Preliminary Discussions on Impacts of Industrial Induced Factors on the Environment of Central Kazakhstan

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Abstract

Many disturbances and changes in nature are caused by a number of human activities, such as mining engineering, town planning, and also by the influences of these industry activities.

Central Kazakhstan is one of the regions of the Republic experiencing enormous pollution pressure caused by giant industry as the coal and metallurgical, mining and chemical and machine construction.

The article reviews main industrial induced factors that define the spatial distribution of negative processes in semi arid climate of Central Kazakhstan where the intensive mining works have been conducted since 1940s and have led to a change of relief formation, groundwater and soil contamination. The damaged areas occupy vast territories, significantly reducing the habitable space for the population of Central Kazakhstan.

The research examined two environmental components to assess and improve the ecological situation at the mining area: (a) land and water as economical component and (b) relief as main natural component.

Key words: mining activity, waste dumps, relief formation, geomorphological hazard, water and soil contamination.

1. Introduction

The Republic of Kazakhstan is rich in mineral resources. It occupies the sixth place on natural resources of the World. The reserve capability contains 99 elements out of 110 elements in the periodic table of chemical elements. Kazakhstan enters the top ten leading countries on developing and extracting the natural minerals in five industrial regions South-, North-, East-, West- and Central Kazakhstan (Nurpeiysova, 2014).

Against the natural reserve condition, industrial loading from existing local enterprises onto the environment and population health is extremely high. Mitigation and elimination of ecological negative influences of toxic materials, accumulated in dumps, is the main waste management problem on the governmental authorities because the industrial wastes, including toxic materials are stored basically without respecting the environmental standards and requirements. (Aisauytov, 2004).

The considerable part of this waste is stored in Central Kazakhstan (29,4%). According to estimation reports the accumulation of industrial waste dumps in here have reached 7,0 billion tons (Baimyrzaev, 2000).

Central Kazakhstan, which has semi arid climate with poor density cover of vegetable and limited water resources has an active mining exploration area. The mining exploration activities at these deposits have led to different land surface change, disturbance of the landscape and pollution of ground and surface water.

One of the negative influences of the mining and metallurgical enterprises on the environment are harmful emissions to the atmosphere is sulfur dioxide (SO_2), nitrogen oxides, hydrogen sulfide, ammonia, hydrocarbons and also considerable amount of emissions of CO_2. The main sources atmospheric pollution are from activities of corporations such as: ‘Kazakhmys’, JSC ‘Kaztzink’ and company ‘AselorMittalTemirtau’. For example the corporation ‘Kazakhmys’ produces 75% of the total emissions of SO_2 in metallurgical industry and 37% of total of solid substances. The solid particles produced (or thrown out) by the corporation ‘Kazakhmys’ varies in sizes (from 1000 to 0,1 microns) and contain heavy metals (cadmium, lead, zinc, copper, chrome, etc.) (Baimyrzaev, 2000, Alpysbaev, 2001, Japarkhanov, 1985). In such a high risk environment, there has been an increase of respiratory diseases and cancerous tumor in the local population. In the country the number of people of this mining region suffering from these two illnesses occupies 8th (21 396,8) and 1st (1361,7) places respectively (Baimyrzaev, 2000).

Probably natural resources at the mining areas bring huge incomes improving the economical condition of the country in financial terms but at the present time these activities damage the most important resource of the nature – human health.

In the current study, according to the types of human activity, the degree of industrial induced factors at the key study areas Temirtau-Karagandy, Zhezkazgan are characterized by the method of the comparable assessment level of nature disturbances: good, satisfactory, unsatisfactory, critical and crisis. This method is developed on the basis of research results in two components: economical and natural.

2. Materials and Methods

2.1 Study area

2.1.1 Location and Climatic characteristics

Central Kazachstan (Karaganda district) is the largest mining industrial district in Kazakhstan, is situated at the central point of Eurasia. It is 480,000 km^2 in size which occupies 15,6 % of the whole size of the Republic of Kazakhstan (Medeu, 2010).

The climate is continental (The Kazakh National Encyclopedia, 2003). The temperature is -40ºC in South and from -45 ºC to -47 ºC in North and North-East in winter, +42ºC in South and +37 ºC in North in summer.

