The impact of the placer gold mining in Eastern Transbaikalia (Russia) on the environment components of river valleys in the Amur River basin

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Abstract. Based on the results of the analysis of satellite images and field observations, data on the length of the gold-bearing placers disturbed by the development along a number of main tributaries of the Shilka and Argun rivers are presented, the formed technogenic relief forms are indicated. Depending on the method of development, two types of technogenic landscapes have been identified – the excavation-dump with hydromonitor mining and belt trench-dump when washing with drags. The main directions of research on the assessment of placer gold mining in the natural complexes of river valleys are proposed.

1. Introduction

The Amur River basin in Eastern Transbaikalia, which by administrative division belongs to the Transbaikal Territory, is represented by sub-basins, according to [1], of the Shilka and Argun rivers, from the confluence of which the Amur proper begins. The development of gold-bearing placers in the region has been going on since the middle of the 19th century. According to these authors in the basin of the river Shilka placers mining affected 137 channels on an area of 345 km\textsuperscript{2}, in total, 975 km or 2.4\% of the total length of channels were disturbed. On the Russian part of the river Argun basin disturbed 11\% of the area of water bodies and 3.3\% of the length of the river network were disturbed. According to the scheme given in the article, the calculation also included the areas of development of tin placers, but the length of the valleys disturbed in this case is generally small. According to another estimate [2], the total length of placer mining in the basins of both rivers is 1076 km, or 1.55\% of the total length of the river network. The length of the disturbed valley sections for specific watercourses is not indicated in these and other publications.

This report presents the quantitative characteristics of the transformation of the placer gold mining of the valleys of specific watercourses, obtained by the authors from satellite images from the Google Earth, and shows the main forms of the formed technogenic landscapes, etc. In addition to remote sensing materials, data obtained from the results of expeditionary research carried out in a small volume during work on other topics were used.

2. Results
According to studies in various regions, the development of placers in river valleys leads to a complete transformation of their geomorphological structure, the formation of technogenic landforms, new channels, activation of channel processes, a change in the runoff characteristics and hydrological regime of watercourses, the destruction of terrestrial vegetation, pollution of the aquatic environment, alteration and depletion aquatic biota, etc. [3–9].

The main structural elements of the technogenic landscapes of gold mining are dumps of overburden (peats) and washing of gold-bearing sediments (sands) with industrial instruments, drags, dumps, pits from excavation of sands, sedimentation tanks and their dams, excurrent ditches, ponds (technogenic lakes) of pits and sedimentation tanks.

In the Shilka River basin, the development of placers covered the entire catchment area, especially along the left-bank tributaries in the lower reaches of the river. Here, gold mining took place along most of the Shilka tributaries of the first and many of the second order. The Chyorny (Black) Uryum River stands out, along the valley of which, not counting the tributaries, the total length of the processed placers reaches 58 km, and the width of the drags polygons is up to 1 km. On satellite images of this and other valleys, the rectangles of drags polygons with sizes from 0.11×0.22 to 0.25×0.56 km², as well as separate drags passages, are clearly distinguished. In the areas where the sands were washed with hydromonitors, the length of the largest man-made lake reaches 1.3 km with a width of up to 0.55 km. Other left-bank tributaries of the Shilka River areas of the valleys processed by gold mining have the following length (in km): Kara – 26, Kudecha with a right tributary – 22, Davenda – 15.3, Gorbitsa – 13.6, Khila – 13. The development was carried out, in addition, both along the tributaries of these rivers, and along other rivers. The processed sections, especially along the tributaries, in some places exceed half of the total length of the river valleys. The sections disturbed by mining, especially along the tributaries, in some places exceed half of the total length of the river valleys.

In the Argun River basin, the disturbance of the river valleys of its main tributaries are, km: Srednyaya Borzya – 60, Gazimur – 36, Nizhnyaya Borzya – 20, Urov – 20, Uryumkan – 16 [10]. In the valley of the Srednyaya Borzya River there formed one of the most extended valley technogenic landscapes in the Eastern Transbaikalia. The main method of washing placers here in the recent past was the work of drags, at present – by hydromonitors; in the middle stream of the river, a drag also works. The length of the worked-out areas along the main valley reaches 45 km; the width is from 280 to 850 m. The pits are filled with water with the largest man-made water body that is 1.2 km long and up to 530 m wide. The areas of the last years have been reclaimed at the technical stage and the leveling of the dumps has been carried out.

