

**A thesis submitted to the Department of Environmental Sciences and Policy of
Central European University in part fulfilment of the
Degree of Master of Science**

**CURRENT ENVIRONMENTAL ISSUES ASSOCIATED WITH MINING WASTES IN
KYRGYZSTAN**

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August, 1999

Budapest

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Nurlan Djenchuraev

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List of Abbreviations

ATSDR	-	Agency for Toxic Substances and Disease Registry (USA)
CIS	-	Commonwealth of Independent States
EPA	-	Environmental Protection Agency (USA)
KR	-	Kyrgyz Republic (official name of the country)
m ³	-	cubic meter
m ²	-	square meter
MEP	-	Ministry of Environment Protection of KR
MES	-	Ministry for Extraordinary Situations of KR
MH	-	Ministry of Health of KR
NCS	-	National Committee on Statistics of KR
NEAP	-	National Environmental Action Plan of KR
NEHAP	-	National Environmental Health Action Plan of KR
SEC	-	Scientific Engineering Centre

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THE CENTRAL EUROPEAN UNIVERSITY

ABSTRACT OF THESIS

submitted by Nurlan Djenchuraev

for the degree of Master of Science and entitled: Current environmental issues associated with mining wastes in Kyrgyzstan

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Mining activity of the recent past and present poses a direct threat to the environment of Kyrgyzstan and neighbouring countries. Located at high elevations in a fragile mountain environment the mining industry has generated and continue to generate hundreds of millions of tons of waste rock and tailings in dumps and impoundments which are badly maintained and serve as a source of permanent pollution of the biosphere by heavy metals, radioactive materials and cyanides. Moreover, Kyrgyzstan belongs to those areas subjected to a great extent to natural disasters such as earthquakes, landslides, floods, mudflows, etc. that can lead to rapidly spreading toxic and radioactive materials downstream, causing disastrous environmental consequences.

A central issue in the geoenvironmental science in Kyrgyzstan presently is the identification of hot-spot mining sites, i.e. those ones which spread the most considerable risks in terms of environmental and health impacts. Although some studies have been devoted to the assessment of environmental and health risks posed by the mining industry at several sites, rather less attention has been paid to the comparative analysis of data obtained from different organisations involved. Furthermore, political risks of the transboundary pollution caused by likely environmental calamities have not been taken into consideration at all.

It is a purpose of this thesis to rank mining sites located in Kyrgyzstan depending on environmental, health and political risks they pose and identify mining hot-spots through a comprehensive analysis of facts collected by different research teams involved as well as data interpreted from seismic, landslide and mudflow maps. Another goal is to classify the anthropogenic and natural hazards, which have an impact on mining sites in the mountainous environment.

The most important natural hazards include earthquakes, landslides and mudflows, while anthropogenic ones comprehend tailings and waste rock mismanagement, incorrect design and location of impoundments as well as ignoring the technological effect on a fragile mountain ecosystem.

It was concluded that the most serious risk is posed by the uranium mining wastes in Mailuu-Suu and the complex-ore wastes in Sumsar due to the considerable anthropogenic and natural hazards impact on corresponding tailings impoundments. Other large group of ponds and dumps in Kadji-Sai, Min-Kush, Ak-Tyuz, etc. incur an intermediate level risk. Another inference drawn was that the mining hot-spots located in close vicinity to Kyrgyzstan / Uzbekistan border pose a direct threat to the environment of both countries and may entail political consequences.

Keywords: environment, mining, tailings, tailings impoundment, Kyrgyzstan, waste rock, mining wastes, uranium wastes, heavy metals, transboundary pollution, contamination, Uzbekistan, Kazakhstan

CHAPTER 1

1. INTRODUCTION

*We have to turn the wastes of war
into war on wastes.*

*Gary Cohen, E-magazine, July
August 1990*

Kyrgyzstan possesses vast and diverse natural resources, which are currently considered to be one of the most significant factors in overcoming the present economic crisis. Long-scale exploitation of the natural resources in the former Soviet era resulted in development in the country of a powerful mining industry.

In the 40's two large combines located in the south of Kyrgyzstan were producing strategic metals: mercury and antimony making notable contribution to the defence industry during World War II. Later, in the beginning of 50's Kyrgyzstan was in the focus of the Soviet military industrial complex in connection with the exploitation of its uranium deposits. Over a period of 20-25 years thousands of tons of uranium were extracted generating millions of tons of radioactive wastes. From the 50's to the 70's the Ministry of Non-ferrous Metallurgy of the former USSR exploited a number of non-ferrous deposits extracting copper, zinc, cadmium, etc. The result of this mining activity is thousands of tons of toxic tailings and waste rock deposited in numerous impoundments and dumps.

The dissolution of the Soviet Union caused these huge amounts of wastes, previously subordinated to USSR ministries, to become unmonitored and uncontrollable. The impact of geological and meteorological hazards such as landslides, floods and mudflows caused severe erosion of several waste rock dumps

and tailings impoundments and consequent wash-off of part of the toxic wastes into rivers. The situation is aggravated by the closeness of several mining sites to densely populated regions, transboundary pollution, high seismic activity of the country's territory and the disturbance of the fragile mountain ecosystem followed by subsequent activation of man-induced natural hazards.

