

THE IMPACT OF EXPLOITING LIGNITE IN LUPOAIA OPEN PIT ON ENVIRONMENTAL WATER

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Abstract: *The impact of extracting lignite in Lupoaia open pit over waters is local and regional, and temporary. The hydrographic network in Lupoaia open pit depends on River Motru, with its afluent, Ploștina and Lupoița Valley Rivers. The aquifers are to be found in the coal layers V-XII, mainly of sands formation. The impact over water in Lupoaia consists of water pollution and of changes in both the quality and the quantity of ground and surface waters. The surface waters are polluted resulting in industrial wastewaters, household wastewaters and waste rainwater. The wastewater is polluted within maximum admitted limits. The quality of groundwaters is influenced and modified by extracting coal resulting in the extinction of some aquifers. Environmental risks that can occur when extracting lignite are water floods, landslides, disasters which can be prevented by building guard channels around the open pit. The actions for reducing the impact are, in general, accomplished through monitoring both the water pollutants and the morphological changes caused by extracting lignite. That is why wastewater treatment plants must function. The impact of the activity in Lupoaia open pit over the hydrographic net of the area is to be observed during the entire extracting period, and monitoring this activity is highly demanded by the European environmental protection laws.*

Keywords: *hydrographic network, impact over water, ground waters, surface waters, wastewater, monitoring, water treatment, pollutants, diminishing the impact*

1. Introduction

Water is absolutely vital to any forms of life and to any social and economic activities, so its management is highly important for rational use and exploitation. [1]

Mining implies a large amount of water and this causes pollution to natural receivers or consumers. Water management means considerable problems for both water supplying and using in technological process, for water purification and for its dumping in natural rivers or creeks. [2]

The carboniferous basin of Motru has numerous surface water and groundwater sources, with the most important one: Motru River.

The impact of exploiting lignite in Lupoaia Mine can be seen in the changes of the hydrographic regime, in the chemical water impurity, and it affects both groundwaters and surface waters in the area.

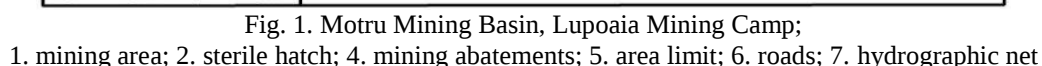
The groundwaters and surface waters are polluted during the entire period of mining, leading to a long term breaking into the hydrodynamic balance.

The potential environmental impact is maintained over the entire period of lignite exploiting and it determines a permanent vulnerability of waters.

2. The hydrogeological description of the area

The hydrogeological conditions of the area of Lupoaia area are correlated with the formation of geological structures, consisting of a complex succession of clay and sand, intermingled by coal layers. [3] The hydrographic net in the area of Lupoaia open pit is represented in figure 1.

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- surface water aquifers
- deep aquifers

Deep aquifers are located in pliocene deposits, and they can be found under pressure or by free level. Their supply source is represented by atmospheric rains that infiltrate deep in the sandy erosion area.

The aquifer from the top of the 5th layer is bench-shaped (1-5), separated by sandy clay, with 0.55 to 18.51 metres thickness. The sandy horizons consist of fine sands, dusty clay sands, which can be found on the top of the V layer, at a distance of 1.2 to 9.5 metres. The hydrostatic level is to be found between 198 metres and 224.5 metres, which leads to a low hydrostatic level, below the top of the 5th coal layer, and so it can be safely exploited.

The aquifer in the VI-VII layers consists of 1 to 4 benches of sandy horizon, lens-shaped. The thickness of the horizon is between 0.5 metres and 8 metres. The hysdrostatic level is under the VI-VII coal level, so it leads to the exploitation of this aquifer.

The aquifer that is to be found between the VII-VIII lignite layers contains fine sands.

77

The aquifer horizons covering the 12th layer consisted of lens-shaped sands, varying between 5 and 10 metres thickness.

The groundwater supplying systems in Lupoia open pit area are:

- the village of Miculești, with the drilling systems, at 250 metres depth;
- the town of Motru, with the villages of Ploștina, Roșița, Horăști, Însurăței and Leurda;
- the commune of Cătunele, with the villages of Cătunele, Valea Perilor, Steic, Valea Mănăstirii and Lupoia.

The delimitation of the area for sanitary protection, according to a strict regime, for all the water sources was completed according H.G. number 930/2005. [5]

The water net in the area of Lupoia is subordinated to Motru River via Ploștina Creek (hydrographic basin code VII.1.36.6) and to Valea Lupoița River (hydrographic basin code VII.1.36.5). Motru River springs from Vulcan Mountains, flows for 134 square kilometres and its basin area is of 1900 square kilometres.