The winter of the region is characterized with less snow and strong winds. The snow cover is usually 30 cm - 12cm thick. The summer is characterized with frequent rainfalls and strong winds. The average annual amount of precipitation varies from 100 to 300 mm. However, evaporation is very high due to permanent hot strong winds blowing from Central Asia deserts. It exceeds the amount of precipitation more than three or four times from the surface > 1000 mm (Medeu, 2010).

2.1.2 Natural Resources and Topography

Geologically, the district lies within the Kazakh Craton where the basale stratum includes different types of minerals such as zink, molybdenum, lead, tungsten and manganese exploited by surface or underground mining. The coal basin Karaganda, which occupies 3600 square kilometers, is situated in the north of the region (Bekseitova, 2014) (Map1).

The relief of the region is flat, but disturbed by low elevations which are the result of the new tectonic raising processes. The highest point at this territory is 1500 meters and the average height is 500 meters above sea level (Bekseitova, 2014).

2.1.3 Soils and Vegetation

Soil and vegetation of Central Kazakhstan is characterized not only by geographical conditions, but also by the continental climate with weakening influence of humid air from the North-West and drying up anti-cyclone in winter.

The soil cover is characterized by the vegetation features and properties of soil forming rocks. The last one is closely connected with the relief formation, which naturally regulates ground waters dynamics and soil process.

The intensive industrially induced relief formation processes led to damage of the soil cover. Particularly ‘soil hazard’ happens at those mining areas where the land surface is periodically covered by industrial accumulated fresh sediments (Faizov, 2000)

In nature the surface cover is formed by light brown soils which contain from 2% to 3% humus. The soil is characterized here with slightly increased alkalinity and heavy mechanical structure (Medeu, 2010).

2.2 Waste Dumps

In Central Kazakhstan the intensive mining works have been conducted since 1940s.
The industrial area occupies 3600 square meters and consists of coal and ore deposits (Map1) (Bekseitova, 2014).

The mining waste, have been collecting for more than 60 years at mining deposits, still have unsolved problems and making powerful impact on the environment.
The considerable part of waste dumps are located in the near of populated areas, cities as Karaganda, Zhezkazgan and are a source of pollution of a relief, an underground and surface water and soils.

2.2.1 Data Collection and Processing Method

Natural resources of Central Kazakhstan had served as a source of an economical income of the former U.S.S.R since 1940s. The ecological state and negative impacts of the industry on environment in this district were sparcely investigated by the scientists of the former Soviet Union.
In order to improve the ecological state and forecast the possible industrial induced hazards in Central Kazakhstan the scientists of the Kazakh National University after Al-Farabi developed a method of comparable assessment level of nature disturbances, such as ‘good’, ‘satisfactory’, ‘unsatisfactory’, ‘critical ‘and ‘crisis’. This method was based on two selected types of research components as economical and natural affected by anthropogenic impacts.

Firstly, to the economical component belong soil and water as main sources of human life. Utilization of mine waters is a big problem for many mining enterprises. The mine waters which are the reason of soil salinization in Zhezkazgan, Karaganda, Zhairem, Aksu cities, cause anthropogenic desertification, pollution of ground waters, flooding of human settlements and soil damage for much or considerable large areas in Central Kazakhstan (Baimyrzaev, 2000).

Secondly, the relief - main natural component, its types and current condition. The research work of the industry activity influences on relief is based, first of all, on a complex processing the cartographical data of the local area, which includes a large scale topographic maps from 1982 to 2014 and surveying field data of the disturbed area (Bekseitova, 2014).

The determination of comparable assessment level of nature disturbances in Central Kazakhstan based are on the following steps:

- Survey measurement, data collection and processing, geomorphologic investigation and contour the key areas of a mining zone Temirtau-Karaganda, Zhezkazgan;
- Chemical analyze of samples of polluted water and soil at the disturbed areas. Table 1 shows the classification of anthropogenic impacts on natural environment including the chemical pollution intensity levels (weak, middle and high);
- Calculating a coefficient of geomorphological hazard (Table 2) based on the relief ratio method (Bekseitova, 2015):

$$K_H = A_{Relief} / N_{Relief}$$

where K_H- coefficient of geomorphological hazard,

A_{Relief}- relief caused by the anthropogenic impacts,

N_{Relief}- relief caused by natural conditions.

