International Journal of GEOMATE, Nov., 2018 Vol.15, Issue 51, pp.195-200
Geotec., Const. Mat. & Env., DOI: https://doi.org/10.21660/2018.51.23412
ISSN: 2186-2982 (Print), 2186-2990 (Online), Japan

MINING CAUSED POLLUTION OF THE NATURAL LANDSCAPE

*Burdzieva O.G.[1], Alborov I.D.[1,2], Tedeeva F.G.[2], Makiev V.D.[1], Glazov A.P.[2]

[1]Geophysical Institute of Vladikavkaz Scientific Center of Russian Academy of Sciences, Russia;

[2]North Caucasian Institute of Mining and Metallurgy (State Technological University), Russia

*Corresponding Author, Received: 7 May 2018, Revised: 24 May 2018, Accepted: 14 June 2018

ABSTRACT: The results of the negative impact of mining and metallurgical production on the natural environment are presented in the article. The objective of the study was to evaluate the performance of the heavy metal speciation in sediments to assess the potential ecological risk associated with anthropogenic waste deposits. An analysis of the factors of the negative impact of the extraction and processing of geomaterials on the components of the natural environment was made in the course of the research. The work reveals a fragmented degradation of the landscape under the influence of the actual production and surface infrastructure of the mining and metallurgical complex. It is shown that the violation of the required sanitary-technical and environmental requirements for the disposal of mining and metallurgical waste leads to dangerous pollution and deformation of the components of the natural environment. Whereas, the long-term functioning of the deformed natural and anthropogenic system leads to unpredictable hazardous consequences, manifested in the development of little-known diseases of the population that lives in the zone of activity of such objects. It is shown that the environmental hazard of a natural and industrial system in mountainous terrain, in comparison with similar flat systems, increases significantly, which implies that additional measures are needed to ensure environmental safety. Moreover, the characteristics of the waste landfills for ore and concentrates processing as well as other materials are given in the paper.

Keywords: Non-ferrous metals, Ore mining, Degradation of the landscape, Dangerous pollution, Tailing dump

1. INTRODUCTION

The territory of North Ossetia is rich in minerals, which led to the development of mining activities here [1]. This causes a significant negative impact on the environment [2]. The presence of the Kazbek volcanic center [3] and the structural style of the surrounding deep structures [4]–[6] stipulates, for example, the possibility of widespread use of geothermal waters [7]. At the same time, here in the mountainous region hazardous geological processes of various nature and activity are developing: glaciers, avalanches, landslides, earthquakes, which necessitates their active study [8]–[11]. At the same time, modern methods of monitoring from macro-size studies to nanotechnology are used [12]–[18].

The history of extracting non-ferrous metals on the territory of Ossetia goes back many centuries. The first information about Sadon's silver ores belongs to the 10th century AD. So, in the village of Nuzal (5 km from Sadon) in the local chapel, there is a record in the Georgian language that the prince Os-Bogatar “... in this world, he stands firmly: the gold-bearing land and silver, like water, he has a lot” [1]. However, only in the eighteenth century, the tsarist government was able to begin a detailed study of the mountain wealth of Ossetia and, in particular, Sadon. Subsequently, the extraction of non-ferrous metals at the Sadon field acquires an industrial character and this continues to nowadays. Ore processing was accompanied by the formation of a large volume of waste since the content of useful components did not exceed the first percent. Wastes from ore processing were stored on terraced elevated sites of the mountain valleys of the rivers Ardon and Fiagdon for a long time. Periodically, during floods, some of them were washed off by river flow and carried out for long distances, up to the water area of the Caspian Sea. Another part of the mountain mass exported from the mines was dumped along the banks of mountain rivers or in the terrain accidents, giving them an anthropogenic appearance. All substandard ore or bedrocks that are transported from the mines to the open surface in the open air become a source of geomaterials emitted into the environment, polluting the atmospheric basin, the aquatic environment, and the lithosphere [2], [19]. Below is given a description of the sources in which the products of enrichment and metallurgy of non-ferrous metals are deposited for a long time.

