Identification of formation factors for ecological state of soils, and impact of overburden

V A Pochechun¹, A I Semyachkov¹,², V V Kuchin¹

¹Department of Geoecology, The Urals State Mining University, 9, Universitetskiy Lane, Yekaterinburg 620144, Russia
²Department of Geoecology and nature management, Economics Institute of the Russian Academy of Sciences (Ural branch), 29, Moskovskaya Street, Yekaterinburg 620014, Russia

E-mail: viktoriyapochechun@mail.ru

Abstract. In this paper formation factors for ecological state of soils in the location area of rock overburden dumps formed as a result of the development of Gusevogorsky deposit are studied. Gusevogorsky deposit is located in the Kachkanar district of the Middle Urals. This deposit contains vanadium-containing titanomagnetite ores, and therefore the rocks and ores of this territory contain the following association of chemical elements: vanadium, cadmium, silicon, arsenic, nickel, chromium, and zinc. A rock overburden dump is a potential source of anthropogenic impact on environmental components, including soils through fugitive dust emissions. Thus, in our work two formation factors for ecological state of soils in the given territory are considered: 1) overburden rock geochemical composition; 2) pollutant dispersion air streams from the dump.

1. Introduction
During the implementation of the system for monitoring environmental components, a field and laboratory study of the existing waste disposal facility - rock overburden dump - was carried out to identify a source of soil pollution. The main goal of this study is a subsequent analysis of the completeness and reliability of keeping a track for this source, with its technology-related impact on the components of the environment as a whole, including soils. The paper gives a description of the environmental impact of waste - overburden rocks formed during the development of a vanadium-containing titanomagnetite ore deposit, taking into account past and current information.

2. Reference and methodology
In the paper methods of environmental monitoring, graphic modeling and a systematic approach are used. The work is based on a large amount of bibliographic sources, geochemical survey and monitoring research data.

3. Results and discussion
Gusevogorsky deposit of vanadium-containing titanomagnetite ores is confined to a gabbro-pyroxenite massif of the same name. The associated overburden rocks extracted during the development of the
deposit passing into the dumps do not form independent bodies, they differ from ore not by petrographic features, but on the basis of condition parameters. According to the lithological composition overburden rocks are represented by dialagic pyroxenites, olivine pyroxenites, amphibolized pyroxenites, plagioclase-containing pyroxenites, and gabbro.

The petrographic characteristics of overburden rocks are given below according to geological reports on exploration and additional exploration of Gusevogorsky deposit [1, 2].

Dialogic pyroxenites occupy over 60% of the volume of rock overburden. Macroscopically they represent massive granular (full crystalline) greenish-gray rocks. The rock-forming minerals are clinopyroxenes of the diopside-hedenbergite series (15-95% of the volume), titanomagnetite - magnetite with decay structures of ilmenite (0-15%), hornblende, belonging to the group of calcium amphiboles (0-10%). Plagioclases, whose composition varies from anorthite to andesite, chlorites — penin, clinochlor, epidote minerals, spinel, and chalcopyrite — are noted as minor minerals.

The olivine and olivine-containing pyroxenites are characterized by the presence of the same mineral constituents as dialogites, the main difference is olivine increased content, which occurs in the form of individual grains and clusters distributed unevenly. Olivines in composition correspond to low-iron forsterite.

Amphibolized pyroxenites, comprising up to 10% of the overburden volume and being heterogeneous-grained rocks with spotty texture due to isolated accumulations of hornblende, are characterized by the presence of clinopyroxene (5-90%), titanomagnetite (0-15%), hornblende (10-50%), plagioclases (0-10%), spinel (0-3%), grains of pyrrhotite, actinolite are rarely observed.

Plagioclase and plagioclase-containing pyroxenites, which make up about 6% of rock overburden, are characterized by plagioclase content of up to 15%. Species of spotted texture due to uneven distribution of plagioclase, are often sossuritized. Rarely, thin, poor impregnation of sulfides is found in the rocks.

Gabbro makes up about 5% of the total overburden and is characterized by the following mineral composition: plagioclase (30-50%), pyroxene (10-30%), hornblende (2-30%). Apatite, titanomagnetite together with accessory minerals in the total amount to no more than 1-2%.