The development of the method for the determination of comparable assessment levels of nature disturbances is based on results of research and calculation procedures given above. Table 3 shows the assessment levels of the environmental condition at the mining zone - Temirtau-Karaganda in five gradations: ‘good’, ‘satisfactory’, ‘unsatisfactory’, ‘critical ‘and ‘crisis’.

Results and Discussion

While Kazakhstan was a republic in the Soviet Union, it produced approximately 111 tons of mineral raw materials per person per year. After the breakup of the U.S.S.R in 1991, production was 50 tons of mineral raw materials per person per year, of this, 95% waste (Buktukov, 2004). Kazakhstan has the highest range of industrial waste materials in the world, which leads to anthropogenic pressure on relief formations, water, and soil. For example, in order to produce one ton of pure coal, the mining industry produces 3 tons of waste material. In addition sour gases emission is produced during the crushing and transporting of coal (Saginov, 1995).

The extraction of non-ferrous materials results in 2% pure product, the remaining 98% is transported to waste dumps (Buktukov, 2004). The primary disadvantage of nonferrous metal production is that the raw materials contain a high concentration of toxic substances in the waste materials. That is why it is not allowed to recycle the waste material for a road construction. (Slastunov, 2001).

In many cases, after the extraction of materials the surface of the mining area is not restored, and often large tailing piles remain at the site. Mining exploration and mineral extraction often result in large scale changes to the land surface and varying degrees of geomorphology disturbance.

In order to determine the influence of industrial induced factors it is necessary to select the main components which represent natural and anthropogenic characteristics (Kochurov, 1997, Slastunov , 2003). The current research examined two environmental components to assess and improve the ecological and geomorphologial situation at the mining area: (a) economy - land and water and (b) nature - relief. Table 3 shows the assessment levels of ecological and geomorphological condition of above mentioned components in five gradations: good, satisfactory, unsatisfactory, critical, and crisis. According to assessment results there is given scientific approved recommendation for improving the measures of environmental management at the key areas of the mining zone - Temirtau-Karaganda (Map 2).

1. Good: environmental improvements are possible without significant expenditure and the economy of the area is stable.

2. Satisfactory: while there are changes to relief formation and groundwater table, the utilization and improvement of land resources is still possible. In this case developing a monitoring program is recommended.

3. Unsatisfactory: significant changes to the relief formation have occurred, decreasing the efficiency of land use due to exhaustion of water resources, resulting in socitial tension caused by ecological problems. This case requires the development of activities to protect natural resources and the implementation of a mandatory monitoring program of geodynamic processes for all types of solid minerals is necessary.

4. Critical: the mining area requires significant re-organization of some parts of mining economic structure, which includes monitoring mineral production which may lead to significant expenditures.

5. Crisis: in this case mining area has been subject to irreversible and significant changes in relief (as shown in Map 2 most mining areas belong to this gradation, and we describe the condition of these areas in detail).

Economy - Land and Water

Land resources of the district are used ineffectively. The reasons are the high concentration of industry induced mineralization of soil and the decrease of the water table for each 10 m in the water-bearing formation (Baimyrzaev, 2000; Slastunov, 2001). Due to hydrogeological changes at operating mines sites, depression funnels are formed which may cover hundreds of square kilometers. Larger and deeper mines result in greater waste areas, this increases the rapidity with which depression funnels form, which leads to decrease of the water quality in the area. For example, during the initial phase of development of Zhezkazgan mining field, at 100 m depth the mine water was fresh, with weak salt and hydrocarbonate and hydrocarbonate-sulfate structure. But with the increase in the depth of mining work, at a depth of 200-300 m, there has been an increase in mineralization of 2,5-3,5 g/l at the water bearing layers with sulfate-chloride waters. On mining at the layer of tectonic disturbances (300-400 m) the waters, including the dry residue, contain chloride of 10-15 g/l. Simultaneously, the mine waters contain harmful chemical elements such as lead, zinc, copper, iron, mercury, arsenic, etc. that make the water unsuitable for use (Japarkhanov, 1985; Saginov, 1995). The operation of mining enterprises in Central Kazakhstan has resulted in the exhaustion of underground water reserves due to the effect of mines drainage.