In the area of Lupoia Quarry, there are two waters, Lupoița Creek and Ploștina River, with the following affluents: The Black Valley, Țigănele Valley, Mărgelu Valley, Cervenii Valley and Draga's Valley.

The regularization works operated over Motru River, for exploiting coal, are the following ones:

- the completion of a section of 7980 metres, between Ohaba River, downstream, and the guard channel, upstream;
- the completion of a 5740-metre dammed section, between the guard channel, upstream, and Loștina River, downstream;
- the aim of completing these sections is the protection from sterile tailings Motru town and Lupoia.
- the technical solution consists of deviating the section via a double-trapezoidal section, the width of the minor river bed = 50 metres and the width of main river bed = 150 metres.

The functioning regime is continuous $Q_{\max} = 1500 \text{ m}^3/\text{sec}$.

For Ploștina Creek and for Lupoia, the regularization has been completed on the length of 2100 metres and $Q_{\max} = 150 \text{ m}^3/\text{sec}$ and $113 \text{ m}^3/\text{sec}$. The impact of exploiting per day results in reducing the groundwater supplies and the changing of the hydrodynamic regime. By reducing the groundwater supplies, flora and fauna are considerably affected, together with ground waters.

3. Estimating the impact

Waters protection remains a priority among worldwide issues due to the efforts people make to ensure the compatibility among the economic development, the rational usage of natural resources, keeping the ecologic balance and improving the quality of this environmental factor. [4]

The impact of extracting coal in Lupoia open pit consists of changes in both quantity and quality of ground and surface waters.

The impact on surface waters leads to:

- water diversion, remodelling, building canals and dams;
- creeks and rivers changes;
- extinctions of some creeks;
- changes in the quality of some surface waters and of some creeks;
- surface water pollution caused by leaking fuel or other chemical substances used in mining.

The impact on groundwaters revolves in:

- changes in underground river courses;
- pollution of groundwaters by fuel leaks or residual water release;
- lowering the groundwaters level;
- changes in the quality of surface waters.

In Lupoia open pit, the impact on waters is determined by:

- excavations and dumping leading to changes in the quantity of water in Lupoița Valley;
- changes in surface waters courses in Lupoița Valley and Ploștina;
- residual water evacuation that produces changes in surface waters quality;
- rainwater and drying water evacuation that changes the quality of surface water in Ploștina and Lupoița Valley;
- changes in underground courses regime;
- low working quotas determine the extinction of old aquifers and the appearing of new ones;
- lowering water level and even discharging some creeks caused by lowering the piezometric level;
- excavating and transporting that modify both physical and chemical balance of groundwaters;
- erosion.

Also, the impact on water determines changes in the relief of the area; changes in groundwater levels and in increasing the quantity of surface waters resulted from drainage activities.

We further display the impact of the main operations developed in Lupoia open pit over the environment as follows:

Firstly, the mining camp is prepared by cutting down the trees, eliminating household decommissioning and fertile soil recovering, making it free from pollutants that are not to be overflowed into the waters.

The substances that are to pollute waters are fuels, lubricants and wastes used in machine operation. Another source of pollution is the fecal matter from the authorized personnel that works at the open pit.

In the actual mining stage, all the activities involved in extracting generate wastewaters, such as:

- fecal wastewater
- drying waters resulted from raining and infiltration in the open pit area.

Wastewater from the pit headquarter is drained into Lupoia Creek after being purged in their own purging station.

The stage of closing and greening is accomplished by land modelling, using earthmoving equipment, and organic cultivation. These activities do not result in water pollution. The sole substances that are most likely to pollute are the fuels used to operate the machines, in an inappropriate usage.

4. Water pollution sources

The surface and groundwaters from the area we analysed are polluted by mining, but, according to A. N. M. P. Gorj, the maximum admitted concentrations are within the limits.

4.1. Surface waters pollution sources

Surface waters are polluted by raining wastewater washing the coal deposit, by household wastewater and by industrial water used to moisten the material in the technological process.

4.1.1. Industrial wastewaters

The industrial wastewater is the wastewater from the open pit and from dumping that are not purged before being evacuated in rivers and creeks. The wastewater is polluted because of the suspensions used in transporting the sterile when moistening the material in the technological process.

