ENVIRONMENTAL IMPACT ASSESSMENT OF INTEGRATED MINING MILL PROJECT

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The construction of an integrated mining mill is projected. The expected environmental implications are:

(1) Significant heavy metals pollution of streams draining the territory of the deposit.
(2) The reduction in fishing stocks in rivers and their exclusion from the category of spawning ones for Chum salmon.
(3) The deterioration in habitats and a fall in the number of wild animals, primarily squirrels, sables and musk deer.
(4) The loss of wood because of:
   (a) felling;
   (b) drying up spruce forests;
   (c) forest fires;
   (d) substitution of indigenous formations for wood species of small value.
(5) Damage due to the loss of medicinal plants (gingsseng, Eleutherococcus, Aralia).
(6) Atmospheric air pollution.

To neutralize adverse environmental impacts the following measures are proposed:

(1) The realization of actions for preventing the outlet of mine water outside the industrial zone. The main objective is to localize injurious components (acidity and heavy metals) which is achieved by the transfer of dissolved forms of metals into solid-phase ones.
(2) Due to the improper choice of placing the tailings pond (location within the zone of the main transfer of atmospheric admixtures from the open pit, unfavourable geomorphological conditions) its transfer to a more suitable place is suggested.
(3) The construction of drainage under the body of one of the dumps to prevent the formation of landslides and mud flows.
(4) The removal and storage of the humus layer with the subsequent recultivation.
(5) The early replanting of saplings into the nursery gardens to create subsequently artificial phytocenosis on the dumps.

The construction and operation of the integrated mining mill are practicable provided that measures mentioned above are realized.

Until recently the issues of technical feasibility and economic criteria have been discussed when assessing a project in the former USSR. The consideration of natural environment was rarely conducted. This was because of the lack of financial resources, whereby the environment might be conceived as a commodity, the difficulty of implementing quantitative EIA of industrial works and the conventional priority given to the growth of the national economy.
The notion of there being a necessity to implement EIA first arose in developed capitalist countries and recently in our country too. This paper has been written as a result of implementing EIA for the integrated mining mill in Prymorsky Territory, Russia (Fig. 1). The ore field consists of alevrolites in interstratification with sandstones at Lower Cretaceous. Sedimentary rocks are broken out by intrusion of granite-porphries, rhyolites and basites. The main ore — controlling factor of the deposit represents the stock of granite-porphries disposed in the crossing of long-lived faults. The major ore target constitutes a stockwork containing commercial reserves of tin, tungsten and associated lead-, zinc- and copper reserves.

Mineralization of striated type represents densely streaky mineralization. The main ore types are those bearing cassiterite, wolframite, sulphides, etc. Cassiterite — greisen and cassiterite — (wolframite) — quartzose types of mineralization, spatially coincided in the stockwerk, are of commercial importance. Primary ores are represented by streaky, dissiminated (greisen) and breccia types. The deposit belongs to the cassiterite — (wolframite) — quartzose formation.

When carrying out EIA of a project it is essential:

(1) to identify the current state of the natural environment (to forecast and predict the future one needs to know what it is available today);
(2) to predict the likely consequences of building and operating a project; and
(3) to suggest measures for reducing damage.
1. Current State of the Environment

When studying the current state of the environment, one needs to identify all its components to be subject to likely impacts as well as natural features of a territory which can complicate the building and operating of a project.

In the most general events the components like soil, vegetation, wildlife, surface water, atmospheric air, etc. are under discussion. To identify natural peculiarities of the territory hindering the building of a project, considerations of issues on engineering geology (hydrogeology, character of ground, seismicity, etc.) and engineering geomorphology is more often required. The study of slope processes (rockfalls, talus, stone streams, solifluxion) and channel ones (mud flows, icing) are necessary in mountain areas.

Thermocarst, thermoregression, swelling, etc. should be discussed on the plain territories, under conditions of permafrost in particular.

The territory under consideration is situated on the west macroslope of the Sikhote Alin range with an area of about 150 square kilometers (Fig. 2). A brief characteristic of the current state of main components in a natural environment is given below.

