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Some anthropogenic changes in the geological environment in Bulgaria

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Introduction

The anthropogenic factor is an equally important factor among the natural phenomena, changing the geological environment. It is displayed to a much higher extent than the natural processes in some sites as open-cast mines, quarries, aggregate quarries, tailing ponds, refuse dumps, landfills, etc. The natural environment is transformed within only a few years to such an outlook, which is impossible to acquire in the course of hundreds of years. A great part of the anthropogenic effects are analogous to the natural ones and have one and the same physical character. A corresponding technogenic analogue is correlated with each natural destructive geological process. However, the proceeding slow changes in nature in the course of hundreds and millions of years take place in a very short time — months and years, as a result of the anthropogenic impact. This impact is concentrated on relatively smaller areas compared to the general scale of the natural processes. The geological hazard in the case of technogenic processes ensues from the fast rates of their development and intensity in particular sites, when the geomorphological, hydrogeological and engineering geological conditions are drastically changed in a very short time. The so called anthropogenic relief is created, which changes radically the geological environment and redirects also the manifestation of the natural processes as the erosion, abrasion, suffusion, weathering, etc., creating at the same time new geostatic and geodynamic conditions by the changed loading in particular parts of the massif. The acting forces in the geological environment are redistributed and a new equilibrium is reached, when it is possible to activate processes as slow creep along the slopes with subsequent landslides. These are one of the most often displayed anthropogenic changes of the geological environment in the open-cast mine development. The stability of the newly formed slopes is always very important in the case of open-cast mine workings. Regardless of this fact, the preliminary calculations cannot always exclude landslide occurrence. There are many similar examples from the open-cast mines in "Maritsa-Iztok", "Medet", "Assarel", "Elatsite", "Pernik", "Kremikovtsi" and elsewhere.

Anthropogenic relief

This type of relief is formed as a result of the excavation and embankment works during the technogenic activities. We distinguish between positive and negative anthropogenic relief or excavation and construction one. It is created mainly in coal and ore mining according to the open-cast method. The most impressive example in this respect are the "Maritsa-Iztok" open-cast mines, where the sites "Troyanovo-1", "Troyanovo-2" (till 1980) and now — "Troyanovo Sever", "Troyanovo-3", "Staroselets-1", "Staroselets-2", "Mednikarovo" and the United North Refuse Dumps occupy an area of about 120 km^2 in a rough approximation. About 50 km^2 of them represent the refuse dumps or the positive anthropogenic relief and the rest 70 km^2 are the excavations or the negative anthropogenic relief. In the course of a period a bit

longer than 37 years — the average time of operation of the three mines, more than 3 billion and 240 million m^3 of covering have been excavated, transported and dumped for the production of 740 million tons of coal. The daily output of coal in the "Maritsa-Iztok" mines amounts to about 70 thousand tons and 280 thousand m^3 of earth mass are excavated, transported and deposited on the average (Банков, 2002). Such rates of transformation of the geological environment are possible only in the case of anthropogenic interference and activity.

Other examples for the surface distribution of the negative effects on natural landscapes are from the "Elatsite-copper" mines, where 11700 decares of land are damaged, "Assarel-Medet" — with 11 300 decares, "Panagyurishte" mines — 3 530 decares, "Kremikovtsi" — 9 635 decares. The refuse dumps of unconditioned mining mass in the open-cast copper ore mines are prerequisites for serious ecological problems. The amounts of the deposited material are huge — 40 500 thousand tons for the "Elatsite-copper", about 50 000 thousand tons for "Assarel-Medet" (Йонева, Александров, 1998).

The refuse dump depots represent examples for a positive type of anthropogenic relief, where the finely ground flotation waste is stored. The bigger waste depots are "Benkovski-1" of "Elatsite-copper" — 133 200 thousand tons, "Lyulyakovitsa" of "Assarel-Medet" — 300 000 thousand tons, "Kremikovtsi" — 550 000 thousand tons, "Elshitsa" of "Panagyurishte" mines — 20 000 thousand tons (Йонева, Александров, 1998).