The required water quantity for moistening is 20000 l/24 h, within the technological wastewater volume can be calculated by using the equation 1, according to STAS 1846/90:

$$Q_u = 0,8 \times Q_s \quad (1)$$

where

Q_s = the average technological water flow required per a day (m^3/day)

Q_u = the average volume of wastewater per day (m^3/day)

Q_u average per day = $0,8 \times 20 m^3/day$

Q_u average per day = $16 m^3/day$

The daily moistening water quantity must be reduced by mounting filters responsible for absorbing dust from suspension during the technological flow. The industrial waters are to be infiltrated into the sterile deposit and the infiltrations are decanted through the drainage systems mounted on the bottom of the deposit in the preliminary stage. [1]

The water supplying for moistening the material is made through water tanks.

4.1.2. Household wastewater

Household wastewater is resulted from mining in Lupoia open pit. The fecal matter from the workers also pollutes water. In order to reduce surface water pollution, built collecting basin and channels were built, from where water is evacuated through guard channels.

Purging household wastewater is accomplished in the station within Lupoia open pit by using an Imhoff aerator, followed by evacuating the water in Lupoia Creek.

The household wastewater is resulted during the mining process and its quantity cannot be reduced; they can only improve the efficacy of the purging systems for a higher quality of the water evacuated, which is within the admitted limits.

The quality indicators of household wastewater are presented in table 1.

Table 1. The quality indicators of household wastewater

Quality indicators	M.U.	Measurements						Maximum admitted values NTPA 002/2005	Analysis method
		Household wastewater within the open pit			Drilling water				
		2019	2020	2021	2019	2020	2021		
1.Physical indicators									
Temperature	°C	17	18	16	16	13	15	35	
2. Chemical indicators									
pH	pH units	6.3	6.1	6.1	7.08	6.8	6.5	6.5-8.5	SR ISO 10523-97
Suspension materials (MS) ²	mg/dm ³	58	62.5	84.23	13	11	7	35.0(60.0)	STAS 6953-81
Biochemical Oxygen consumption every 5 days (CBO5) ²	mg O ₂ /dm ³	11.10	11.80	15.56	-	-	-	25.0	SR EN 1899-2/2002
Chemical Oxygen consumption (CCO _{Cr}) ²	mg O ₂ /dm ³	21.02	22.89	29.78	1.78	1.90	1.90	125.0	SR ISI 6060-96
Nitrogen amoniacal (NH ₄ ⁺) ⁶	mg/dm ³	0.15	0.13	0.18	0.1	0.1	0.1	2.0 (3.0)	SR ISO 5664:2001 SR ISO 7150-1/2001
Nitrites(NO ₂ ⁻) ⁶	mg/dm ³	1.9	1.2	1.70	-	-	-	1(2.0)	SR EN 26777:2002
Sulphates (SO ₄ ²⁻)	mg/dm ³	113	112	148	-	-	-	600.0	STAS 8601-70
Phenols entrained by water vapour (C ₆ H ₅ OH)	mg/dm ³	-	-	-	0.0001	0.0001	0.0001	0.3	SR ISO 6439:2001 SR ISO 8165/1/00
Synthetic detergents	mg/dm ³	0.1	0.9	0.15	-	-	-	0.5	SR EN 903:2003 SR ISO 7875/2-1996
Chloride (Cl ⁻)	mg/dm ³	-	-	-	10.21	8.60	9.4	500.0	STAS 8663-70
Filtered residue at 105°	mg/dm ³	170	160	170	180	175	170	2.000.0	STAS 9187-84
Calcium (Ca ²⁺)	mg/dm ³	-	-	-	68	81	84	300.0	STAS 3662-90 SR ISO 7980-97
Total ionic iron (Fe ²⁺ , Fe ³⁺)	mg/dm ³	-	-	-	0.47	0.29	0.35	5.0	SR ISO 6332-96
Magnesium (Mg ²⁺)	mg/dm ³	-	-	-	47	40	44	100.6	STAS 6674-77 SR ISO 7980-97

4.1.3. Rain wastewater

Rain wastewater is the rain water washing up the coal deposit and the open pit platform and contains pollutants as powders and petroleum products. Petroleum products can affect the surface water quality because of inappropriate storage and because of leakage. Water can also be polluted during machines fuel supplies.

