive.

The fissuration according to the actual state of the mining works does not significantly influence the stability, as the excavations were made in hard rock that did not necessitate support of mines.

The role of the fissuration is also not important regarding the water infiltrations in underground. The hidrogeological research and the long history of the Avram

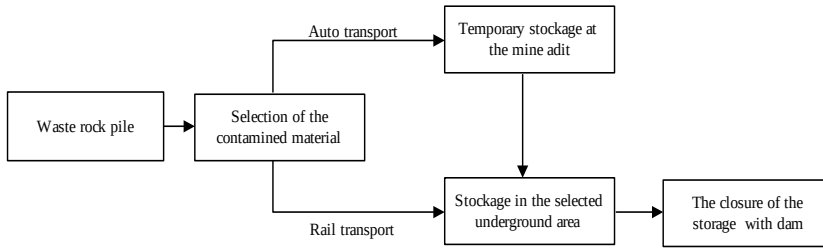

Fig. 1. The main steps in disposal of radioactive waste from the pile to the storage places

Iancu mine demonstrated that the underground water penetrated into the mining works only when the fissures communicated through major active faults.

The relocation places were chosen out of the areas affected by fissures and active faults.

The chemical analysis of the underground waters underlines two critical aspects for establishment of the relocation places:

- the determinations for carbon bioxide indicate the absence of the aggressiveness against concrete.
- the pH between 6.2 and 7.6 show a slight acid tendency but insignificant regarding a high chemical aggressiveness.

The conclusion was that the infiltrations of water in the relocation areas will not create chemical disequilibrium that can generate supplementary pollutants.

The Environment, health and safety compliance

The relocation of the radioactive mining waste in the abandoned pits must be made in respect of the regulations concerning the protection of the environment and human health.

The radiological security norms established for the management of the radioactive waste from the mining and preparation of the uranium and thorium ore (NMR - 02/2002) explicitly recommends that the solid waste represented by mineralized rocks and waste rocks generated by the opening and operation of the mines "can be and must be used as filling material for resloping of the pits and other mining works, starting from the operational age of the mine"

The same national regulation recommends that when the solutions for the mine closures are analyzed, of a great importance is to check the possibility to use the waste rock as filling material for resloping and other mining works, situated in the deep area of the mine.

Other recommendations and regulations are given through the following documents:

- the law of the environmental protection
- the law of the waters

- the law of the mines
- the law concerning the safety of the nuclear activities

The planning and the execution of the mining works

The relocation of the radioactive waste rock from the surface to underground areas of the mine pits took place following a simple planning chart (Fig.1), based on the technical possibilities available at the Avram Iancu mine.

The selection of the radioactive material was made by radiological measurements on the waste rock piles and at the mine entrance.

After selection, the waste rock was transported to the underground relocation area either directly from the waste rock pile or from temporary piles containing material brought from other piles, according to the different conditions existing in the western and eastern sectors of the mine.

The load of the material and the transport to the mine adits were made with a front loader and trucks. The transport of waste rock within the mine, in the transverse galleries and the reshaping were made mechanized, where possible, and manual.

Table 2. The underground locations of repository and its characteristics.

Mine work	Level of external gamma irradiation μSv/h	Resloped length (m)	Cover thickness (m)	Distance to the gallery entrance (m)
Gal. 25.1.16	0.30-0.45	150	325 – 330	1000
Gal. 21.1.16	0.30-0.45	150	290 – 300	900
Gal. 8.1.16	0.30-0.45	50	290 – 310	840
Gal. 6.1.16	0.30-0.45	150	290 – 310	800
Gal. 4.1.16	0.30-0.45	150	240	960
Gal. Tr. 3	0.30-0.45	50	240	640
Gal. 4.a	0.30-0.45	150	240 – 260	620
Gal. 5.a	0.30-0.45	50	220	580
Gal. 4.c	0.30-0.45	150	230	460 – 560
Gal. 4.b	0.30-0.45	150	220 – 230	460 – 560
Gal. 3.1.16	0.30-0.45	150	260 – 270	540
Gal. 2.3.1.16	0.30-0.45	150	180 – 190	580
Gal. 2.1.16	0.30-0.45	50	180 – 190	580
Gal. 1.c	0.30-0.45	150	170	520 – 540
Gal. 14.1.16	>0.45	300	320 – 330	900 – 1200
Gal. 12.1.14	0.30-0.45	150	330	1060
Gal. 2.18.1.14	0.30-0.45	50	260	1100
Gal. 20.1.16	0.30-0.45	50	270 – 280	1100
Gal. 9.1.16	0.30-0.45	150	270	800
Gal. 17.1.16	0.30-0.45	150	270 – 280	1150
Gal. Dir. 1.14	0.30-0.45	150	over 100	1000