1.1. Soil

The soil cover is rather composite. Mountain brown taiga soil and mountain podsolonic ones are distributed on the watershed surfaces under high mountain spruce forests (total altitude from 900 to 1000 meters above sea level). Their soil profile
is distinguished by a strong skeletal structure, good drainage, and small thickness. The strongly acid reaction, high content of humus and its fulvate composition are typical for them.

The mountain-forest soil are developed under cedar-broad-leaved forests at a height of 500-800 meters above sea level. They are characterized by a weakly acid reaction, gleying of upper and middle parts of the profile, accumulation of a great quantity of soluble forms of iron in the upper part of the profile, and lower fertility comparing with brown-taiga soils.

Inundate soil complexes of small thickness littered with sandy-shingle deposits are formed under willowshrub and poplar stand in narrow river valleys.

1.2. Vegetation

The forest vegetation occupies 95% of the territory. Commercial fellings have not been performed on a large scale and devastating forest fires have not been noted here which have allowed vegetation to be well conserved. The forests are mainly mature, of middle age from 180 to 200 years. However, in valleys of streams and rivers, younger spruce forests up to the age of 90 are found. In percentage relation, forest formations may be presented as follows:

1. abies-spruce forests with mean wood stock of 200-230 cubic meters per hectare — 30%;
2. cedar-broad-leaved forests (300-320 cubic meters per hectare) — 35%;
3. yellow birch forests (220-240 cubic meters per hectare) — 20%;
4. valley spruce forests (220 cubic meters per hectare) — 10%;
5. valley broad-leaved forests (230 cubic meters per hectare) — 5%.

The forests as a whole are characteristic of underwood of mean thickness, well developed herb-shrub layer and significant moss cover (an average of 70–80%). The drug plants (ginseng, Eleutherococcus, Aralia) and a pointed yew, which is cited in the Red Book of USSR as a rare species, are found.

1.3. Wildlife

The territory under consideration is inhabited by the Amur tiger cited in the Red Book of IUCN and the Asiatic bear cited in the Red Book of USSR. Of the main hunting and commercial species, valuable fur-bearing animals including the sable, Siberian weasel, squirrel, mink, lynx and ungulate animals including Manchurian deer, wild boar, musk deer, roe, elk and brown bear are extremely common.

Sable is the most valuable among fur-bearing animals; its density amounts to 8.9 individuals per 1000 hectares. The density of a squirrel equals to 53.7 individuals per 1000 hectares in the average and it increases two to three times in productive years.

Among ungulates, a background species of maximum population density is a musk deer (from 7 to 14 individuals per 1000 hectares). The importance of this
species is the great demand for its main product, “musk deer’s spurt”, (which is a musky gland of a male) on the international market. The population density of other species of ungulates is low (between 0.1 and 0.9 individuals per 1000 hectares) on the territory studied.

![Diagram](image.png)

Fig. 3. Layout of the area investigated within the Dalnaya-River Basin. Symbols: (1) gage lines; (2) spot of taking water samples on content of heavy metals; (3) area of ore deposit.

The effect of building and operating the integrated mining mill on fish fauna will extend beyond the territory under consideration and touch the Dalnaya and Tigrinka River Basins (Fig. 3). The Dalnaya River falls into the water courses of the highest category in fishing water as it is a spawning river for autumn chum salmon. On the upper sections of the river are its spawning grounds with a total area of 162,000 square meters. The spawning run of the autumn chum salmon into the river amounts to about five thousand fish lasting from 20 September till 10 December. Other valuable fish species including a taimen, a grayling, a lenok also spawn and hibernate in this river. The Tigrinka-River which is a left-bank tributary of the Dalnaya River also falls into the first category for fishing water use. Between 1 October and 15 November the autumn chum salmon enters the river for spawning. A taimen, a grayling and a lenok are also found in the Tigrinka-River with their spawning in the mouth sections of its tributaries.

