The exploitation of lignite deposits in relation with the surface and groundwater in the mining area — The case study of Potamia basin, Thessaly, Greece

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Abstract The aim of this paper is to investigate the correlation of water resources and exploitation of lignite deposits. This research took place in Elassona basin, in Thessaly, where two lignite deposits have been found, but the exploitation of them has not started yet. Multiple criteria have been analysed (geological, hydrogeological, hydrological, hydrochemical etc) with the purpose of estimating the changes that will be caused during the mining activities in the area. The difficulties that the surface and groundwater cause to the lignite exploitation are also examined.

Key Words mining, aquifers, hydrogeology, surface run-off, groundwater

Introduction

Elassona basin is located in Thessaly, Central Greece. It is crossed by the Titarisios River, which drains an area of 107.75 km^2. The geological basement of the basin belongs to the Pelagonian Zone.. In Potamia basin, (Elassona –Thessaly), two lignite deposits of 187.5 × 10^6 tn (Domeniko: 167 × 10^6 tn and Amourion: 20.5 × 10^6 tn) have been identified (Dimitriou 1997). The exploitation of these two lignite deposits will result in changes of the natural and human environment of the area.For the understanding and estimation of the environmental impacts that will incur from the prospective lignite exploitation, the evaluation of the current hydrogeological, hydrological, geomorphological characteristics and the land use is of great interest. Specifically, the water balance, hydrometeorological data, quantitative and qualitative analysis of the drainage networks of the area were studied. In this paper we compare the current status in the area to that existing 30 years ago and anticipate the trend in the future. At this time there are no specific plans for the exploitation of these two lignite deposits, the research is in preliminary stage.

Geological Settings

The basement of the Neogene basin of Elassona geotectonically belongs to the ''Pelagonian Zone'' (IGME sheet, 1987). It consists of (figure 1):

- Marbles of the middle Triassic, which form the north outcrops near Evagelismos and Paleokastro and part of the south-east boundary of the basin, near Domeniko. They also have been penetrated by some boreholes in the basement of the basin.
- Schists, gneiss-schists and gneisses, which underlay and form a ''ring'' around the above mentioned karstified marbles.
- The Paleozoic gneiss with acid intrusions of granites, which forms the western boundary of the basin.

Hydrogeological settings

Hydrogeological conditions of this area determine the exploitation or not of these deposits. The area is covered by Quaternary and Neogene deposits, in which the permeability varies. Potamia basin is more or less surrounded by impervious formations, schists, gneiss-schists and gneisses, which form impermeable boundaries. (Beloukas 1988) The overlaying marbles of the Pelagonian series are of limited extend and thickness, especially in the area of Evagelismos and in the basement of the basin, the total recharge volume of it was estimated at about 3 × 10^6 m^3/year. So they are of minor importance concerning their water storage capacity. In the same formation, south of Domeniko, groundwater flows mainly to the east and has a discharge point out of the basin. The only karstic formartion of major importance is the one of the autochthonous series north of Kefalovriso (karstic massif of Krania). Groundwaters have significant recharge from infiltrations, percolations of rivers, torrents and karstic volumes (Manakos, 1999).

The springs at Kefalovriso (40 × 10^6 m^3/year) with an average flow of 1.3 m^3/sec is the main discharge point of the above mentioned karstic aquifer (figure 2). These marbles as well as the Titarisios River are the main sources of recharge for the aquifers of the filling of the basin at the northern boundaries of it. It was estimated that an average quantity of 28 × 10^6 m^3/year, are percolated in the karstic mass of Krania (Vasileiou 2011).

