

Specifics of Environmental Problems of Mining Natural Management in River Valleys

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Abstract – Ecological consequences of prolonged mining natural management in the valley of the river Baksan are analyzed. Main sources of emissions of heavy metals compounds, the nature and extent of their pollution are revealed. Ecological indicators of the post-exploitation state of landscapes can be considered residual levels of toxic compounds in the grass-rhizomatous systems of forage lands. Methods for reducing the concentration of chemical compounds in the main elements of valley-river landscapes are proposed. Indicators of the flow of Baksan affluents, on the basis of which it was concluded that “optimal amount of pollution” had reached the beginning of Zaiukovo village, are analytically calculated. Possibilities of embedding ecological blocks in the structure of old assimilated mining landscapes are considered. Biological recultivation is proposed to carry out in the form of simplified and less capital-intensive sanitary and hygienic works. The idea of the alternate use and recultivation of tailing dumps in the area of Bylym village is proposed to test.

Keywords – ecological risk; biological recultivation; mountain-valley natural management; ecological and economic framework; chemical pollution; material-energy flows; environmental monitoring points.

I. INTRODUCTION

Problem Statement: Unlike economic activities on the plain, mining natural management in mountain river basins causes a number of acute specific problems associated with unusually high environmental risks: transient and large-scale deterioration of the sanitary-hygienic situation in a dynamic semi-enclosed space, man-made transformation of mountain-valley landscapes, deterioration in quality of water and natural forage resources, atmosphere.

Due to the current global market conditions for non-ferrous metals, the mining and enrichment of ores of tungsten and molybdenum in Baksan valley ceased. In these circumstances it seems to be appropriate to reconsider the environmental consequences of prolonged functioning of Tyrnyauz tungsten-molybdenum plant and the search for options to optimize the

existing natural management at a new technological and environmental level.

II. STATEMENT OF THE PROBLEM

In accordance with the identified problem, an alternative to the traditional system of natural management can be the formation of a complex ecological-economic zone, in which, on the one hand, ecological interests of nature and local residents are organically balanced, and on the other hand, economic motives of the enterprise are stimulated. In the case of an acceptable project of ecological and economic framework, the chance of increasing the natural capacity of relatively safe economic activity will appear in the basin of Baksan river. In the process of restarting the enterprise, properties of the ecological element of the framework can be sequentially optimized.

The purpose of the study is to assess the geo-ecological assessment of the post-exploitation state of valley-river landscapes within the middle flow of Baksan, to formulate the main approaches to reducing environmental risks at the upcoming new stage of mining natural management.

III. METHODS AND MATERIALS

Using the method of field research, the geo-ecological state of two tailing dumps and the degree of man-made disruption of mining landscapes are assessed. On the basis of the paired module method, the average annual flow of rivers that do not have hydrometric observations is revealed, based on a comparison with adjacent rivers studied during the Soviet period and being in identical natural conditions. The evaluation of the mechanism of dilution of the main watercourse with affluents is made using statistical analysis methods.

For the main elements design of the ecological-economic zones (EEZ) and their approbation, mountain valleys are taken as the base areas. They reproduce a significant part of the components of natural complexes in the mountain-foothill altitude zone of the North Caucasus. The choice of a specific approach to EEZ construction is tied to the degree of economic

development of river basins being different due to physiographic characteristics [1]. The current analysis was carried out in relation to the middle flowing of the old assimilated valley of Baksan river. The economic component of the proposed zone has already one-sidedly been formed. Therefore, the task in this particular case is seen in the saturation of the old development area with an adequate volume of environmentally-stabilizing technical and biological structural elements.

For several decades, the linear valley-river landscapes of Baksan partially neutralized the anthropogenic pressure of Tyrnyauz tungsten-molybdenum plant (TTMP). The sources of chemical compounds leakage were the mining allotment of the plant, unpreserved underground and surface mines, old tailing dump, 10-kilometer flow line of the slurry pipeline; 2 new tailing dumps represented by Ullu Gizhgit and Gitche Gizhgit.

IV. RESULTS

It has been revealed that during the years of intensive exploitation of the field in the area of the ore field and downstream no significant environmentally-stabilizing “counterbalances” to the man-made pressure have been formed. Therefore, taking advantage of the forced “vacations” of the stopped working plant, it is necessary to design and propose an ecological framework structure adapted to the current situation in an advanced order. The latter is necessary to neutralize the likely new wave of foci exacerbation of environmental tension.