2. A DESCRIPTION OF THE SOURCES PRODUCTS OF ENRICHMENT AND METALLURGY OF NON-FERROUS METALS

2.1 Unal deposit of anthropogenic waste

Mining and processing of minerals in the Terek river basin go back centuries, and industrial development of ores began at the Alagir silver-bearing lead artel created by the Russian Belgian Joint-Stock Company "ALAGIR" in the middle of the eighteenth century on the basis of Sadon mine.

Later in Osetia on the basis of the Sadon polymetallic deposit, the following mines were discovered: Verkhnii Zgid, Arkhon, Buron, Kholst, Fiagdon. Processing of mined non-ferrous metal ores was carried out at the Mizur processing plant by flotation and then using the method of heavy suspensions.

Fig. 1. Unal tailing dump

At the initial stage of the processing plant work, the enrichment tailings were stored on a terraced area above the village of Mazur in the floodplain of the river Bad. After the next overflowing of the Bad-Don river, the enrichment tailings were washed away by water into the Ardon river. Later after 1968 enrichment tailings were transported by pipeline hydrotransport to the landfill site on the terraced area of the left bank of the Ardon river downstream in the Unal tailing dump, with an area of about 20 hectares, with a volume of about 3.2 million tons (Fig. 1). The tailing dump is located in the vicinity of the village of Unal, nine kilometers from the Mazur processing plant. Near this tailing dump passes the federal highway "Transkam". In some areas, the distance between the body of the tailing dump and the road is no more than 20-30 meters.

With gusts of wind more than 15 m/sec., the visibility on the interstate highway is reduced to 5 meters or lower, which creates an unacceptably high risk when operating such a category of roads.

It was established in 1991 by specialists of the Moscow State University (report in the archive of the plant), that there is an unacceptable concentration of mobile forms of lead and zinc in fruits and vegetables grown in the area of operation of the Unal tailing dump [20-21]. The potential risk in the case of destruction of constructions integrity of the Zaramag cascade reaches catastrophic values, which puts at hazard the safety of the population and the operating infrastructure in the entire gorge and the entire flat flooding zone.

As a result of a comprehensive study of the components of the natural-anthropogenic environment in the area of the Sadon lead-zinc plant, natural and anthropogenic anomalies in soils, bottom sediments, water systems and the main types of agricultural crops of the area have been identified, associated with secondary halos and fringing flux of lead and zinc of deposits and ore occurrences by dumps and mine waters of deposits Dzhimi, Boxing, Kholst, a system of irrigation ditches, wind erosion of the Unal tailing dump.

The main sources of the water system pollution in this district are the tailings and mining dumps of the Dzhimi, Boxing and Kholst deposits. Among the main pollutants of bottom sediments there is the series Zn> Pb> Ag> As> Cu> Sn> Bi.

The impact of the tailing dump causes high concentrations of heavy metals in dust, soils and apple foliage on the lower terraces of the river. Ardon. The intensity of dust precipitation in the garden territory is 74-304 kg/km^2/sec.

In 2000, the ranking of the Unal site was carried out on the contamination of the territory (Fig. 2). In 2010, the soil was re-ranked in the vicinity of the tailing dump (Fig. 2, a dotted line).

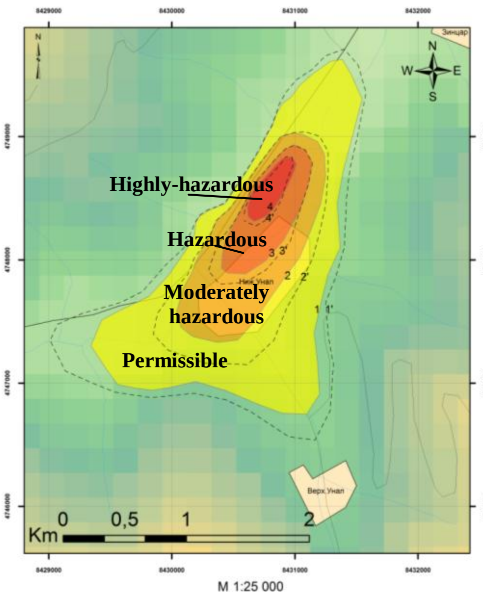

Fig. 2. The pollution map of the Unal site

Comparison of the results of the studies at both stages revealed that, with a slight decrease in the concentration of pollutants in stage 2, the contamination area increased (Table 1).