1.4. Surface water

As a main source of information on assessment of the level of river pollution, data of hydrometeorological service’s observations were carried out regularly in 57 gage
lines on rivers of Primorsky krai. The two gage lines, nearest to the area studied are located at distances of 30 and 70 kilometers. The water in both gage lines are assigned to a category of pollution with significant excess of permissible concentrations of ammonia, phenols, petroleum products close to a norm by suspended matters, and low contents of synthetic surface active substances.

Information on the content of heavy metals in surface water were obtained when analyzing samples were taken from the Dalnaya River and the Tigriny spring. The water composition was also analysed in one of the adits. Data of analyses indicate the content of heavy metals in the Dalnaya River corresponds to background concentrations for the Sikhote Alin range while it repeatedly exceeds them in the Tigriny spring, draining the territory of the deposit and in waters of the adit. Thus, for instance, the content of cadmium amounted to 1814 background concentrations in waters of the adit and 24 concentrations in the Tigriny spring, zink — 305 and 29 concentrations, manganese — 740 and 6.7 concentrations respectively.

Data indicate that the mine run off large supplies of quantities of metals. There is no doubt the influx of metals into natural waters will increase many times when mining.

1.5. Atmospherie

The territory under consideration is within the zone of transition from the continent to the ocean. It is characterized by acute cyclonic activity in the summer as a result of which steady carrying out of the air occurs from the ocean to the coast. This feature together with peculiarities of the relief determines conditions for originating fogs, advective evaporations, cloudiness changing to the fog on the slopes and watersheds. In cold seasons the area studied obtains large amounts of insulation against the background of great differentiation by expositions. In the boundary layer of the atmosphere west winds dominate the year with the exception of June and July.

The analysis of meteorological data of many years indicates that inversion retains steadily within the layer up to 300 meters throughout the year. The wind speed is close to zero in the surface layer. These conditions are extremely favourable for atmospheric pollution.

1.6. Geomorphological conditions

The relief is one of the most reliable indicators of the state of subjects of inanimate nature. It is fast in its response on deviation from established dynamic equilibrium. In the course of mining, the extent of man's impact will grow considerably including extending the area of the open pit and dumps, enlarging a body of disintegrated rocks, rising intensity of the solid and liquid discharge, etc. The analysis of the geomorphological situation made it possible to carry out zoning of the territory by a degree of expected anthropogenic load and to pick out localities with a predominance of the process of removal, transit and accumulation of the material.
2. Prediction of Environmental Impacts of Integrated Mining Mill and Practicable Measures for Decreasing Damage

The range of environmental problems resulting from mining production is discussed adequately in the book Down and Socks (1977). In this paper, the aspects of direct impact on man (direct danger to human life, indirect injury to man's health, direct financial losses, hindrances and discomfort) are not discussed but consideration is given to impact on building and operating integrated mining mill on components of natural environment. Clearly, the subdivision suggested is rather conventional since the damage caused to the individual components of natural environment is found both on other components and man's activity.

2.1. Soils

Commercial mining, as a rule, entails destruction of the fertile soil layer of forest lands. The small thickness of humus horizon, its great vulnerability to the sheet wash under conditions of steep mountain slopes increases the danger of degradation of the soil cover.

Peculiarities of the relief in the area under study (significant dissection with drastic difference in heights) together with carrying out phytotoxic rocks to the surface will greatly hamper the recultivation of territories of this kind, and require a large volume of earth moving work. Mining recultivation should be performed during the operation of an open pit. The first stage of recultivation is selective excavation, storage of the humus layer of soil and non-toxic rocks for further use. The second stage is the formation and planning of the dump surface. The third stage involves formation of potential fertile root layer for the following biological melioration.

Taking into account the significant steepness of slopes, it is expedient to employ a technique of terracing. In the first stage of recultivation, it is important that dumps be landscaped rapidly otherwise rocks of dumps including toxic ones will be transferred by water and wind and overlay the upper root layer of soils.