4.2. Groundwater pollution

Because of the extraction process at Lupoaia open pit, groundwater sources have been polluted, determining modifications. (Figure 2)

Future extension of the work front will increase drainage influence on groundwater level in Lupoaia area. Since 1985, ICSITPML Craiova has conducted researches and studies estimating the drainage influence, based on mathematic patterns, over the area. Analysing the evolution of the drainage systems and comparing it with the initial parameters of the aquifers, observed in the drilling process, specialists succeeded in simulating a drainage process in open pits in different locations or positions depending on the flow directions of groundwater sources. [1]

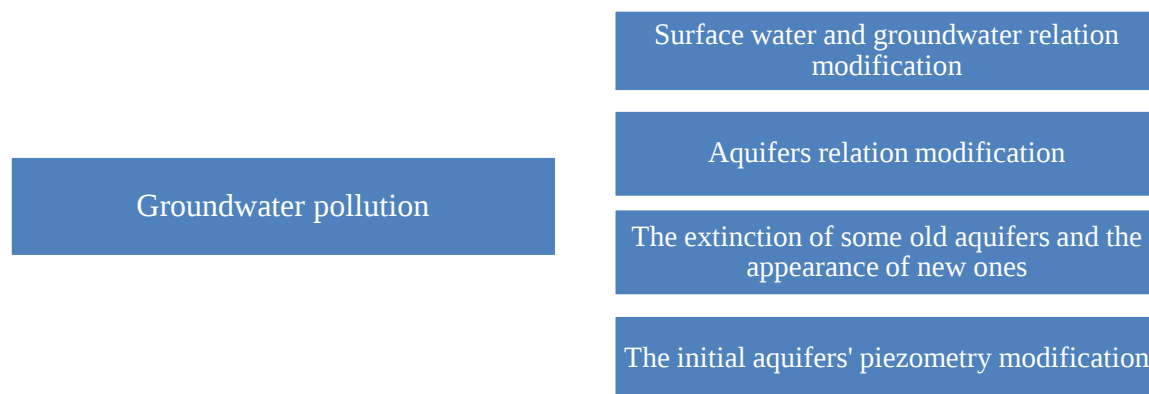


Fig. 2. The pollution effects on groundwater

There are changes in groundwater caused by aquifers pollution and by their chemical composition modification. The aquifers are also affected by the excavating process and by charging the surface water with particles or impurities.

The work that is being done at the surface of the open pit, the petroleum material contamination, fertilizers and other pollutants cause reduction in the aquifers quality.

Besides chemical composition, there are also:

- pH decreasing;
- lowering the general piezometric level;
- deterioration of quality indicators;
- disruption in the aquifers continuity.

Total hydraulic restoration of aquifers would be possible only if the open pit was closed, and partial restoration could happen in case of heavy long-term rains.

Currently, a freatic aquifers restoration in Lupoia open pit area has not been possible because of the short distance between the two pits, Lupoia and Roșița.

Hydraulic aquifers restoration in the coal complex is very low because of the quaternary formations, that do not allow water to infiltrate, and because of the sedimentary accidents. The artesian aquifer is hydraulically restoring very quickly because its development is based on continuous fuelling, and recent research has proven that drainage must be accomplished before the heart of the coal pit gets to the 5th coal layer.

From a hydrogeological point of view, by observing the evolution of groundwaters levels in the body of the open pit, two-sandy-level aquifers were identified, on different depths, as it follows:

- a surface level obvious in most of the drillings (FP1, HG1, HG2, FP5, HG4, HO2, HG5, HO3, HG8, HO4, HG7, HO5, HG6, FP3, FP4, FP7, G1, G2, G3), situated at 0.5 – 5.0 metres under the terrain level, reporting monthly changes in the depth (quota) of groundwater, caused by direct influence of rainwater or infiltrations, and also changes in the existence of a surface drainage, natural or directed; the waters are generally at a free level, captive at times, slightly ascending;
- a ground level, situated at 10-15 metres under the terrain level, intercepted by the drillings HO1, HG3 FP2, HO6, between +335.35m and +314.4 m. The monthly measurements also highlighted changes in groundwaters depth, but less obvious than in the case of surface waters level. [1]

The technogenic regime of groundwaters sustains the watering of surface aquifers, by direct and indirect infiltration from surface waters, and, as a consequence, by activating the global hydric balance within the depression boundaries. [3]

5. Risk Situations

Regarding landslides and land stability, there are some compulsory measures to be applied:

- following the technological norms of excavating and dumping;
- following the geometrical elements of both work stages in an open pit and dumping area and final ones, by maintaining the general slope angle both in the pit and in the dumping area and by maintaining the slope angle during working and at the final stage – according to geotechnical studies;
- permanent management of groundwater and rainwater within the mining area, by building step channels, guard channels, outlets for collecting and transporting pit and dumping waters and, respectively absorbing and collecting draining systems in zones where there are risks of landslides and high humidity;
- affore stating the working area.