There is also rich surface run-off. The springs at Amourio area (figure 3; 13 × 10^6 m^3/year), in the alluvial sediments of the basin. Additionally, the basin is crossed by Titarisios River (109 × 10^6

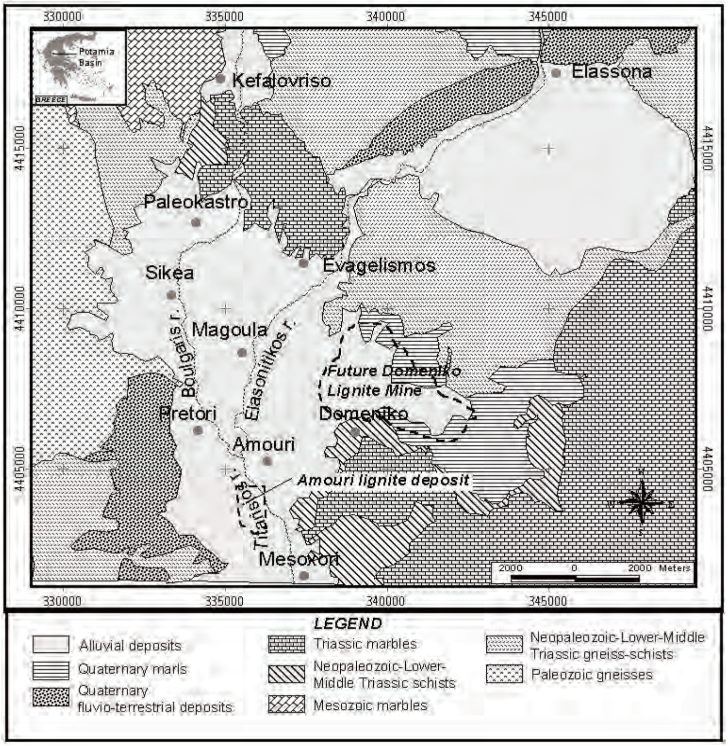

Figure 1 Simplified Geological map of the Potamia basin.

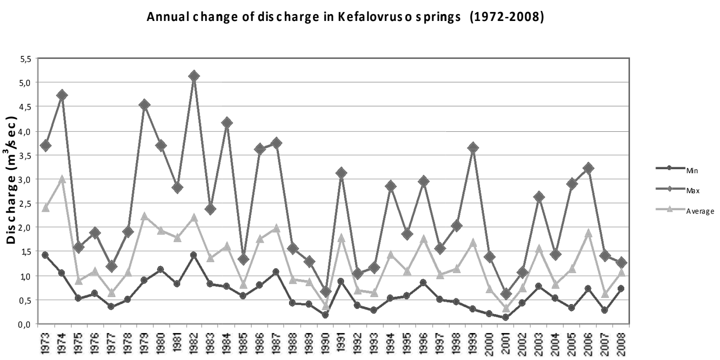

Figure 2 Diagram of discharge fluctuation in Kefalovriso springs.

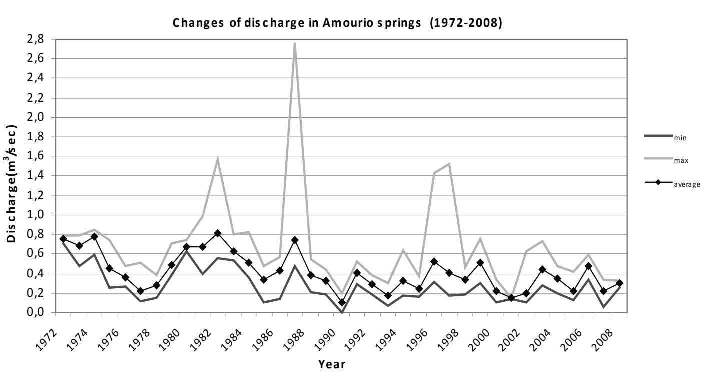

Figure 3 Diagram of discharge fluctuation in Amourio springs.

m^3/year), which is developed by the conflux of Boulgari and Elassonitikos Rivers. The annual rain fall in the area, is about 549 mm/year. The total amount of evaporation is very high in about 80%, the percolation is about 12% and the surface run off 8% (Vasileiou 2011). The recharge of the basin is supported additionally by the infiltration of the rivers. The recharge from Boulgaris and Elassonitikos rivers is rich, because it comes from other hydrological basins in higher elevations, in which the rainfalls are higher. Boulgaris River has additional supply from the Kefalovriso springs and some small torrents in the west boundaries of the area. In figures 2, 3 it is obvious that Kefalovriso springs have a big capacity, even though there is a decrease during the period 1973—2008. The dried up rate (Maillet, 1905), $a=10^{-2}\ d^{-1}$, shows that this karstic system is drained very quickly. On the contrary Amourio springs have value of dried up rate about $a=10^{-3}\ d^{-1}$, which means that this is a very good hydraulic system, with normal operation (Vasileiou, 2011).