Table 1 Comparison of research results at both stages

Value levels	Area of pollution, thousand m^2			
	Stage 1 (2000)	Stage 2 (2010)	Change of area	
			thous. m^2	%
Permissible	620	680	+60	9.6
Moderately hazardous	380	420	+40	10.5
Hazardous	210	220	+10	4.8
Highly-hazardous	44	40	-4	9.1

Hence, it can be concluded that the termination of work by a mining enterprise did not improve the state of the environment in a ten-year period.

2.2 The Fiagdon anthropogenic waste deposit

The Fiagdon tailing dump was constructed in 1971 to store enrichment waste from the polymetallic ores of the Fiagdon processing plant. It contains about 3.3 million tons of lead-zinc ore processing waste on an area of 5.6 hectares (Fig. 3).

Fig. 3. Fragment of the body washout of the Fiagdon tailing dump in 2011

The tailing dump is located in the picturesque Fiagdon Gorge, in an area where the number of sunny days a year exceeds the well-known health resort areas of the North Caucasus, Kislovodsk, and Teberda. This sunny valley is the favorite recreation zone of the republic's population, at the same time it serves as a balneological center, attracting lung patients, tourists, and recreators. In this situation, the body of the tailings dump poses a serious threat to the environment, as its maintenance goes with violations of the current Federal Law “About Production and Consumption Waste”, so if there are no urgent measures to prevent the tailing dump body from flushing the Khanikom-don waters, the threat of catastrophic contamination of the water area of the republic remains inevitable. There are heavy and toxic metals of the first and fourth hazard class in the tailings. Under the influence of natural factors and chemical processes, the buried geomaterials are transformed and remain a continuous source of dangerous pollution for the components of the natural environment.

The zone of negative impact in the valley due to winds covers not only the Fiagdon resort and recreational area, but also other significant space for rest with occasional catastrophic manifestations. For example in 2011 when overflowing Khanikomdon river, that is flowing through the tunnel under the body of the tailing dump, with a cross-section of 7.5 square meters, a length of 70 meters, due to the collapse of the tunnel about 45.000 tons of enrichment tailings were removed by water flow, with significant ecological damage to the flora and fauna of the whole water area up to the Caspian sea, which was regarded by specialists as the Fiagdon ecological disaster. The high level of the river flow pollution has spread far beyond the borders of the republic. Taken samples of water in the river Fiagdon (downstream one kilometer from the confluence of Khanikom Don), according to the results of laboratory studies, showed that the content of zinc in the river was seven maximum permissible concentrations (MPC), copper - 3.5 MPC, manganese - 2 MPC, iron - 4 MPC, cadmium - 0.8 MAC and lead - 0.5 MPC.

Investigations revealed that the reason for the accidental removal of enrichment tailings at the Fiagdon tailing dump was the violation of its maintenance regime, in particular, the absence of monitoring observations of the hazardous waste storage facility. At present, the condition of the landfill body is in the regime of continuous flushing with atmospheric precipitation and with increasing rainfall, the risk of deposited waste removing in the landfill remains uncontrolled and may become a regular ecological catastrophe in critical cases.

2.3 Clinker of JSC “Electrozinc” Ural Mining and Metallurgical Company Holding

Wastes from processing concentrate to metal were located on the territory of the enterprise (Fig. 4), with an area of about 19 hectares and on the dump field (Fig. 5), an area of about 17 hectares.

The total amount of waste at 2 sites is -3.2 million tons. According to geologists, there are more than 354 tons of mercury, 8019 tons of arsenic, 4714 tons of selenium, wastes containing lead and its compounds amount to 5280 tons. The emission of solid and gaseous pollutants into the atmosphere from the body of deposited wastes has stabilized and is in a state of imaginary stagnation, while the migration of heavy and harmful constituents as solutions to the lithosphere increases due to the physicochemical processes taking place in the body of this object. The absence of the possibility of monitoring observations over changes in the composition of subsoil water and groundwater does not allow a real assessment of their impact on the quality of groundwater, while the current regulations do not allow to contain these wastes without integrated environmental monitoring. Such a program was adopted earlier at the end of the last century, but the monitoring was suspended and not carried out at the present time. The current situation is a violation of the rules for the maintenance of industrial waste and consumption in the Russian Federation by the subsoil user on the territory of the capital of the republic.