Natural vegetation in the contours of the development were completely removed, the soil cover during the development of placers on undisturbed lands has been stored in recent years. The overgrowth on recent workings (up to 10–15 years) is weak, with a low projective cover. In the valley of the Unda river (the Shilka River basin) on leveled dredging dumps, composed of sandy-gravel-pebble material, over a 30-year period, tree-shrub communities have formed practically without herbaceous vegetation. By this the composition of woody forms is dominated by Chosenia arbutifolia (Pall.) A. Skvorts., which grows in single specimens under natural conditions.

The technogenic relief formed by the mining of placers, with differences in size and combination of forms, is generally similar. Depending on the method of mining placers, we have identified two types of technogenic landscapes of alluvial gold mining [11]: the excavation-dump if the washing placers by a hydraulic method and the band trench-dump landscape if works of drags (figure 1).

The impact of gold mining is manifested in a change in the hydrological regime. According to [12], the minimum and average annual runoff of the Bagdarin River in the catchment area adjacent to the Shilka river basin, in the valley of which the placers were mined by drags decreased, while the maximum runoff increased. Such studies were not carried out on the rivers of the considered territory. For small rivers of the steppe zone, the total runoff a priori decreases due to evaporation from the surface of the formed reservoirs, since evaporation here is up to two times higher than the amount of atmospheric precipitation.
Water erosion is most pronounced during the formation of new channels, often with the division of a watercourse into several channels (multi-channel) (figure 2a). Among the engineering-geological processes in the valley of the River Dunda-Khongorun (Onon River basin, a tributary of the Shilka River), a landslide was observed in one of the dried up sedimentation tanks (figure 2b).
As a result of water erosion and the discharge of process waters, the evacuation of suspended solids increases many times over, as does in the concentration of metals also increases. So, the concentration of suspended solids and iron in the water of the Srednyaya Borzya River reached 278 and 6.5 mg L\(^{-1}\), increased markedly, exceeding the fishery standards in the contents of copper, chromium, cobalt, nickel. In this case, the pollutants are carried out by streams far beyond the bonder of gold mining, up to 10 km or more.

3. Directions for further research
Despite more than a century and a half of the development of gold-bearing placers in Eastern Transbaikalia and its significant load on the natural complexes of river valleys, the processes, consequences and the scale of this impact are still poorly understood. The scale and environmental consequences of alluvial gold mining in the region, according to expert estimates, are not inferior to the environmental impact of the development of its ore deposits and require targeted research. The authors consider the most important directions to be:

- study of geomorphology and the influence of technogenic landscapes of alluvial gold mining on the formation and regulation of water flow;
- assessment of technogenic mass transfer and the role it plays in activating water-erosion processes;
- assessment of pollution of the aquatic environment and its impact on aquatic biota, in particular on ichthyofauna;
- study of natural restoration of vegetation on the disturbed lands, including the reclaimed lands, and development of methods for biological reclamation of disturbed lands with the selection of optimal plant species and their communities.

4. Conclusion
In the basins of the Shilka and Argun rivers, the river network and valley landscapes are more or less subject to changes as a result of gold mining. In the valleys of their individual tributaries, the length of the processed sections reaches 58–60 km. The types of emerging technogenic landforms and landscapes directly depend on the method of mining placers. The two types of technogenic landscapes of placer gold mining are most distinctly distinguished – the belt trench-dump when mining placers with dredges and excavation-dump landscape, characterized by larger relief forms and grounds differentiated in composition, during the hydromonitor mining. In either case, the vegetation in the disturbed areas restores badly, especially on the slopes of dumps that are prone to water and wind erosion. As a result of water erosion and the discharge of process waters, the carrying out of
suspended solids increases many times over, the concentration of metals in the water increases, and the pollutants spread along watercourses far beyond gold mining. The proposed areas of research will allow not only to assess the real scale of the impact of the development of placers on the natural environment, but also to develop optimal directions and methods for reclamation of the disturbed lands.

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