2.2. Vegetation

When mining, rather productive large spruce and cedar forests are subject to felling. The open pits, dumps, working areas, tailings storages will be located in their place. This will entail the pollution of vegetation with dust, arsenic and heavy metals. The construction of settlements and roads will result in a great anthropogenic load on vegetation, felling and fires will be enhanced. Recultivation of rock substrates of industrial dumps is needed since their overgrowing goes on very slowly (pioneer groupings are sometimes observed only by the tenth year after fill). For making artificial phytocoenoses on dumps the cultivation of saplings in nursery gardens is required in advance. The establishment of an environmental service which would follow their functioning is therefore essential. The list of promising tree and shrub
species for making phytocoenoses as well as the rate of their growth, either naturally or artificially should be determined by experiment.

2.3. **Wildlife**

Undoubtedly, the construction of integrated mining mill will result in a fall in the number of animals. It will first touch such commercial species as squirrel and sable and it will also have an essential impact on the population of musk deer. Other species will be less likely to be at risk. With the possible impact of building the industrial enterprise on species like the Amur tiger, the population of “a master of Ussuriskaya taiga” will not be affected severely when thousands of hectares of forests having small numbers of wild animals (wild boar, Manchurian deer, roe) as its prey is seized from it, if it is remembered that the mean area of the tiger’s habitation equals that of 50 thousand hectares. However, the emergence of another “seat of civilization” characterized by the adequate anthropogenic stress in the very centre of the tiger’s estate and for a long period, surely, will affect further well-being of this conserved species.

2.4. **Surface water**

The degree of transformation of natural water is dependent on a lot of factors, the main of which are as follows:

1. the quantity of sulphides in mined rock mass, acid forming first — pyrite, pyrohotine, arsenopyrite determining the possibility to form acid water.
2. The composition of ore-bearing rocks: carbonate rocks neutralize sulfuric acid process all with negative consequences while neutral silicate ones (sedimentary and volcanic) do not inhibit its development and bring aluminum, manganese and other components into the water;
3. The degree to which containing sulphide rocks are affected by the oxidation process: when forming dumps of rocks are subjected to oxidation, the flux of ore elements into natural drainage system immediately gains great intensity; fresh unoxidized sulphides must pass an "incubation period" before the flux of acidity and metals is formed;
4. The technique for mining: with the open pit rock mass exposed to agents of hypergenesis is far larger than that of deep mining and therefore increases the risk of adverse environmental implications.
5. The peculiarities of ore beneficiation: discharge of most of acid-forming sulphides in tailings storage when dressing lead-zink, sulphide-cassiterite ores forms new foci of scattering heavy metals for natural drainage system; use of sodium silicate in dressing scheelite-sulphide ores mobilizes a great quantity of arsenic into the solution.
6. The extent of purifying a mine run-off: in most mines it at best, consists of short-term stay of water in the sedimentation tanks where only course material is settled; dissolved forms of metals and dispersed particles pass through the
sedimentation tanks by transit; for purifying drainage runs-off of dumps and tailings storage equipment needed is not normally provided; processes of self-purification of mine acid water are confined to iron hydroxides falling out of them that absorb arsenic actively but do not remove other ore elements out of migration in acid medium.

(7) The lifetime of dumps and tailings storage: over 20-40 years of lifetime of objects attenuating the processes of sulphuric acid leaching and a reduction in the intensity of mine fluxes are not noted; the duration of their environmental impacts are far longer than the operation period of mine — industrial objects themselves and is likely beyond the century.

To decrease the effect on the ecology of mining enterprises, the development and realization of a complexity of equipment and buildings preventing an outlet for mine water with a high concentration of metals, which go beyond the industrial zone, are required.

The prime objective is the maximum localization of adverse components (acidity and heavy metals) which is impossible without the transformation of dissolved forms of metals into solid-phase ones.