In Potamia basin, two aquifers are developed, one unconfined aquifer overlying of lignite deposits, that has low capacity and one confined aquifer underlying. In Domeniko sub-basin, the upper unconfined aquifer will be totally drained due to the exploitation of lignite. The average thickness of it is about 100m and the capacity is low. The transmissivity values are about 10^{-4}–10^{-5} m^2/sec, which are approved from the low well discharges (30—40 m^3/h). The hydrostatic pressures from the confined aquifer will be significant in the areas that the thicknesses of lignite deposits are very small, the average thickness of this aquifer is about 60 m and the discharge is about 20—30m^3/h (figure 4). This happens only in the west boundaries of the mine, in the central area of the basin near to the River Elassonitikos. In this area there is expected recharge from the river and the Quaternary deposits. A net of wells drainage will be necessary in this area, to ensure the right exploitation of the deposits.

Amourio lignite field has different hydrogeological characteristics, Titarisios River crosses the lignite field in Amourio area and the diversion of it is necessary, which highly increases the financial cost of exploitation. The geological formations (coarse grained materials and fluvial terraces) have higher percolation than Domeniko area. Significant is the recharge in this area, along the river, because of the infiltration of Titarisios and the percolation (figure 5). This will cause slope stability and dewatering problems. The unconfined aquifer has significant capacity and high water heads have to be confronted in the floor of the open pit. The high discharges in the artesian wells of this area (250 m^3/h and 100 m^3/h) must be considered. Additionally there is continuous recharge from north and east to south due to the piezometry of the basin (Vasileiou 2011).

Several chemical analyses were executed in the area (50 water samplings) and the evaluation of them showed that the water is of good quality, without any specific problem; this is a very interesting element, because Thessaly has to confront very intense problems with nitrate pollution. In the area of lignite field of Domeniko, high concentrations of Mn^{+2} have been measured, because there are abandoned mines of manganese in the area (Vasileiou et.al. 2004).

The area has two main characteristics, the extended agricultural activities and the over exploitation of the water resources for covering the irrigation and potable needs. A volume over $9.5 \times 10^6\ m^3$/year is pumping from the drills, mainly along the River Titarisios and Amourio springs area (Vasileiou 2011).

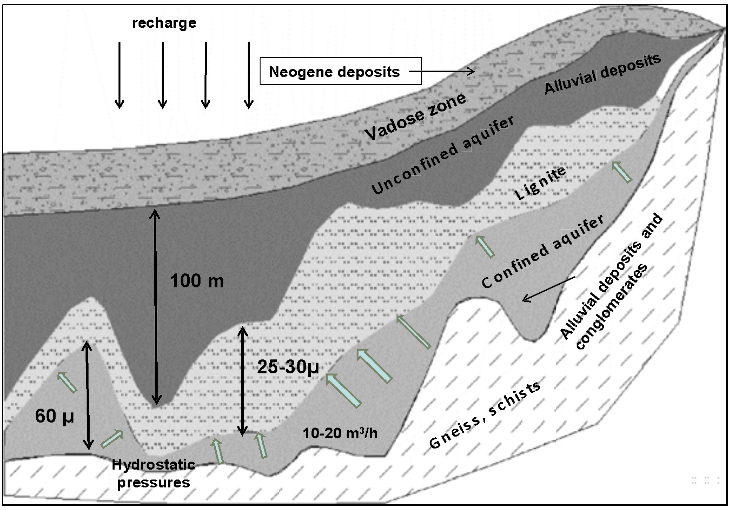

Figure 4 Schematic section of Domeniko area.