The high probability of resuming the mining natural management is due to the absolute city-forming role of TTMP for mono-city, the demand for tungsten and molybdenum by the military-industrial complex of the Russian Federation. In addition, social “price” of the issue is high: 1 thousand new work places and a corresponding increase in incomes of mountain residents.

The main function that needs to be laid in the ecological block of the proposed zone is a sharp decrease in the diffusion of liquid effluents of toxic compounds into the environment. Certainly, the production resuming should take place on a new technological basis. In the conditions of a significant altitude difference between the lower and upper ore occurrences (1400 m), it is more expedient to revive the ore enrichment by X-ray luminescent separation technology [2]. However, it seems to be unreal to completely eliminate the effect of heavy metal compounds on nature. Therefore, the action of the proposed environmental construction should be focused on the elimination of high activity of toxic waste. But the range of ways to achieve the goal is limited in such a dynamic surrounding as steep slopes and turbulent mountain river.

The main channels of contamination of mountain-valley landscapes are surface effluents that intersect TTMP quarries, overburden dumps and water courses from a diversion tunnel. In accordance with the general direction of the fall of the terrain heights, the wastewater enters the riverbed and gradually settles in the form of inclusions in the hollow reservoirs of soils. Periodically seasonal Baksan floods transform bottom and coastal soils, which is accompanied with denudation and migration of deposited chemicals to lower elevation levels. The

localization of this channel of pollution can be twofold: toxic substances can be withdrawn from circulation or prior to discharge into the watercourse, or removed from the river. Of course, the first approach is more preferable due to the fact that concentration of heavy metal compounds is significantly higher before discharging them into the river, and, consequently, the method is more drastic at much lower costs.

But an attempt to isolate toxic compounds will require an improvement in the current standards of water protection zones. It seems to us that the practice of designing a water protection zone according to a geometrical principle is not adequate to the current situation applying to Baksan. For example, within the Tyrnyauz ore field, the material and energetical closely interconnected landscapes of the valley width are not included in the composition of the water protection zone: steep watershed slopes, back marshes, low floodplains, terrace cusps, convex bend slope lines, which are characterized by a fairly high exogenous dynamic potential. Therefore, the internal structure of the water protection zone must be differentiated into subzones of strict protection, moderate restrictions, and partial restrictions.

For the ecological well-being of the entire river complex and settlements of the gorge, the choice of a suitable regime for regulating the water-protection zone is best done depending on the specific hydrogeological and landscape-geomorphological features of the valley and floodplain: man-made disturbance of the basin, frequent rainfall, mostly intense snowmelt, significant slope of the area, low water permeability of surfaces with frequent outcroppings and low thickness of the soil horizon [3].

Certainly, absolute wastewater treatment due to technological complexity and extremely high capital intensity is impossible, so some of the pollution will be dispersed in the watercourse. During the pre-shutdown period, the average concentration of tungsten and molybdenum compounds in a river water within Tyrnyauz ore field varied within 15-fold MAC. The pollution picked up by rapid watercourse cannot be removed back. In the case of this scenario, the hydrochemical composition of Baksan can be managed only by dint of affluents flowing below Tyrnyauz. These are rivers of the 2nd and 3rd order with mainly snow and rain feed. With an increase in the water mass of the main river, its physicochemical characteristics improve [4]. A decrease in the concentration of heavy metal compounds by the dilution method is a logical consequence if we consider Baksan as a continuum with gradually changing parameters as it moves downstream. The degree of dilution and the duration of this process depend on the average long-term water consumption by affluents (Table 1)

Due to the lack of hydrometric observations in relation to affluents, a module, according to which the average effluent from water catchment areas in the North Caucasus with rain and snow feed is within 30 l/s is applied. Taking into account the pronounced tendency of stepping up mountain-foothill landscapes of the northern slope of the Central Caucasus [5], we find it necessary to adjust this indicator up to 25 l/s per 1 km² of water catchment area.