Disturbing of soil and upper layers reduces the availability of underground water. The considerable portion of the territory is exhausted, which in turn leads to a reduction in the number of vegetation species and soil structure damage. Continuous development of mineral extraction is the active cause of the anthropogenic desertification process, and entail significant costs and sustainable environmental management program for the fundamental re-organization of economy and improvement of human life in the area.

Nature - Relief

The largest disturbances of the surface environment of these areas are explained as consequences of the surface and underground mining. The changes caused by surface disturbances (Figure 1 a, b, c) are related with relief formations as a result of open pit mining and the attendant waste dumps. Surface mining development has direct negative effects on the relief, hydrology, soil, flora and fauna. It also results in the development of a number of dangerous geomorphological processes: erosion, landslides, flooding (Figure 2 a,b), collapses that occur on the walls and the bottoms of pits and on surface of dumps (Figure 3 a, b) (Bekseitova, 2014).

Developing underground mining lead to the deformation of upper layers and the formation of a settlement crater, buckling of the layers under the influence of empty weight, and horizontal rock shift. Further collapse of mine ceilings due to the influenced of upper layers of the mine, fracture formations, and intensive crushing which increases rock pressure. Dredging for mineral leads to the collapse of overlying rock formations, additional subsidence (Figure 4 a, b) and caving zones (Figure 5 a, b). As a result, factors enumerated above often lead to the disturbance of surface water flow and damage of soil covered area (Alpysbaev, 2001). In addition, there are changes to the thermal, gas content and geochemical area in the upper part of the lithosphere. It has been observed that mineral extraction results in the disappearance of springs, shallow rivers, and lakes (Bekseitova, 2014).

3. Conclusion

The lands disturbed by geological exploration, mining exploitations, and other resource intensive enterprises, occupy vast territories, catastrophically reducing the habitable areas for population of Central Kazakhstan. In addition, one may observe an influence of the exploitation of mines on the character and intensity of relief formation processes through the changes of structural components of geo-systems. These influences include pollution of surface and underground water, change in soil structure, and the transformation of the structure of vegetation species.

The operation of mining enterprises in Central Kazakhstan causes intensive exhaustion of underground water reserves due to a strong effect of the mines drainage. Exhaustion and lowering the level of underground water reduces the number of vegetation species and alters the soil structure which leads to intensification of damage from wind and water erosion.