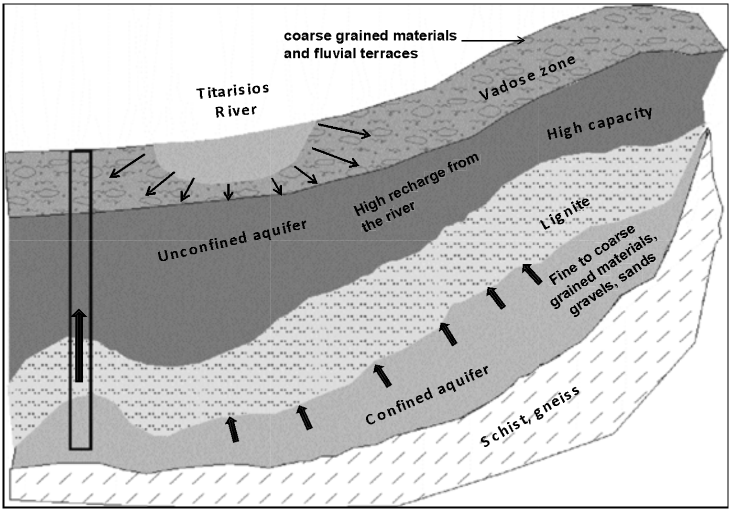

Figure 5 *Schematic section of Amourio area.*

It was estimated that the operation of Domeniko mine will pump about a quantity of 10×10^6 m^3/year, for the water needs of Tower Power plants. This quantity of water will be found from the drainage wells and the pumping from Titarisios River which has rich surface run off and recharge from other hydrological basins.

A surface of 30 km^2 will change land use from agricultural to industrial, because of the excavations, the waste disposal areas, the roads, the Power Plants and the other activities due to mining. This means that the pollutants for the aquifers will be different and various. These changes in land uses will cause effects to the economy of the area, in which the only source is agriculture at this time.

Conclusions

The rational management and protection of water resources is a priority in mining otherwise many problems could make the exploitation of lignite deposits forbidden, some of them are: slope stability, safety of exploitation, financial cost of pumping, diversion of rivers, filling the mine voids with water after mining works (lakes; Dimitrakopoulos et.al. 1989).

Exploitation of Domeniko deposit demands the destruction of the upper aquifer, but huge problems are not expected during the excavation, except for the need for pumping. A part of the lignite in the central area must be vanished because inflows are expected from this area and the thickness of lignite is small so it wouldn't be exploitable. The reverse of the small stream named Drafos which crosses the lignite field is necessary. But the cost of it, in comparison to the quality and quantity of lignite deposit is very low. The west part of the lignite may not be exploited due to the small thickness of it and the inflows which are probably expected, because the drainage drills will cause drawdown of water table and reversal of piezometry.

On the contrary the deposit of Amourio cannot be exploited, because of the hydrogeological and hydrological conditions in this area. The problems from the recharge and the high hydraulic over heads of confined aquifer will cause significant difficulties, which make the exploitation of this lignite field financially forbidden. The small thickness of lignite deposit and the rich recharge in Amourio area will increase the cost of the exploitation.

The mining activities in the region may cause negative water balance, if there isn't a water management plan. This plan has to include the possibility of the development of mining industry. The changes will be several in quality and in quantity of the water resources. The application of Phreeqc modelling showed qualitative deterioration of groundwater. Water pumped out for the protection of the mines could be used directly for irrigation or for the artificial recharge of the aquifers. In this way the potential of the aquifers will be maintained and the increased quantity of water will be available during the irrigation period.

Two models were applied, examining the environmental status in the area, the Strengths, Weaknesses, Opportunities and Threats of Potamia basin and which are the Driving Forces, the Pressures, the State, the Impacts and the proper Responses of confronting all environmental problems and the future threats as mining. The application of SWOT analysis and DPSIR model for Potamia basin showed that the area has environmental pressures, but not so significant (Vasileiou 2011). The future exploitation of lignite deposits wills increase these pressures and will cause problems to the quality and quantity of the water resources. The national environmental legal framework in correlation to the European Directive 2000/60, will immunize the rational water management, the protection of water resources. The mining activity in the area must follow these rules for decreasing the environmental impacts. The proper water management will reduce the threats to mining works from the water.

The water is capable of making the exploitation of an ore financially and geotechnical forbidden and this is the case of Amourio lignite field. The correlation between water and mining activities is very strong.

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