Another example of a mixed type of anthropogenic relief — excavation and construction one, is the metallurgical waste depot of the "Kremikovtsi" metallurgical complex. It occupies about 1.0 km^2 to the north of the Yana village. The greater part of the excavations is filled and refuse dumps (heaps) with irregular height (from 3-4 to 15 m) have already been formed. The greatest amount of fine dust particles in the Sofia kettle is accumulated in this depot. There is no operating sprinkling system and the dust creates problems within the range of the depot even in calm not windy days. It is the broadest source of large quantities of wind blown dust in the kettle. The state of the landscape in the region of the depot is critical. A constant water level is established in the empty part of the excavations. The colour of the water in the shallow lake is unnaturally green. Polluted water flows into these excavations, which is infiltrated through the tailing pond wall near the Bouhovo village, situated at a distance of 200-300 m to the north. The technogenic interference in this section has led to irrecoverable pollution of soil and water.

The industrial waste depots and the landfills represent mainly solid waste products of heterogeneous composition, size and properties, superposed above the natural lithological varieties. Preliminary excavation works are carried out for the construction of planned depots and landfills and the empty volumes are filled with the stored wastes. The uncontrolled landfill formation is connected with filling the natural negative relief forms and river valleys, gullies and ravines are most often subjected to this adverse trend, as well as many of the abandoned quarries during the last years. When there are no "suitable" places with negative relief forms, the landfills occur as low heaps in the open. The biggest landfills for household waste are those of the Sofia City near the Dolni Bogrov village (an area of more than 1.0 km^2) and near the Souhodol quarter (an area of more than 0.6 km^2).

The huge changes and redistribution of earth masses in the open-cast workings, the construction of tailing ponds, quarries and aggregate quarries, the industrial waste depots, the landfills, etc., cause a number of consequences that ensue from the changed geomorphological, hydrogeological and engineering geological conditions in the range of the affected areas and the terrains situated in their proximity. The positive and negative anthropogenic relief changes visually the natural relief and landscape in adverse direction. The contours of the open-cast mines, the quarries and aggregate quarries represent a sharp interference in the development of natural relief and landscape. However, these are not the only changes imposed by the anthropogenic relief. The geochemical and geodynamic conditions in the corresponding regions are often radically altered. As a result a number of processes and unfavourable phenomena occur.

Negative impacts

The negative impacts on the environment due to the newly formed anthropogenic relief are expressed in the following. In the case of the negative anthropogenic relief the groundwater table is observed as a running sore, so providing the possibility of introducing all kinds of pollutants in the water. The problem with the quarries and aggregate quarries is especially serious. The aggregate quarries in the Sofia kettle along the

Iskar River represent a negative example in this respect. The biggest landfill for household waste of the Sofia City near the Dolni Bogrov village has been merged with the sand quarry near the Chepintsi village. The wastes of the landfill are in direct contact with the groundwater exposed in the quarry in the form of a small lake. The waste is discharged in the established water level and pollutes directly the groundwater. The aggregate quarries in the Sofia kettle along the Iskar and Lesnovska Rivers occupy a total area of 3 km^2 and represent open surfaces for different types of pollution. The chaotic discharge of big amounts of construction and household waste is also directed to these regions. Another negative example is the aggregate quarry in the immediate proximity of the Sofia airport, where a lake has been formed and all kinds of waste fall down into it from its steep bank slopes. The landfills themselves represent a new technogenic relief type. Officially the number of household waste landfills on the territory of the Sofia kettle is 180, 85 of them being already filled and abandoned. The Sofia district municipality discharges 800 thousand tons of solid household waste annually and the landfills have taken away 300 decares from the fund of agricultural and forest land (according to data of the City Council — Sofia). The adverse effect of the landfills ensues from the potential possibility to be turned into constant sources of biological infection and irrecoverable chemical pollution. In 90 % of the cases the unregulated discharge of household waste is made along the gullies and river terraces. This creates the conditions for transporting the pollutants at great distances. The rainwater reaches easily the groundwater table due to its infiltration through the landfills.