Fig. 4. The dump field of OJSC “Electrozinc” Ural Mining and Metallurgical Company Holding

Fig. 5. Clinker on the industrial site of OJSC “Electrozink” Ural Mining and Metallurgical Company Holding (1.7 million tons)

Even external painting of building walls can carry traces of the negative impact of dust and gas pollution sources.

A two-stage study similar to the Unal site was carried out at the Vladikavkaz site (in 2000 and 2010 respectively).

A comparison of the results of the studies in both stages revealed that in stage 2 with an insignificant decrease in the concentration of pollutants, the area of the permissible and moderately hazardous contamination zones increased by a significant amount (Table 2).

Table 2 Dynamics of changes in soil contamination parameters by the plant

Value levels	Area of pollution, thousand m^2			
	Stage 1 (2000)	Stage 2 (2010)	Change of area	
			thous. m^2	%
Permissible	22	26	+4	18
Moderately hazardous	12	18	+6	12.5
Hazardous	6	6	0	-
Highly-hazardous	2	2	0	-

Hence, we can conclude that a significant reduction in the volume of processing of mineral raw materials by the metallurgical plant has not reduced the load on the ecosystems of the environment. The results of two-stage studies are used as a basis for a map of the dynamics of soil contamination with time under the influence of tailing dump (Fig. 6).

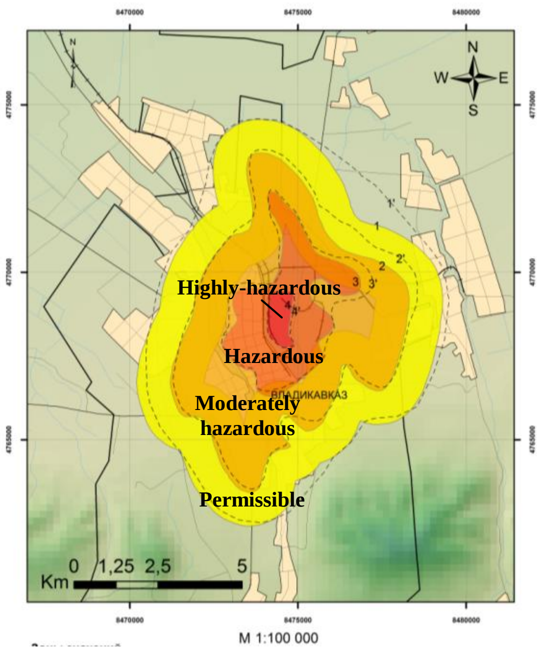

Fig. 6. The pollution map of Vladikavkaz site

Only an integrated approach to the restoration of the soil horizon with subsequent biological reclamation can ensure the safety of the child population in the conditions under consideration.

Recently, at the initiative of the company's management, the activity of lead production was stopped, which was perceived by the environmental community and the population of the city as a humane action. However, the stop should be made on the basis of a special project to restore the territory, which housed both the production itself and a dangerous source of its impact. For this, special engineering surveys are required with the determination of the depth of the soil horizon and the level of pollution with anthropogenic ingredients of plant genesis. With regard to the removal of deposited waste in such portions, it also requires a design solution, since the clinker body is mothballed and loosening it for loading into the recovery vessels requires the development of measures to ensure environmental safety as for loading operations so for the burning of coke prevention (about 11%) due to the free access of the oxidant-oxygen of air through the destroyed surface.

3. DISCUSSION AND CONCLUSIONS

The presence of significant areal pollution sources of the natural environment in the limited territory of the Republic of North Ossetia Alania leads to increased pollution of the local ecosystem, periodically exceeding the established sanitary standards by several times, which is confirmed by bioassay (fruit, vegetables) analyzes taken in the area of operation of the Unal tailing dump.

In the active zone of technogenic deposits degradation of the natural landscape develops, biodiversity is depleted, fragmentary destruction of the soil cover occurs, and in separate sites become stable.