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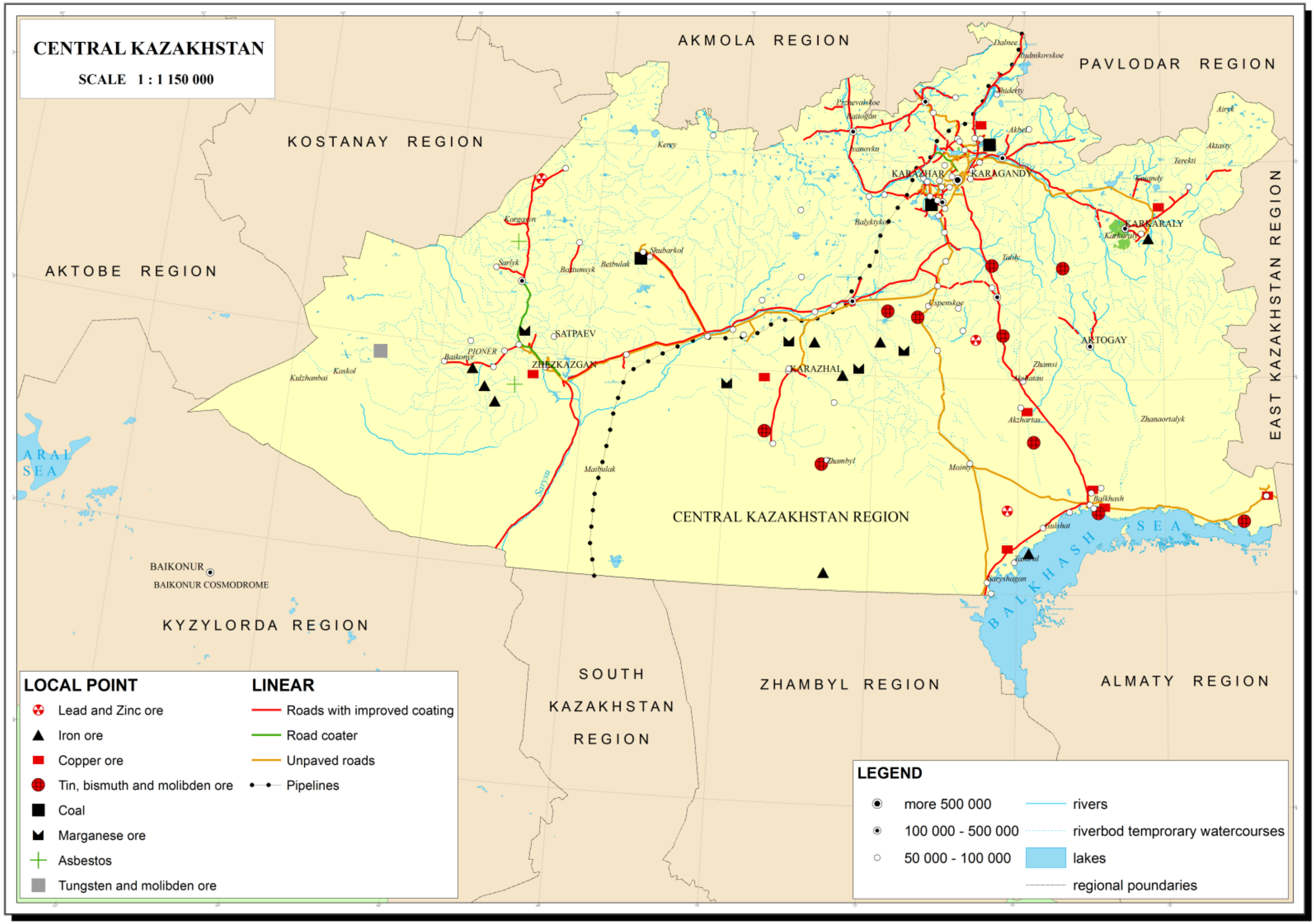


Map 1: Map of environmental management of Central Kazakhstan (Department of Cartography and Geoinformatics, The Kazakh National University after Al-Farabi, Almaty, the Republic of Kazakhstan, 2016).