The study of the content of harmful impurities in the petrographic types of overburden identified at the deposit was carried out as part of the work to calculate the reserves of titanomagnetite ores as of 01.01.1988 [2]. In this case, we used data from a macroscopic description of rocks, a petrographic description of thin sections, and data from mineralogical and chemical analyses.

The studies carried out have established the presence of chalcopyrite, pyrite, and rarely pyrrhotite in all types of rocks, which are represented as single phenocrysts and mild impregnations, and even at maximum concentrations their content does not exceed 1-2%. The sulfide content ranges from 0 to 0.3%, averaging 0.1%.

Iron hydroxides are diagnosed as goethite and hydrogutite, forming rims around sulfides, they are accessory minerals rarely represented by finely divided varieties.

In small amounts in the form of single plates graphite can be met with its content not exceeding fractions of%. Apatite is represented by single small grains and recognized as an accessory mineral. Chlorite - penin and clinochlor, a secondary mineral, has the greatest development in cataclase zones, its amount does not exceed the first%.

Of the impurities in overburden, the most common is titanomagnetite (magnetite with decay structures of ilmenite), the content of which varies from the first% to 10-15%.

The weighted average magnetite content is 5.8%.

An analysis of the petrological and mineralogical composition of overburden rocks shows that the rocks are predominantly mineral compounds sufficiently resistant to water-chemical weathering - pyroxenes, amphiboles, olivine, plagioclases.

1 Stopping limit of total iron – 18%, minimum mineable thickness of ores – 10m, maximum minable thickness of dradge beds – 15 m.
Potential hazards for geochemical environmental pollution are sulfide minerals (pyrite, chalcopyrite, pyrrhotite) and chalcophilic chemical elements (As, Sb, Pb, Hg, Cu, Zn) concentrated in these minerals [3]. Sulfides are unstable under hypergenic conditions - they are oxidized by oxygen and water with the formation of soluble forms of the elements that make up their composition.

Data on the chemical composition of overburden rocks are given in Table 1. The contents of the components in the overburden rocks are compared with regional Clarke elements in the soils of the Urals [4].

### Table 1. Overburden chemical composition.

| Waste component          | Content, weight % | Content in soils of the Urals, weight % | Exceedance ratio |
|--------------------------|-------------------|----------------------------------------|------------------|
| Aluminium                | 1,12              | 7,1                                    | 0,16             |
| Vanadium                 | 0,058             | 0,01                                   | 5,80             |
| Iron                     | 6,3               | 8,6                                    | 0,73             |
| Cadmium                  | < 0,0005          | 0,00005                                | 10,00            |
| Calcium                  | 6,5               | 6,7                                    | 0,97             |
| Silicon dioxide (in terms of silicon) | 36,4           | 24,0                                   | 1,52             |
| Magnesium                | 2,1               | 4,5                                    | 0,47             |
| Manganese                | 0,039             | 0,08                                   | 0,49             |
| Copper                   | 0,008             | 0,02                                   | 0,40             |
| Arsenic                  | < 0,0005          | 0,0002                                 | 2,50             |
| Nickel                   | 0,006             | 0,003                                  | 2,00             |
| Lead                     | 0,0005            | 0,001                                  | 0,50             |
| Sulphates (in terms of sulphur) | 0,02             | 0,03                                  | 0,67             |
| Titanium                 | 0,15              | 0,4                                    | 0,38             |
| Chromium                 | 0,02              | 0,01                                   | 2,00             |
| Zink                     | 0,006             | 0,005                                  | 1,20             |

The data presented in Table 1 show that the average content of elements in overburden, in general, does not exceed their Clarke values. A slight excess over the regional Clarke (up to a maximum of 10 times) is noted for vanadium, cadmium, silicon, arsenic, nickel, chromium, and zinc.

Overburden rocks during the development of the Gusevogorsky deposit, due to the lack of need in their processing, are located in dump No. 1. The dump no. 1 is located on a swampy land in the floodplain of the Vyya River.

The dump started its operation in 1961. The life of the dump is until 2050. The nearest settlement is Valerianovsk, located 0.5 km north - north-east of the dump. Currently, the dump covers an area of 235.2 hectares. The development of the dump goes in the northeast direction. This is a three-tier dump. The elevations of the first tier are 240 m, the second - 265 m, the third - 280 m. (Figure 1)

![Figure 1 Dumping of dump No. 1.](image-url)
Technological processes of dumping and static storage of overburden and host rocks in dumps lead to the formation of air and water flow pollutant dispersion, which causes additional geochemical load on the soil adjacent to the dump territories.