TABLE I. MAIN HYDROMETRIC INDICATORS OF AFFLUENTS FLOWING INTO BAKSAN RIVER FROM TYRNYAUZ TO ZAIUKOVO

No.	Affluent name	Inflow side	Affluent inflow place	Affluent length (km)	Basin area (km ²)	Annual average water consumption (m ³) (revealed by analytical method)
1	2	3	4	5	6	7
1	Sukoshsu	right affluent	Tyrnyauz	5.7	7.1	0.17
2	Mystylkol	right affluent	Bylym village	13.3	15.2	0.38
3	Gizhgit	left affluent	Bylym	28.0	151.0	3.7
4	Kestanty	right affluent	Bylym	28	146.0	3.6
5	Tashuko	right affluent	Bedyk village	8.7	9.3	0.23
6	Bedyk	right affluent	Bedyk	16.5	24.1	0.6
7	Brukol	right affluent	Lashkuta village	7.1	13.2	0.32
8	Khaiuko	left affluent	Zhankhoteko village	2.0	7.7	0.19
9	Gundelen	left affluent	Zaiukovo village	21	589.0	14.7
10	Shtauchuko	right affluent	Zaiukovo	13.7	20.5	0.51
11	Zeiuco	left affluent	Zaiukovo	6.9	7.4	0.18
12	Khanagok	right affluent	Zaiukovo	9.3	11.2	0.28
13	Kachkortash	right affluent	Bedyk	11.0	49.0	1.2
14	Argaiuko	right affluent	Zaiukovo	16.0	25.7	0.64
						Total: 26.7 m ³

Taking into account the size of the river basins, total annual effluents of 14 affluents are revealed by the analytical method - from Tyrnyauz to Zaiukovo village. It is 26.7 m³/s, that is, the volume of water increases by 78% in the indicated sector of Baksan. Consequently, the initial concentration of chemical compounds should be proportionally reduced by analogy. It is not excluded that the dilution will be more efficient due to feeding with groundwater, but there is no specific data on such a relationship.

As a result of water mixing, the concentration of chemical compounds should be reduced to below a critical level. In the absence of other significant external pollutants, the downstream water quality will not deteriorate, namely, the so-called "optimal amount of pollution" will be achieved. With water volume increase in Baksan, other parameters of the watercourse also change positively: the wetted perimeter of the bed increases up to the high level of Zhankhoteko village (about 840 m), the volume of water sediments decreases, which causes an increase in the surface area of absorption and, in part, the mechanisms of primary isolation of pollution.

By the end of the indicated area of Baksan river, the situation is corrected so that spawning and feeding space for the river fauna in terms of the hydrochemical composition of water is almost optimal. An indirect confirmation of this thesis is the presence of stable productive communities here, similar to those on undisturbed affluents.

At the same time, fixing the fact of a positive situation is not a sufficient basis for long-term forecasts with regard to the water quality, which is due to the limited size of the improved river section, as well as the propensity of aquatic populations to migrate.

According to gauging station Tegenekli, the source of 55% of the effluent in relation to the one third of Baksan length is glacial water. The river originates from the most intensely melting glacier - Bolshoi Azau, which retreats 20

meters annually. No doubt, this trend is associated with global changes in solar activity, which directly affects the dynamics of the daily and seasonal state of high-altitude landscapes, including glacial ones [6].

Over the past two decades, the water consumption of Baksan has increased by 10% on the average. In case of complete degradation of the glacier, the mechanism for the natural regulation of the water hydrochemical composition will collapse. The indicated dynamics and forecast of its consequences will require a separate large-scale study.

A natural management function should be laid in the ecological block of the proposed ecological-economic zone. This property should be focused on reducing the scale of toxic fine-dispersed dust emissions, the sources of which are: abandoned mining quarries ("Vysotnyi" and "Mukulanskii"); an old tailing dump in Bolshaia Mukulanskaia gully and two functioning lakes - sumps. The scale of diffusion of toxic dust is tens of kilometers, mainly down the gorge in accordance with the prevailing mountain-valley winds, the frequency of which varies within 60%. Moreover, the dust cloud always covers Tyrnyauz, which often causes a 50-fold excess of background values.

Ecological indicators of the post-exploitation state of mountain-valley landscapes are residual levels of accumulated toxic compounds in the root and terrestrial parts of the grass on hayfields and pastures [7]. Usually, the background concentration of molybdenum in the herbage in conversion to dry substance is 4-6×10%. Herbal test systems showed that even after 15 years after the plant had been shut down, the molybdenum concentration in the grass-rhizomatous systems directly confined to the industrial infrastructure of the plant sometimes reached up to 100× 0%. This indicates that persistent tungsten and molybdenum compounds are difficult to derive from geobiocenosis. This conclusion is confirmed by the results of an episodic chemical analysis of local livestock products produced by the Veterinary and Sanitary Expertise Department of Kabardino-Balkaria Ministry of Agriculture.