In order to avoid water floods and landslides, field protection against the excessive water flow from the valleys in the mining area must be accomplished by building channels on definite steps or even outer from the exploiting area. Within the area, there are channels for guiding water on the outline of their platforms.

In addition, in order to provide transportation on the guard channels, periodical clearing works and vegetation removals are required. Within the exploiting perimeter, solid suspensions settling, during heaving rains and afterwards, is highly sustained by collecting basins, called sumps. Conducting rainwaters and infiltrations to sumps placed in sites with the lowest levels is done by a local net of ditches, channels and drains.

Water evacuation from the heart of the pit and from the wide benches on the slopes of the excavating steps, outer the pit, is done by pumping stations evacuating into the valleys nearby. At the stations from the pit heart, the pumping capacity is calculated so that the water volume, considered for 2% accumulation, should be evacuated within maximum 24 hours (according to the law).

In order to prevent pit floods, any activities conducting to partial or total damage in hydrotechnical water draining and collecting the torrents works are forbidden.

6. Measures of impact reduction

In order to reduce the impact over water, permanent surface waters monitoring is required for registering quality and morphological changes, and groundwaters monitoring their qualitative and quantitative analyses.

The maintenance of the purging systems at their highest functional level within the pit is also important. The measures for reducing the impact over water due to the preparing stages of the exploitation, the exploiting of the geological extracted material and the closing and greening period are as follows:

The preparatory stage for exploiting:

- avoiding contamination with toxic substances;
- avoiding losing fuels from the machines by periodical checking;

The geological material extracting stage:

- applying prevention measures and accidental pollution control, according to current norms;
- ensuring optimal operation of the purging systems within the headquarters of the pit in order to maintain water evacuation within limits;
- ensuring storage for waste material in order not to be dumped into surface waters;
- maintaining machines in optimum operation by periodical revisions;
- manipulating fuels in specially designed sites in order not to pollute water and soil;
- maintaining the guard ditches for collecting rainwaters.

The closing and greening stage in extracting lignite

- the appropriate storage of dangerous substances;
- periodical checking of machinery for avoiding accidental fuel leakage;
- performing operations in order to avoid floods on the slopes and in the valleys unaffected by mining during greening.

7. Environment protection measures

In order to avoid water contamination, protection zones at the beginning of the water supplying works were settled, considering all the factors, local, natural and atrophic, that can determine water contamination:

- geomorphological, geotechnical and geotectonic characteristics of the site;
- hydrogeological structure and parameters of the layers situated above the captured aquifer;
- surface water quality, when they are hydraulically connected to the captured aquifer;
- capture exploitation regime;
- the punctual and diffuse sources of existing pollution;
- other characteristics observed at the sites;

Water protection measures during exploiting:

- applying prevention measures and accidental pollution control, according to current norms;
- an optimum functioning of the purging systems within the pit in order not to break with the maximum water evacuating concentration;
- ensuring the compliance with the technical norms for installations exploitation;
- protecting surface waters by not allowing any dumping of waste material into waters;
- ensuring an optimum functioning of the installations by periodical checking, according to specifications from the technical data sheets.

- ensuring collecting rain waters from all the pit functioning stages (opening, preparatory and exploitation).

In order to avoid pollution, absorbing materials will be used, placed in the most likely to be polluted sites, that is in the fuels, waste materials and lubricants storage areas. In order to also protect water in the area of Lupoia pit, all the waste material, fuels and oils must be pre-collected in sealed or watertight tanks and periodically carried to specially designed storage areas and, finally, to an authorized waste storage.

A permanent monitoring of the pollutants is required, on both surface waters and groundwaters by collecting samples, from times to time, to be analysed at the laboratory. Monitoring of both the quantity and the quality of the water evacuated from the pit resulting from freatic horizons, from raining and from fecal matter wastewater is also required.

The monitoring of household wastewater and dewatering into their emissary, Lupoița Creek and Ploștina Creek is also required during functioning. The collected data must be compared to the admitted values in H.G. no. 352 /2005. [6]

8. Conclusions

The impact over water caused by extracting coal in Lupoia open pit is a long-term one, local and regional, lasting during the entire period of mining. This impact influences both the quantity and the quality of water due to polluting of surface water and rainwater, to lowering the piezometric levels, to reducing underground water supplies by changing the whole hydrodynamic regime. The impact over water lasts during the entire pit functioning period determining an increased and permanent vulnerability, due to changing the natural balance and to polluting.

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