The formation of the airborne pollution flow occurs due to the presence of finely divided particles in the stored rocks - fine earth, part of which is mobilized by the dispersion air stream and, passing into an aerosol, it is carried outside the dump.

The annual gross emission of rock dust from dump No. 1 is 156.826 t/year. According to the recommendations [5, 6], the area of the greatest dust loss around the mining zone (quarries, dumps) is 10 km² (the radius of the geochemical pollution zone is 1.8 km). According to [5, 6], up to 30% of solid aerosol falls out in this zone, the rest is included in global atmospheric dispersion flows and involved in the formation of the background load.

A quantitative assessment of the technology-related geochemical load (annual) on the territory adjacent to dump No. 1 is given in Table 2.

Table 2. Quantitative assessment of the technology-related geochemical load on the territory adjacent to dump No. 1 from the dispersion air flow.

| Element      | Load, kg·year/km² | Element      | Load, kg·year/km² |
|--------------|-------------------|--------------|-------------------|
| Aluminium    | 52,694            | Copper       | 0,376             |
| Vanadium     | 2,729             | Arsenic      | 0,024             |
| Iron         | 296,401           | Nickel       | 0,282             |
| Cadmium      | 0,024             | Lead         | 0,024             |
| Calcium      | 305,811           | Sulphur      | 0,941             |
| Silicon      | 1712,540          | Titanium     | 7,057             |
| Magnesium    | 98,800            | Chromium     | 0,941             |
| Manganese    | 1,835             | Zink         | 0,282             |

The accumulation of dust precipitation from the atmosphere will occur in the upper soil layer - a natural depositing medium for dispersion air flow [7-18].

We assessed the quality of soils in the impact zone of dump No. 1 based on the results of observations as part of the Environmental Monitoring Program for environmental components.

Soil testing in the area of dump No. 1 was carried out at one test site. To ensure the necessary representativeness, five soil samples were taken at the site combined into one combined sample using the "envelope" method [19-26].

The list of pollutants to be controlled includes the following items: iron, pH, petroleum products, vanadium, manganese, copper, lead, mercury, 3,4-benz (a) pyrene [27].

The results of observations of the geochemical state of the soil cover in the area of dump No. 1 are shown in Table 3.

Table 3. The geochemical state of the soil cover in the area of dump No. 1.

| Factor      | Pollutant content, mg/kg |
|-------------|--------------------------|
| Concentration | Benzopyrene Oil products Vanadium Lead Mercury Copper Manganese Iron Cadmium Arsenic Nickel Zink pH |
| 0.0001      | 16.3 110.7 <0.5 105.8 891.8 24194 <0.25 0.8 25.5 61.7 6.14 |
| LOC         | 0.02 150 32 2.1 132 1500 - 2 5 80 220 - |
| LOC index   | 0.005 0.738 0.016 0.002 0.802 0.595 - 0.125 0.16 0.319 0.280 - |
Studies of the composition of soils in the area of dump No. 1 of Vanadium OJSC conducted as part of environmental monitoring (Table 3) showed that the metal content in soils does not exceed the maximum permissible concentrations.

4. Conclusion

Overburden dump is a source of additional geochemical load on the soil.

The geochemical composition of waste - overburden is determined by the geological structure of the mined Gusevogorsky deposit, the petrological and mineralogical features of the mined rock mass.

The formation of air streams of pollutant dispersion takes place as a result of static storage of waste in the dump, as well as during the implementation of dumping technological processes. The formation of an aerogenic flow of pollution occurs due to the presence of a fine fraction in the stored waste, part of which is mobilized by the dispersion air flow and, passing into an aerosol, is brought outside the waste disposal facility. The area of the greatest dust loss around the waste disposal facility is 10 km² (the radius of the zone of maximum pollution is 1.8 km). Annually, up to 24.8 tons of pollutants fall onto the territory adjacent to the dump.

The maximum technology-related geochemical load (in absolute terms) is observed for silicon, iron, calcium, aluminum, magnesium, titanium, and vanadium.

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