Table 1: Classification of anthropogenic impacts on natural environment

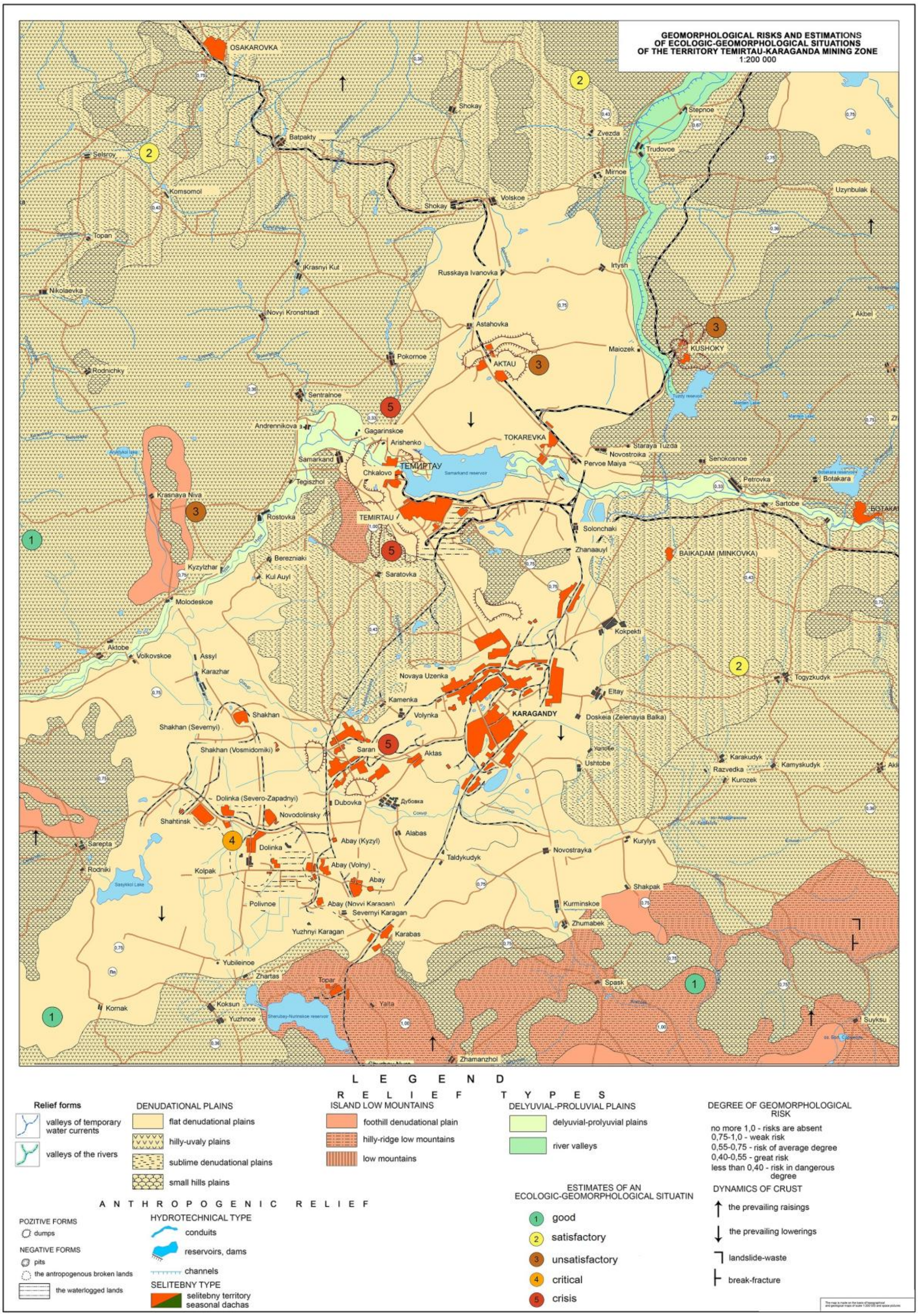
Natural Environmental Management	**Types**	**Land Surface**	**Intensity levels of chemical pollution sources**		
			low	middle	high
Mining and Hydroscience and Engineering	Mining development (ore production)	- Pits - Underground working off - Dumps - Storage	 +	 + +	+
	Mining	- Enterprises of developing industry - Enterprises of processing industry		+ +	+
	Hydro Engineering	- Reservoirs, including household and economic drains - Channels		+ +	
Urbanising	Urban	- Big city agglomerations - Cities		+	+
Agriculture	Agricultural Engineering	- Dryland agriculture - Irrigated agriculture		+	+
	Pasture	- Pasture			
Transport and Communication	Transport	- Railroads - Highways			+ +
	Communication	- High voltage line - Supply pipelines	+ +		
Military, Science and Strategy	Polygon	- Test polygon			+
	Space rocket	- Space polygon			+

Table 2: Assesment level of geomorphological hazard in Central Kazakhstan

Types of relief	**Sub - types of relief**	**Coefficient of geomorphological hazard (K_H)**	**Assesment level of geomorphological hazard**
Low - mountain relief	Hillside low-mountain	1,0	Very weak
	Submontane denudation plane	1,0 – 0,75	Weak
Deluvial - proluvial plains	Deluvial - proluvial plumes	0,75 – 0,55	Middle
	River valleys		
Denudation plains	High denudation plains	0,55 – 0,40	Significant
	Mounds	< 0,40	High

Table 3: Assessment degree levels of disturbance of the geomorphology at the mining zone Temirtau-Karaganda in Central Kazakhstan

Assessment degree levels of the geomorphological condition	**Indicators**		**Main recomendations for improving the geomorphological condition**
	Nature **Relief**	**Economy** **Land and Water**	
Good	No changes	No changes	Improvement of the environment without essential expenses is possible. Stabilized economic structure activity.
Satisfactory	Changes of the relief forming processes	Changes in use of natural resources	Improvement of use of land resources including agricultural technology is possible. Monitoring of land resources is necessary.
Unsatisfactory	Degradation of separate landscapes, breaking of a morpholitogenny basis	Decrease of efficiency of land use	Demand to improve the nature protection activity is necessary. Monitoring of geodynamic processes for all types of solid minerals development is necessary.
Critical	Formation of new natural and anthropogenous forms of the relief	Decreasing of usage efficiency of land and water resources	Expensive costs for re-organization of some parts of mining economy structure
Crisis	Deep and irreversible changes of a relief, degradation of landscapes	Economic crisis	Highly expensive costs for fundamental re-organization of economy



