

Environmental Effects of Possible Landslide Catastrophes in The Areas of Radioactive Waste Warehousing in Kyrgyzstan (Central Asia)

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Abstract. Kyrgyzstan is an Alpine country located in the Central and Western part of the mountainous system in Tien-Shan (Fig. 1). The new and developing Tien-Shan Mountains are characterized by high topography energy, therefore in mountain areas of Kyrgyzstan the gravitational mass movements are actively generated and widely propagated, as the following: landslides, avalanches, rockfalls, mudflows, snow avalanches and glacial shearing. The most troublesome are the landslides, which occurred on mountain slopes and in narrow canyons. Presently within the Kyrgyz part of Tien-Shan more than 5 thousand new landslides have been registered, vast majority of which is developed in Loess Belt of submountain areas of Fergana Valley (Fig. 1). During the last 20 years against a background of noticeable climate changes a great increase of landslide activity is registered. Within the 1993-2008 period more than 300 large-sized ($V \geq n \cdot 10^5 \text{ m}^3$) landslides have occurred taking lives of 240 people. The volumes of rocks and soils moving in the time of landsliding run up to many millions of cubic meters. Landslides destroy inhabited localities and objects of infrastructure, exert destructive influence on local economy and subsistence of Highlanders, and hamper the expansion of mountain areas.

According to statistical data, in Kyrgyzstan up to 70% of present landslides is the result of unreasonable man-caused (anthropogenic) activities in mountain areas, mainly it is related to mining and processing operations. The distinctive features of "man-caused" landslides are the following: their greatly more extended volumes and striking effects in comparison with natural-origin (genesis) landslides; concentration of man-caused landslides in small-volume mining areas; continuous and undamped mode of their expansion. Most hazardous are the landslides appearing in the areas of warehousing and storing of radioactive and toxic wastes of mining industry. In most cases in Kyrgyzstan these tailings are located on weakly stable rocks, and/or close to landslide-hazardous slopes, in valleys of narrow mountain rivers. Therefore, landslides and secondary effects in a form of floods and mudflows triggered by them, may lead to radioactive contamination of vast territories in down-stream rivers flowing into the densely populated valley areas of Kyrgyzstan and neighboring countries. This hazard poses a great problem in northeastern part of Fergana Valley, in Mailuu-Suu river basin, as well as in a vicinity of Min-Kush settlement, and in Naryn (Syrdarya) river basin. The present paper discusses environmental risks on the territory of above-mentioned areas related to direct and/or indirect

influence of landslides on tailing dumps of uranium ore mining and processing.

Keywords. landslides, radioactive waste tailings, hydrodynamic and environmental risks.

1. Landslide geoenvironmental hazards in Mailuu-Suu

Mailuu-Suu area is a territory of the former large-sized industrial mining complex located in north-eastern foothills of Fergana depression (Fig. 1). A strong man-caused pressure upon weakly stable geological environment of this area, related to mining operations (uranium, coal, oil) and associated infrastructure development appeared as a distinctive trigger mechanism, which apparently stimulated to intensive growth of landslide processes.

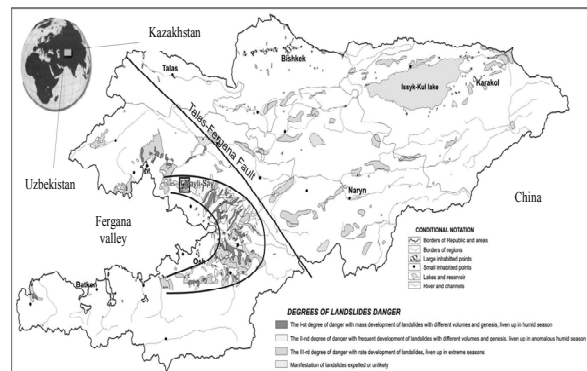


Fig. 1 The map of landslide susceptibility of Kyrgyzstan

Landslide processes most frequently (98%) occur in a mid-stream of Mailuu-Suu River (Fig. 2), in a band of midmountain (900-1600 m) topography development, on a propagation zone of Meso-Neozoic sediments strongly crushed in folds, which due to their lithologic (presence of loess-like loams and clays) and stratigraphic (alternation of water-permeable and waterproof soils) features are predisposed to slumping. Hence, presence within the study area of the both ancient and the newest folded and disjunctive structures of various kinds, high geodynamic regional activity conditioned by meridional compression of Tien-Shan, and wide propagation of ancient landslides caused to active development of new landslides, from which 50% confined to slopes of ancient-slope genesis.