The system of cleaning mine waters should be considered to be a component link of the production — engineering process. The drainage should run through the cascade of settling basins providing the residence time of runs-off in them which is sufficient for the complete precipitation of suspended matters. With acid waters, the formation of the autochthonous suspension in runs-off should be stimulated through alkalization and intensive aeration for producing iron oxides, hydroxides, manganase and aluminum. In the alkali oxidizing medium the sorption of ore elements by these sediments increases and hydrolysis of dissolved forms of ore elements is possible. The neutral runs-off with high content of arsenic require the formation of technogenic barriers of iron oxides. The metal scrap can serve as a material for them. The formations of dumps of stripping rocks should be carried on differentially depending on the content of iron sulphides. The sulphide-containing rocks should be stored separately from oreless ones providing localization for drainage waters in well-defined hollows of runs-off. The building of carbonate geochemical barriers in the form of dams of carbonate rocks deepened into porous deposits for intercepting the underground drainage is practicable in the path of the drainage run-off. The capacity of the barrier, that is a quantity of carbonates, must provide neutralization of all stock of acidity in the dump mass. The stock of acidity is determined by the iron sulphides quantity in rocks.

Analogously the neutralization of acidity and metal sedimentation from drainage waters of the slime storage are practicable. But one should take into account that in the event of using sodium silicate in the process of flotation at initial stages of filling the slime storage, the liquid phase of slurry and drainage water correspondingly, may heavily be enriched with arsenic since the sulfuric acid process and the formation of iron hydroxides as precipitants of arsenat-ion have not still managed to progress
to a sufficient extent. Because of this the problem of purifying runs-off becomes more complicated. The sorption-iron barrier should be the first stage, then as acid processes are progressed in the slime thickness — the carbonate one.

To estimate the capacity of carbonate geochemical barriers, data of a quantity of potential acid — forming ability and metals transferred with rock mass into the dumps and slime storages — are required. To do this one needs to estimate a quantity of sulphides and metals — pollutants both in the contour of ore bodies and circum-ore range which distinguishes the portion affected in mining.

2.5. Atmospheric air

Open pit mining involves the exposure of areas which combines to deepen the surface, therefore new land forms appear which to some extent changes the microclimate which existed before, and affect the local climate. In this connection, when evaluating the atmospheric air pollution by open pit mining it is essential to distinguish:

(1) Air pollution within the open pit arising from mining.
(2) Atmospheric pollution over the surrounding territory.

Air pollution in the open pit depends mainly upon the following factors:

(1) blasting;
(2) trucking;
(3) bulldozer and excavator operations.

The wind flow speed forming at the expense of the joint action of surface air flows and thermic non-uniformity of the interior surface of the open pit, geometry of the open pit and roughness of underlying surface are main parameters determining distribution of pollution inside the open pit volume.

The atmospheric pollution over the surrounding territory is mainly determined by background wind, regime of the locality and deviation from it due to roughness of the surface relief.

The studies performed allowed to draw the following conclusions regarding the atmospheric air pollution:

(1) The most intensive air pollution in the open pit will occur in definite types of weather accompanied by slow wind speed, cloudiness, fogs, inversions. The natural exchange of air is not able to purify the atmosphere in the open pit regardless of the amount of admixtures.
(2) The self-purification of the air in the open pit is practicable in high surface wind speed but only at rather low concentrations of pollution.
(3) It is necessary to carry out complete studies including meteorological, airological, actinometric, etc. in the case when an open pit is constructed to get values of atmospheric pollution and its capability for self-purification.
(4) According to the existing plan the settlement and main structures of the integrated mining mill are located within the area of the major air mass transfer from the open pit that will determine the increased atmospheric pollution.

2.6. Geomorphology

The analysis of the geologic-geomorphological situation within the area of mining and its nearest framing indicated that there exists geomorphological risk due to mining. To neutralize man's impact on natural subjects a series of supplementary structures and measures are recommended.

1. The change of the route for the tunnel diverting water from the tailings storage. The tunnel projected is placed within the fault zone with shattered rocks.
2. Building up a drainage system under the body of one of the dumps to prevent an accumulation of water above the dump, dilution of the ground and any possibility of forming landslides and mud flows.
3. The slope steepness and form, thickness of loose slope deposits (from 1 to 4 meters), additional bulk of loose material (dumps), possibility of arising local confining beds encourage origination of landslides and mud miniflows. This will result in undesirable consequences (avalanches on roads, intrusion of slope deposits onto the territory of engineering structures). To neutralize consequences of these processes, it is advised to build traps, fencings and dams.
4. The planned settlement is placed on the territory exposed to exogenic slope processes. Two versions of locating it more favourably are proposed.