In the case of positive anthropogenic relief, conditions for solving and extraction of harmful components are created under the action of precipitation and drainage of water. Processes of oxidation and leaching take place in the refuse dumps of the copper producing open-cast mines and as a result the water pollution by heavy metal ions (manganese, iron, lead, zinc, copper, etc.) exceeds many times the admissible limits. In this way the water running from these refuse dumps pollutes their affiliated areas and the natural water sources in the region. The hydrogeological conditions, the mineralisation and chemical character of surface and ground water are changed.

The depots for wastes from flotation processes create prerequisites for pollution by wind blown fine dust, containing harmful components when they are dried out. The dust pollutes the soils in the neighbourhood, making them unsuitable for agricultural activities. The "Elshitsa" waste depot provides a similar example for the pollution of more than 100 decares from the agricultural fund (Йонева, Александров, 1998).

The uranium mines and the processing plants generate large volumes of waste with increased radioactive substance content and are serious sources of pollution of the environment. These wastes are stored in tailing material depots, which represent a positive anthropogenic relief. Tailing material depots are developed for storing waste from other ore extraction activities. For example, four tailing material depots are built in the Sofia kettle, which are connected with the production of the "Kremikovtsi" metallurgical complex (MC) and with the Enterprise for Hydro-metallurgical Processing (EHP) "Metalurg" in Bouhovo.

The materials obtained after iron extraction are stored in the two tailing depots of the "Kremikovtsi" MC. Their total area amounts to about 2.2 km^2 and their volume — to 26 million cubic meters and it is possible to enlarge this volume by an additional superstructure. The two tailing depots represent technogenic relief changes and they also create the potential hazard of ecological disasters in case of accident situations. The tailing materials have liquid-viscous consistency with high fluidity. After reducing their water content they acquire plastic consistency and are disintegrated in a loose dusty mass after drying. The latter is inadmissible because the material is easily blown and carried away by the wind. For this reason sprinkling systems are functioning in the tailing waste depots. Regardless of this fact, there were cases of blowing the tailing materials and winds carrying fine particles had polluted the neighbouring villages of Chelopechene, Dolni and Gorni Bogrov.

The tailing material depots of the Enterprise for Hydro-metallurgical Processing "Metalurg" near Bouhovo are situated next to one another and are provisionally called "the old" and "the new" one. Their total area amounts to about 1.25 km^2. The tailing materials from uranium ore processing in different sites in Bulgaria for the period 1958-1992 are stored in them. The tailing depots near Bouhovo are structures with high potential hazard because of the specifics of the deposited tailing materials, the construction technology and the location on a slope. The washout technology was accepted for the depot development. The finely ground waste had been washed out in the course of years and the sup-

porting prism of the wall is built of it. Its strength parameters are determined by the quality of performing the washout process, the degree of segregation of the materials and the particle size, ensuring higher filtration coefficient. The sizes of the prism and its dry part, the degree of consolidation of the deposited material and its susceptibility to liquefaction under seismic impact are very important factors. The technological performance of the washing out was not good and the strength parameters of the supporting prism and the total stability of the wall were aggravated. If wetting of the supporting prism happens, the wall of the built in this way tailing depot will be destroyed (Кузманов et al., 1995).

About 21 million cubic meters of tailing materials are stored in the two depots near Bouhovo. In general, the tailing material depot represents a serious hazard for radioactive pollution in the Bouhovo-Zhelyava-Yana region. The flow rate of polluted filtration water through the depot wall is Q = 1 l/s and the admissible limits for radium content are exceeded several times. The constructed reservoirs with pumps under the wall, which have been envisaged for capturing and returning this water back in the depot, are not in operation. The water flows freely in an open channel in the direction of the refuse dump for metallurgical waste of the "Kremikovtsi" MC near the Yana village.

As a whole, the tailing material possesses specific physico-chemical characteristics, which place it among the strongly hazardous geoindustrial matter, threatening the ecological safety of environment. The flowing of tailing materials out of the depots is impermissible. From an ecological point of view the tailing material depots are localised and controlled sores in the earth environment but they cannot be avoided at the present level of technical development. However, their potential hazard has to be taken into account by considering the eventual unfavourable consequences under various effects and critical situations. The example with the destruction of the "Sedmochislenitsi" tailing material depot above the town of Vratsa should serve as an Aldis lamp in the history of the geological hazard in Bulgaria. As a result of intensive precipitation and suffusion through the wall, on the 1st of May 1966 a mass of tailing material and water created also a shock air wave. The consequences were fatal for the Sgurigrad village and a part of the Vratsa suburbs. There were 196 destroyed residential buildings, 96 people were dead and 25 people were missing (Цуински, 1990).