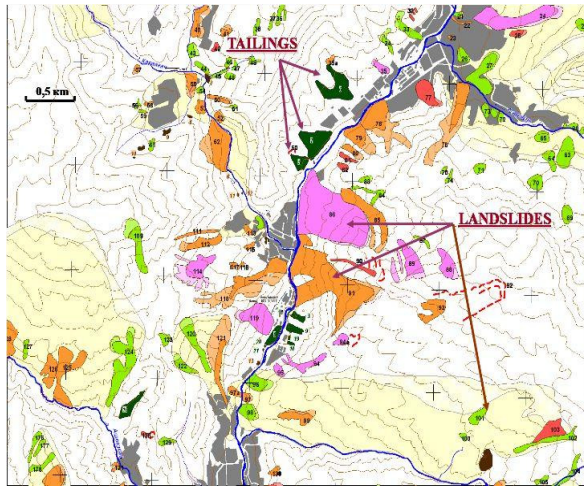


Fig. 2 Landslides and tailings in Mailuu-Suu valley

Presently, in this area more than 200 new landslides of various scale (volume is up to 8 mln.m³), genetic age, and development stages have been registered. Based on the situation at the beginning of 2008, the whole area affected by landslides estimated to 6.37 km², and the total volume of landslide masses moved during 1950-2005 - 260 mln.m³. More than 30 landslides are in a preparation stage for the main movement, and they pose a direct danger to the population, objects of economy and infrastructure, as well as to radioactive waste tailings.

In terms of a complex mountain topography due to a deficit of balanced and available areas the housing estates, communications, industrial objects, including radioactive waste tailings (tailing dumps and stockpiles) were placed along riverbeds, in floodplains and over-floodplain terraces of Mailuu-Suu river and its tributaries, at mountain foothills and/or on slopes themselves, as well as on weakly stable ancient-landslide sites (Fig. 2). In such a situation characterized by high susceptibility of the area to landslide processes and their phenomena, including their frequency, landslides appear as a source of great risk for life activity in Mailuu-Suu town.

Most hazardous are the landslides, which are formed on edges of river valley and its tributaries (Fig. 2) since, their development, and, particularly their final stage - mixture, often has a synergetic character (domino effect).

Synergetic character of landslide movements in mountain river basins proves that landslide event in a narrow river valley is triggering a series of other hazardous phenomena by the following scenario: landslide - rockslide-landslide blockage of riverbed or river valley - landslide dam upstream submergence - breach of this dam - downstream flood or mudflow.

Quite often these hazardous phenomena triggered by a landslide, cannot yield, but sometimes even prevail by their destructive force and causing damage over the initiating event, i.e. the landslide. During the latest 17 years in Mailuu-Suu area more than 10 landslide movement episodes with a blockage of a river and its tributaries have been registered.

The most destructive of them was a river blockage on Tektonik landslide zone in June 1992, when as a result of landslide mass movement about 2 min. in the dam with 15 m height and 800 m length was formed, and simultaneously a small-sized tailing No 17 was blown into the river.

A special hazard development of such synergetic scenarios is related to that in transit zones of landslide masses, submergence, or in a spread zone of breach flows can be not only housing estates, but tailings and dumps of radioactive wastes (RAW) located along riverbeds of Maily-Suu, Karagach and Kulmen-Sai (Fig. 2). In case of possible destruction of these tailings the propagation areal of radioactive materials stored in them may be substantially expanded owing to their propagation through the drainage network of Mailu-Suu river inherited in Syrdarya river basin.

We have explicitly studied environmental risks related to destruction of tailings as a result of direct fall of landslide masses in the articles (Torgoev et al. 2004). Risks concerned with tailing submergence with breach and mud-flow effect on them are highly probable and sound, if taking into account a series of previous incidents having place in the study area (Torgoev et al. 2006). Therefore, in April 1958 following a No 7 tailing dam destruction triggered by extremely heavy rainfall and increased seismic activity in the nearest zone ($R < 100$ km), the mass of radioactive tails with a volume of 400-600 thousand m³ bursting from this tailing dump, propagated as a mudflow with 250m³/s water discharge downstream Maily-Suu river, causing to men death, destruction of some industrial-civil objects and radioactive contamination of a bed, a floodplain and a valley train of the river including Uzbekistan areas.

Presently the largest risk of tailing submergence with their subsequent destruction and catastrophic environmental effects in a form of radioactive contamination of a valley and a valley train of Mailuu-Suu river is registered on the site of a vast ($V > 5-7$ mln. m³) Koitash landslide (Fig. 2). In case of a river valley blockage during simultaneous unloading of this landslide the dam with 15-25 m in height may be formed, and weakly stable tailings No 5, 7 (Fig. 3) with total RAW volume about 800 thousand m³ may be in this submergence zone. The largest submergence risk is in spring season and at the beginning of summer, when water discharge in Mailuu-Suu river at crest segment may reach to 100 m³/s. Totally the computation shows that based on the most pessimistic scenario - absolute destruction of tailings No 3, 5, 7, 8, 18 (Fig. 2) through a direct or indirect influence of Tektonik and Koitash landslides, the total volume of radioactive "tails", which may be dispersed in a flood-plain and on debris cone of a river, may be approximately 1 mln. m³ (total activity is about 10 thousand Ku), and the total volume of radioactive contamination - about 100 km².