Map 2: Map of geomorphological risks and estimations of ecologic-geomorphological situations of the territory Temirtau-Karaganda mining zone (Department of Cartography and Geoinformatics, The Kazakh National University after Al-Farabi, Almaty, the Republic of Kazakhstan, 2016).

a b c

Figure 1 a,b: Surface Minings (Annensky, near the city Satpaev and c) Koundarsky near the city Balkhash (by Bekseitova R.T.)

a b

Figure 2 a,b: Flooding caused by surface mining, 8-10 km from city Satpaev Kazakhstan (by Bekseitova R.T.).

a b

Figure 3: a) b) Dumps near the city Satpaev, Kazakhstan (by Bekseitova R.T.)

a b

Figure 4: a) b) Subsidences caused by underground mining near and in city Karaganda, Kazakhstan (by Bekseitova R.T. and Veselova L.K.).

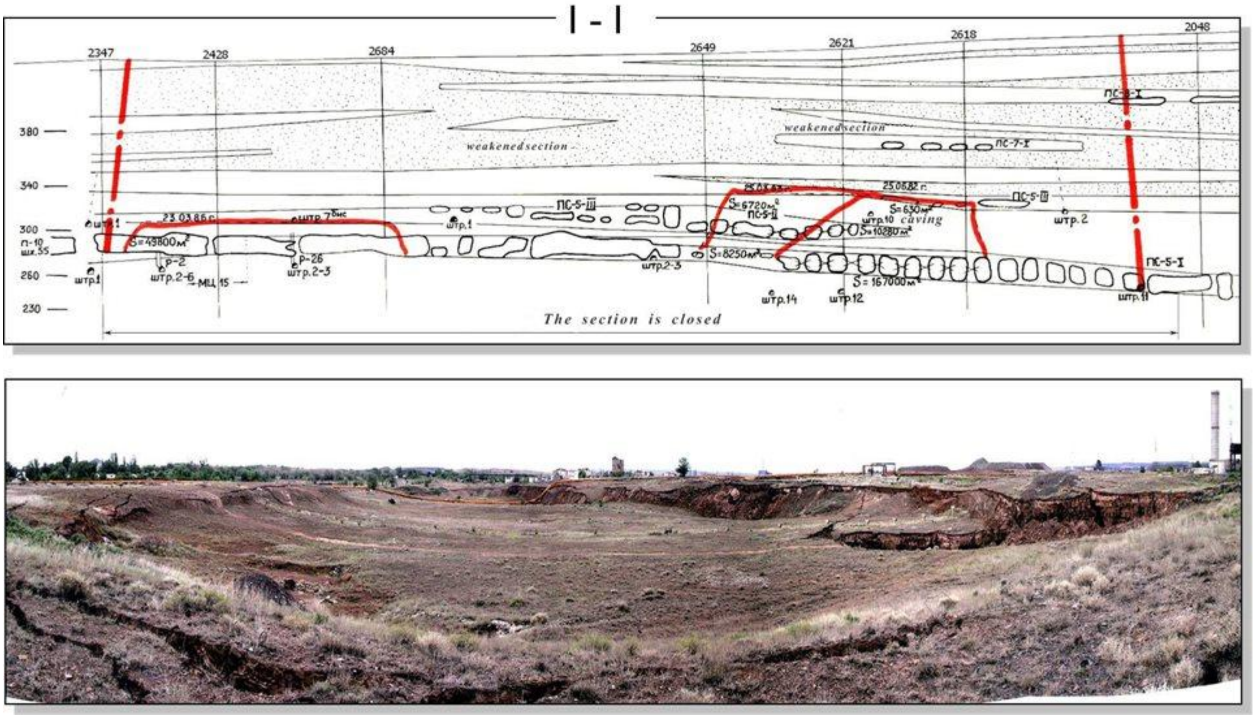


Figure 5 a): Large-scale caving zone in Zhezkazgan mining area (Bekbergenov D.K., 2016)

Figure 5 b): The cave to the surface in Zhezkazgan mining area (Schmidt, F, 2012)