Formed anthropogenic sources of a deposited waste of mining and metallurgical redistribution are located in a zone of increased ecological risk, capable of causing the anthropogenic catastrophe with significant damage not only to economic buildings but possible human casualties in certain natural conditions (destruction of the Zaramag hydroelectric dam, overflowing of the Fiagdon and Ardon rivers).

Despite the fact that the mining industry is not working pollution continues. Same effects are observed in many cases when heavy metals indicate their former most important environmental sources [22]–[28].

The other important result is a reduction of the highly-hazardous zone for Unal site (Table 1). It may cause by leaching and weathering [29] in the kernel of pollution, while other zones had been proportionally spread. Leaching may be also affected by different “amendments” [30].

4. REFERENCES

[1] Questions of improving mining production (To the 125th anniversary of the Sadon mines). Ordzhonikidze, 1968, pp. 3-15.

[2] Burdzieva O.G., Zaalishvili V.B., Beriev O.G., Kanukov A.S., Maysuradze M.V. Mining impact on the environment on the North Ossetian territory // International Journal of GEOMATE, 2016, T.: 10, Vol.: 19. pp. 1693-1697.

[3] Zaalishvili V. B.; Nevskaya N. I.; Nevskii L. N.; Shempelev A. G. Geophysical fields above volcanic edifices in the North Caucasus // Journal of Volcanology and Seismology. 2015. Vol. 9. Issue 5. pp. 333-338.

[4] Gorbatikov A.V., Rogozhin E.A., Stepanova M.Y., Kharazova Y.V., Andreeva N.V., Perederin F.V., Zaalishvili V.B., Mel’kov D.A., Dzeranov B.V., Dzeboev B.A., Gabaraev A.F. The pattern of deep structure and recent tectonics of the Greater Caucasus in the Ossetian sector from the complex geophysical data // Izvestiya, Physics of the Solid Earth, 2015. 2015. T. 51. No 1. pp. 26-37.

[5] Rogozhin E.A., Gorbatikov A.V., Zaalishvili V.B., Stepanova M.Y., Andreeva N.V., Kharazova Y.V. New data on the deep structure, tectonics, and geodynamics of the Greater Caucasus // Doklady Earth Sciences, 2015. 2015. T. 462. No1. pp. 543-545.

[6] Shempelev A.G.; Zaalishvili V.B.; Kukhmazov S.U. Deep structure of the western part of the Central Caucasus from geophysical data // Geotectonics. 2017. Vol. 51. Issue 5. pp. 479-488.

[7] Zaalishvili V.B., Burdzieva O.G., Dzhgamadze A.K. Geothermal waters of North Ossetia // Ecology, Environment and Conservation. 2015. T. 21. No 5. pp. 151-155.

[8] Zaalishvili V.B., Mel’kov D.A. Reconstructing the Kolka surge on September 20, 2002, from the instrumental seismic data // Izvestiya, Physics of the Solid Earth September 2014, Volume 50, Issue 5, pp. 707-718.

[9] Zaalishvili V.B., Rogozhin E.A. Assessment of seismic hazard of territory on basis of modern methods of detailed zoning and seismic microzonation // Open Construction and Building Technology Journal. 2011. T. 5. pp. 30-40.

[10] Milyukov V.K., Yushkin V.D., Kopaev A.V., Mironov A.P., Dem'Yanov G.V., Sermyagin R.A., Basmanov A.V., Popad'Ev V.V.,

Nasretdinov I.F., Zaalishvili V.B., Kanukov A., Dzeranov B. Monitoring Current Vertical Movements of the Northern Caucasus by Absolute and Relative Gravimetry // Measurement Techniques. 2014. T. 56. No 10. pp. 1105-1110.

[11] Zaalishvili V.B., Nevskaya N.I., Melkov D.A. Instrumental geophysical monitoring in the territory of Northern Caucasus. // Izvestiya. Physics of the Solid Earth. 2014. Vol. 50. No. 2. pp. 263-272.