After the reshaping of the material, at the mine adits were closed with dikes. The waste rock with a gamma activity of more than 0.45 μSv/h (approximately 900 m^3) was relocated in one separate gallery with supplementary security measures.

The volume of radioactive contaminated material was of approximately 3 m^3/m of gallery. The relapsed length and the characteristics of storage places are presented in Table 2.

Types of disturbances and potential dangers

The evaluation of the disturbances that can appear in time must take into consideration that the relocation and the storage of the radioactive waste rock in the abandoned pits is definitive, as it is connected to the mine closure.

In the case of the Avram Iancu mine, the solution that was chosen for closure guarantees the long term safety.

The future possible potential dangers, concerning the stability and the security of the relocation areas may be considered as unforeseen events generated by the following causes:

- subsidence phenomena
- topographical modifications
- modification of the hydrogeologycal configuration
- landslides

Analyzing the factors that lead the transmission of the underground fallings towards the surface, on the basis of calculations that take into consideration the physical and mechanical properties of the rocks, the thickness of the cover and the void size left after the settlement of the embankment, it resulted that only a small part of the upper part of the cover is affected. There are not expected subsidence phenomena that may lead to the creation of natural water reservoirs with infiltration potential.

On the other side, the locations selected for definitive storage of the waste rock are placed outside the area of influence of the exploited space and not in the vicinity of profound active faults.

The stability of the surface guarantees the geo-dynamical long-term external geo-dynamical equilibrium, without topographical modifications or important landslides.

From the hydrogeologycal point of view, as long as the underground fallings are not transmitted towards the surface, there are not expected any important infiltrations in the relocation areas, this way the waste rock remaining in a dry state.

The risk of environment contamination with radionuclides is minimum, except the waters infiltration due to the unexpected events. In this case the danger is eliminated by free flowing of the waters up to the radioactive depollution stations – module following the route of mining works (Fig. 2)

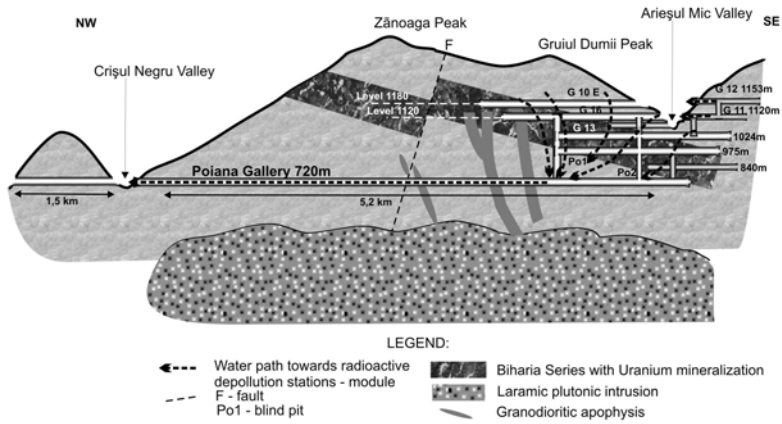

Fig. 2. Schematic cross – section of Avram Iancu uranium mine.

Conclusions

The paper presented here is an example of using the underground excavated space for disposal of the radioactive mining waste resulted from uranium ore exploitation in the case of a mine which is under a program of closure. The preservation of horizontal mining works in a good shape and the favourable geologycal – mining conditions, were the reason that decided upon the procedure of contaminated material relocation in the abandoned pits.

The deep disposal of the radioactive mining waste, the stability of the covering rocks and the favorable hydrogeologycal conditions guarantee the long term safety in respect of the regulations concerning the protection of environment and human health.

This option is the most advantageous for the specific conditions of the mining area Avram Iancu, easy to realize and with the lowest costs compared with other solutions, because a lot of activities are included in the mine closure programme.

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