It is often necessary to correct riverbed parts or even move entirely natural courses in the case of open-cast workings. Such radical changes in nature are possible only if strong cataclysm, for example — an earthquake, occurs. Natural water sources are often annihilated with the advance of mine workings. For example, the "Vreloto" water source, which is important for the drinking water supply of the town of Dragoman, is endangered by annihilation because it is situated in the immediate proximity of the coal field of the "Beli Breg" mine, section "Nedelishte". This water source has a complex structure and can be lost because the mine workings are approaching it (Чушков, 2001).

Provoked processes

The anthropogenic interference in the geological environment and the newly formed relief redirect the action of the natural destructive geological processes from given sites to quite another ones. For example, the refuse dumps in the positive relief and the slopes and steps in the negative relief are subjected to active erosion. Very often the newly built slopes and embankments are in boundary equilibrium and processes of slow creep are exhibited along them, followed by the formation of small- or large-range landslides. The biggest sizes and volumes belong to the landslides originating during the operation of the "Maritsa-Iztok" open-cast mines. Serious difficulties and problems arose during the construction of the "Troyanovo-1" mine. As early as during the first year of construction — 1962, swelling reaching 2 m occurred in the bottom of the section trench. Sliding along the non-operating board of the mine took place in the next year 1963. Landslides were formed also in 1964, 1965 and 1968. They were the reason for long interruptions of the active operation and reduced coal output.

The first landslide in the "Maritsa Iztok" basin emerged in April 1963 after a preliminary period and slow creep in the course of about one year. About 5 million cubic meters of earth mass was included in active movement at a distance of 1 km along the non-operating board of the "Troyanovo-1" mine. The landslide damaged the internal railway of the mine. It was accompanied by big ruptures and subsidence of the terrain. A second sliding took place along the same non-operating board in September of the same year. This hampered the mine workings due to the removal of the slide mass.

Four big landslides were activated within the course of 5 years (from 1963 till 1968) in the "Troyanovo-2" mine: in September 1963, August 1964, January 1966 and December 1968. The sizes of the landslide in 1966 were big — a block of about 15 million cubic meters slid from the operating board of the "Troyanovo-2" mine. The last landslide from 1968 was the biggest and had the worst consequences. The movement included 55 million cubic meters of earth mass and coal along the operating board of the mine. It spread on all covering steps at a length of 1600 m and width from 130 to 180 m to the north of the top step, thus moving all covering and coal horizons with 100 m towards the central part of the mine (Банков, 2002).

Another more recent example of landslides in open-cast mines of smaller size is the one in the "Stanyantsi" mine. A landslide occurred in January 1999, which included about two thirds of the mine field. About 1.2 million cubic meters of coal and covering were moved (Чушков, 2001).

The landslides, partial falls and collapses accompany all open-cast mines. These processes provoked by human interference cause time losses for restoring the destroyed sections. They represent a danger for the people and equipment working in the open-cast mines.

Conclusions

The anthropogenic changes of the geological environment are permanent and long-term type of interference, which radically alter the natural geomorphological, hydrogeological and engineering geological conditions in a given earth massif or territory. This leads most often to changes in the geostatic and geochemical circumstances in the range of the anthropogenic activities. It is difficult to recover the ecological consequences for the neighbouring areas and regions too. In fact the anthropogenic interference is related with the pollution of soils and surface and ground water. When certain limits (the admissible concentrations) for the amount of some chemical elements in the atmosphere, soil and water are exceeded, harmful effects are exerted on the development of biological processes. The natural development of plants is disturbed, the health and life of living organisms is threatened, which represents a substantial element of the geoecological hazard. Continuous observations, investigations and scientifically substantiated propositions and solutions for remediation of the damaged terrains will be necessary for the restriction and prevention of the harmful influence of the anthropogenic interference.

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