[12] Zaalishvili V.B., Melkov D.A., Dzeranov B.V., Morozov F.S., Tuaev G.E. Integrated instrumental monitoring of hazardous geological processes under the Kazbek volcanic center // International Journal of Geomate, July 2018. Vol.15, Issue 47, pp.158-163.

[13] Grigorkina G. S.; Ramonova A. G.; Kibizov D. D.; Kozyrev E.N., Zaalishvili V B., K. Fukutani, Magkoev T.T. Probing specific oxides as potential supports for metal/oxide model catalysts: MgO(111) polar film // Solid State Communications. 2017. T. 257. pp. 16-19 a.

[14] Mritunjoy Sengupta Environmental Impacts of Mining Monitoring, Restoration, and Control // Routledge, 6.02.2018 г., 512 p.

[15] Ravi Jain Environmental Impact of Mining and Mineral Processing // Management, Monitoring, and Auditing Strategies, Butterworth-Heinemann, 3.08.2015 г., 322 p.

[16] Christopher Gordon Down, John Stocks Environmental impact of mining // Applied Science Publishers Ltd., 1977, 371 p.

[17] Robert E. Redmann Environmental Effects of Mining // Routledge, 6.02.2018 г., 368 p.

[18] Jose M. Azcue Environmental Impacts of Mining Activities // Emphasis on Mitigation and Remedial Measures, Springer Science & Business Media, 6.12.2012 г., 300 p.

[19] Golik V., Komashchenko V., Morkun V., Zaalishvili V. Enhancement of lost ore production efficiency by usage of canopies // Metallurgical and Mining Industry, 2015. pp. 325-329.

[20] Alborov I.D., Tedeeva F.G. Environment-forming factors in extraction and processing of ores, Sustainable Development of Mountain Territories. No.2 (4) 2010, pp. 39-46.

[21] Alborov I.D., Zaalishvili V.B., Tedeeva F.G. et al. - Environmental risk, principles of environmental assessment and public health, Vladikavkaz: IP Tsopanova A.Yu. 2013, 343 p.

[22] Wardhani1 E., Notodarmojo S. and Roosmini D. Heavy metal speciation in sediments in saguling lake west java Indonesia International Journal of GEOMATE, June 2017, Vol.12 Issue 34, pp. 146-151.

[23] Zhang, H., He, P., Shao, L.M.,. “Fate of heavy metals during municipal solid waste incineration in Shanghai”. Journal of Hazardous Materials Vol 156, 2008 pp 365-373.

[24] Zhao, X., Dong, D., Hua, X., Dong, S.,.”Investigation of the transport and fate of Pb, Cd, Cr (VI) and As (V) in soil zones derived from moderately contaminated farmland in Northeast, China”. Journal of Hazardous Materials 170, 2009570-577.

[25] Israel Razo, Leticia Carrizales, Javier Castro, Fernando Díaz-Barriga2 and Marcos Monroy Arsenic and heavy metal pollution of soil, water and sediments in a semi-arid climate mining area in Mexico. Water, Air, and Soil Pollution 152: 129–152, 2004.

[26] Héctor M. Conesa, Ángel Faz, Raquel Arnaldos Heavy metal accumulation and tolerance in plants from mine tailings of the semiarid Cartagena–La Unión mining district (SE Spain). Science of the Total Environment 366 (2006) pp. 1–11

[27] Zhou Jian-Min, Dang Zhi, Cai Mei-Fang1 and Liu Cong-Qiang Soil Heavy Metal Pollution Around the Dabaoshan Mine, Guangdong Province, China. Pedosphere 17(5): 588–594, 2007. pp. 588–594.

[28] Rodrıguez L., Ruiz E., Alonso-Azcarate J., Rincon J. Heavy metal distribution and chemical speciation in tailings and soils around a Pb‑Zn mine in Spain. Journal of Environmental Management 90 (2009). pp. 1106‑1116.

[29] Fanfani L., Zuddas P., Chessa A. Heavy metals speciation analysis as a tool for studying mine tailings weathering. Journal of Geochemical Exploration 58 (1997). pp. 241-248

[30] Schwab P., Zhu D., Banks M.K. Heavy metal leaching from mine tailings as affected by organic amendments. Bioresource Technology 98 (2007) pp. 2935–2941.