A major source of toxic fine-dispersed dust is the first tailing dump - an artificial construction with a 180-meter bulk dam. Its protective banks represent a "dead" zone without a biocenosis. In the last decade, individual microcracks have formed in the dam, extending into its depth. In the case of the pessimistic development of events, the destruction of the dam will lead to the largest man-made mudflow with unpredictable environmental consequences. Therefore, the external slopes of the dam should be sown with sod-forming herbs with a strong root system as a precautionary measure; it is more expedient to place the aboriginal tree-shrub flora on the edges of berms, which in the complex will have a significant environmentally-stabilizing effect.

A separate ecological framework unit should be created 10 km below Tyrnyauz. Two lakes are located on the left bank of Baksan, which are actually the tailing dumps of TTMP. During the launch of the tailing dumps, no filtration measures were taken. Therefore, it cannot be completely ruled out that a certain amount of liquid waste is filtered through the underlying layer of water reservoirs even during the post-exploitation period. The crystalline schists, which are constituents of the dam site of the Baksan gorge in the lakes area, do not guarantee isolation of the bed from possible underground drains. The implementation of the project of advanced recultivation of tailing dumps would contribute to the elimination of increased environmental risk, since it should be carried out only in the absence of exploitation.

At the stage of mine technical recultivation, it is necessary to localize the flow rate of water from the similarly-named river to the lakes, and then pump out the liquid from the tailing dumps. It is necessary to form a layer of a mixture of carbonate neutralizing materials with capillary-interrupting gravel-pebble materials on the exposed muddy bottom of water reservoirs. Final 20-cm the layer is applied in the form of fertile soil [8].

Since a new stage of the involvement of tailing dumps in the manufacturing process is expected, the biological stage of recultivation can be carried out in the form of simplified, less capital-intensive sanitary and hygienic works. It is advisable to place salt-resistant (awnless brome, creeping wheatgrass) adapted to the acidic environment (sheep and meadow fescue, red clover, meadow timothy) grasses and aboriginal shrubs (sea buckthorn, rose hips, etc.) on the laid soil.

It would be advisable to work out in detail the possibility of alternate use and recultivation of lakes, which are 1.5 km apart from each other. Of course, a complete solution to the problem would be the full utilization of waste accumulated in the tailing dumps, but its astronomical capital-intensity makes the project implementation hardly probable [9].

The space between tailing dumps and Baksan riverbed in a straight line is 3 km, which needs an environmentally-stabilizing effect. Embedding a small-mass forest park with an area of 3×5 km in this space except for the leading environmentally-stabilizing function will have a dust-absorbing and shielding effect: it will filter air masses, prevent chemical denudation from water catchments, and regulate underground and surface effluent [10].

Regardless of the specific method of increasing the stock of environmental sustainability, a prerequisite for reducing man-made risks in the study area is the formation of point networks of operational ecological monitoring near the most important elements of mining infrastructure.

For many years as a subject of natural management in Elbrus Municipal District, TTMP involves the adjacent Baksan district in the process of geosystems degradation by transboundary toxins. Therefore, the construction of a balanced ecological-economic zone will require inter-district agreement and coordination, and joint environmental protection actions. First, it is referred to the ecological state of Baksan river and mountain-valley landscape in the long term.

V. CONCLUSIONS AND SUGGESTIONS

1. Spatial confinement of mining natural management to a dynamic valley-river complex predetermined the nature and vector of chemical contamination of vast mountain-foothill spaces.

2. Most vulnerable elements of geographic systems turned out to be underground and surface water, pastures and hayfields, soils, and the atmosphere.

3. A specific section of Baksan was revealed, being the most susceptible to chemical contamination; the mechanism and degree of water normalization were determined analytically.

4. Conclusion about the need for recultivation of TTMP tailing dumps was made, due to the continuing threat of contamination of valley-river landscapes, and an increased risk of the spread of toxic dust from consistently drying and denudation sections of tailing dumps.

5. It was suggested to link the recultivation of tailing dumps with forced manufacturing "vacations" of the tungsten-molybdenum plant, and an algorithm for its implementation was outlined.

6. Idea of alternate use and recultivation of two tailing dumps was expressed. It is sufficient to carry out simplified and less expensive biological recultivation with the approach to the waste conservation.

7. It is advisable to build in forests of various sizes and shapes in the structure of the ecological framework as ecological blocks. They are able to effectively influence the filtration of the atmosphere, prevent chemical denudation in water catchment area, and regulate the underground and surface effluent.

8. Embedding an adequate transformation of the ecological framework into the space of technogenic landscapes will make it possible to compensate for a considerable part of the lost mechanisms of natural sustainability.

9. Conclusion about the need to establish a point network of operational environmental monitoring points near the main elements of the mining infrastructure on a regular basis, which will ensure the reduction of technogenic risks, was made.

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