3. Conclusions

Thus the construction and operation of the integrated mining mill will cause serious damage to the environment both within the building area and contiguous territory. Here one should distinguish the detrimental impact on nature due to the operation of the integrated mining mill, and damage due to man's impact on this territory in general.

The pollution of surface water is the most significant both in intensity of impact and degree of spreading. In turn, it will have an adverse effect on the state of fish fauna. Other results of building and operating the integrated mining mill will be a fall in the numbers and a deterioration in the habitats of a number of wild animals, loss in wood and nonwood resources, atmospheric air pollution, etc.

The negative environmental implications can be neutralized so that measures can be proposed.

The major undertakings are aimed at preventing an outlet of mine water containing high concentrations of metals beyond the industrial zone. To do this requires localization of adverse components (acidity and heavy metals) through transforming dissolved forms of metals to solid-phase ones.
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<thead>
<tr>
<th>Type of Process</th>
<th>Type of Impact</th>
<th>Changes in nature</th>
<th>Mitigation measures</th>
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<tbody>
<tr>
<td>Drilling</td>
<td>Gas and dust emission, noise and heat impact, vibration</td>
<td>Air pollution, vegetation suppression, animals escape (squirrel, sable, musk deer, etc) to adjacent areas</td>
<td>Application of dust eliminating equipment (mechanical, hydraulic, filtering, electric)</td>
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<td>Blasting</td>
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<td>Performing under specific weather conditions, wetting, application of explosives of low oxygen balance</td>
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<td>Handling</td>
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<td>Wetting</td>
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<td>Trucking, stockpiling of wastereck (dumps, tailings)</td>
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<td>Dust elimination on roads and dust-producing surfaces (sprinkling with water and solution of calcium sulphate and magnesium sulphate, emulsion treatment, prompt recultivation)</td>
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<tr>
<td>Ore extraction and stockpiling of waste rock</td>
<td>Deformation of Earth’s surface</td>
<td>Formation of negative (guarries) and positive (dumps) landforms, disturbance of natural drainage, destructions of medicinal plants and rare species</td>
<td>Transplanting of most valuable medicinal plants (ginseng, aralia, Eleutherococcus) and rare plant species (Iapanese yew)</td>
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<tr>
<td>Ore extraction and stockpiling of waste rock</td>
<td>Drainage from mine workings, drainage effluent of dumps and tailings, discharge of quarry water</td>
<td>Geochemical transformation (cadmium, zinc, manganese, etc.) of surface water. Pollution of forage lands and spawning grounds for calico salmon, taimen, grayling, lenok, reduction in numbers</td>
<td>Maximum localization of harmful components (acidity and heavy metals) by transformation of dissolved forms into solid-phase ones. (1) Construction of a cascade of settling basins for precipitation of suspended materials. (2) Stimulation of autotrophic suspension formation through alkalinization and aeration in acid run-offs. (3) Formation of geochemical barriers of iron oxides for neutral run-offs rich in arsenic. (4) Separate storage of sulphide-containing rocks and oreless ores. (5) Construction of carbonate rock dams in the way of drainage run-off</td>
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<tr>
<td>Ore extraction and waste rock stockpiling</td>
<td>Aquiferous layer opening, infiltration of polluted water</td>
<td>Degradation in ground water quality, rise of ground water level, vegetation succession, slide and subsidence processes</td>
<td>Elimination of prospecting holes, drainage construction, circulating water supply, antifiltering curtains, construction of traps, fences, dams</td>
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<tr>
<td>Deposit drainage</td>
<td>Water pumping out of the quarry</td>
<td>Decrease of ground water level, reduction in run-off volume, vegetation suppression</td>
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Other measures are to transfer the settlement to another place, change of route for the drain tunnel, construction of drainage under one of the dumps, recultivation works, etc.

The building and operation of the integrated mining mill are practicable provided that the measures mentioned above are carried out.

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Reference