Aiming to reduce a risk of uranium tailing landslide destruction in Mailuu-Suu at present time it is planned during the nearest 2-3 years to provide a series of preventive measures and projects including the southern flank unloading of Tektonik landslide, transportation of No 3, 8 tailings to a safer zone, bypass tunnel construction on a site of possible river blockage by Koitash landslide, as well as monitoring

and early warning of landslide process hazard in the area of uranium tailings.

2. Geoenvironmental risks in Min-Kush settlement

Within the last years alarm condition has arisen in the area of Tuyuk-Syy uranium tailing located directly in analogous river-bed (Fig. 3) related to Naryn river basin (Syrdarya). This tailing is placed at a height of more than 2000 m above sea level, and it occupies 5 hectare volume zone, where 640 thousand m³ of Kavak uranium tailing wastes including 450 thousand m³ of radioactive tails have been concentrated.



Fig. 3 The common view of the tailing and landslide in valley of river Tuyuk-Suu.

Based on the results of comparative risk analysis connected to the Tuyuk-Syy tailing it is determined that at present time the most hazardous risk is the destruction of supporting dam and by-pass channel, that can happen following mudflows passing through it, and landslide event with a volume of more than 1.2 mln. m³. This landslide began to develop during moisture-abundant springs in 2004 on a right side of narrow valley 120-150 m lower than the study tailing area (Fig 3).

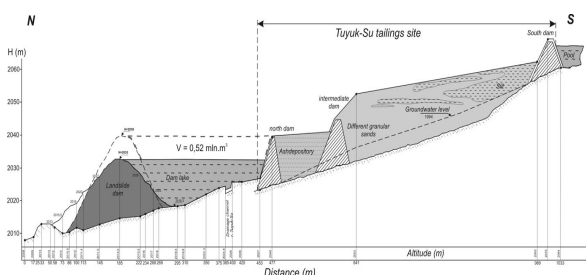


Fig. 4 The modeling results of landslide blockage of river in lower part of tailing Tuyuk-Su.

The phase of this landslide general movements predicted to occur during a spring 2009, is fraught with this narrow valley blockage by a landslide dam, which height, according to calculations, may be more than 30 m over the Tuyuk-Suu river bottom (Fig.4).

It is inevitable that under-pond lake creation with a volume of more than 500 thousand m³ will lead to a tailing submergence. The results of stability assessment of lower

supporting RAW storehouse dam showed that due to a great water-saturation of this tailing body the stability factor is rather low even without taking into consideration a submergence and/or dynamic forces from possible earthquakes. In case of landslide dam unexpected outburst, which usually coincides with water overflow, the outburst flow (wave) with initial water discharge up to 600 m³/s with capturing and entraining radioactive tails into this movement, can be formed. In the final analysis there is a high probability of not only the destruction of Min-Kush settlement apartment buildings located in the adjoining zone of Tuyuk-Suu river outfall (hydrodynamic breakdown), but of the subsequent extensive contamination of Min-Kush, Kokomeran, Naryn riverbeds and flood-plains by radioactive wastes.

As the preventive measures presently landslide movement monitoring is carried out, moreover, special arrangements for controlled and maintained water discharge in case of river blockage by landslide masses have been worked out. Besides, the fundamental plan is to transfer Tyuk-Suu tailing onto the safer zone adjoining the Min-Kush settlement.

Conclusions

The increased probability of hydrodynamic accidents and environmental catastrophes of both regional and transboundary character in warehousing areas of radioactive and toxic mining wastes in Mailuu-Suu, Min-Kush, and other areas of Central Asia is conditioned by that these waste storehouses are located in the influence zone of hazardous geological processes (earthquakes, landslides, avalanches, mudflows), which are typical for geodynamic active mountain areas of Tien-Shan.

Recently one of the major triggering factors of great number of failures in tailings and dumps, negative impacts of these tailings on the environment, as well as the increasing probability of environmental catastrophes appearing on the mentioned objects, consists in the following. During designing and building of these objects "flat reasoning and experience" of planners prevailed upon without taking into consideration mountain region specificity; increased geodynamic activity of new mountain-folded zones; weak geomechanic stability of mountain slopes in terms of intensive man-caused effects; all-round propagation of hazardous natural processes and phenomena in mountain areas; high environmental vulnerability of mountain zones to anthropogenic pressing and climate changes. Short-sighted engineering decisions made during warehousing of radioactive and toxic wastes in catchment areas in narrow river valleys and on landslide-hazard slopes after 40-50 years have led to transformation of local landslide hazards into environmental risks of radioactive regional and/or transboundary contamination.

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