At present, the overwhelming majority of dumps and tailings impoundments in Kyrgyzstan are badly maintained being a source of permanent pollution of the biosphere by heavy metals, toxic substances and radioactive materials. Along with everyday gradual pollution of the atmosphere and hydrosphere the mining industry menace environmental and political safety by uncalculated impacts arisen from natural hazards. A worst case scenario is a tailings impoundment dam failure as a result of a natural hazard and dispersion of toxic or radioactive tailings by watercourses and contamination of ample territories.

To refine the scope of this thesis hereinafter in Section 1.1 it is necessary firstly to distinguish two groups of risks related to mining sites as demonstrated in Figure 1.1. The first group (Risks I and II) includes risks posed by natural and anthropogenic (technological) hazards to the mining sites, i.e. mudflows, landslides, earthquakes as well as mining waste mismanagement and other mistakes of human origin. The second group (Risks III, IV, V), in its turn comprises those risks spread by the mining sites themselves including environmental and health ones, and also risk of transboundary pollution followed by likely political tensions.

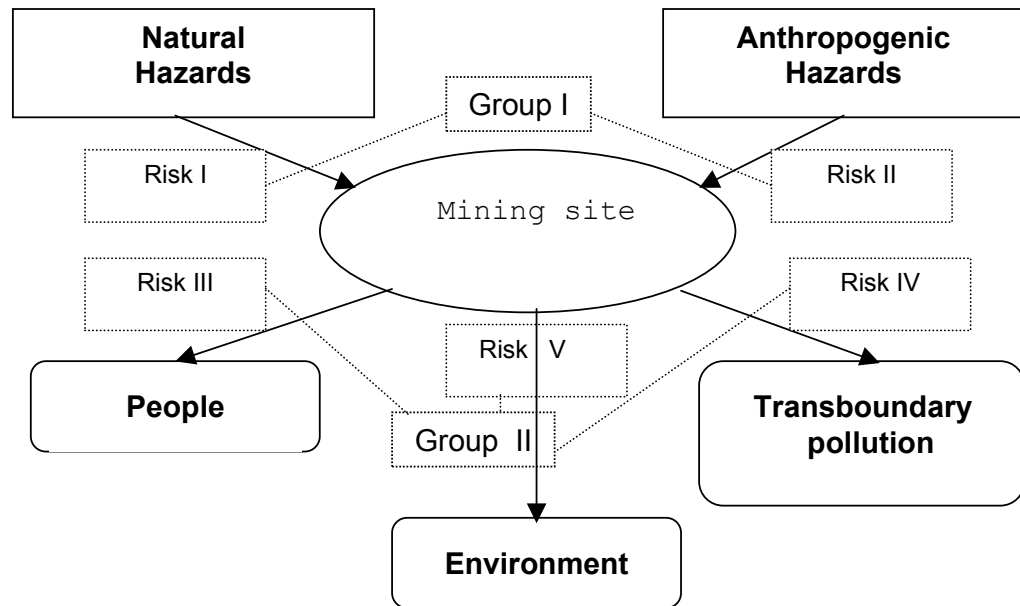


Figure 1.1 Classification of risks posed by natural and anthropogenic hazards and mining sites in Kyrgyzstan

1.1. Scope of the thesis

To begin with it should be stated that this thesis brings to a focus environmental issues related to mainly hard-rock mining since it is a key field of the mining industry in Kyrgyzstan. Additionally, the scope of the research is limited principally by the assessment of risks posed by tailings impoundments and waste dumps, although it also encompasses environmental impacts of the mining industry in general.

On the whole, the purpose of this thesis is as follows:

- to identify anthropogenic and natural factors having impact on the mining sites both abandoned and operative located in Kyrgyzstan;
- to rank mining sites on the basis of cumulative risk level assessments (low, intermediate, high) through analysis of information on mining sites collected by

various organisations and experts involved as well as own estimation of natural and technological risks posed by the sites;

- to identify mining hot-spots posing the highest risks;
- to estimate political risks arising from transboundary pollution caused by environmental calamities involving mining hot-spots in the following regions:
Kyrgyzstan / Uzbekistan and Kyrgyzstan / Kazakhstan borders.

CHAPTER 2

2. METHODOLOGY

The methodology used in this research was based principally on collecting and comparative analysis of facts gathered from different information sources, namely:

- ◆ reports and papers of organisations involved in the environment protection in Kyrgyzstan: MEP, MES and SEC Geopribor as well as report prepared by foreign experts (NEAP);
- ◆ personal communication with leading experts in the field working in Kyrgyzstan;
- ◆ own data gathered and interpreted from a set of maps including seismic zoning plan, mudflow activity map and landslide activity map of Kyrgyzstan.

In general, an algorithm of data collection and interpretation may be demonstrated as follows:

1. Collection and analysis of information from reports and papers of SEC Geopribor. Personal communication with experts. Ranking of the mining sites according to the SEC Geopribor. Assessment of risks I, II, III, V; Fig 1.1. (Results are demonstrated in Section 5.1 and Table 5.1).
2. Estimation of appropriate data obtained from reports of MEP & MES and also personal communication with an expert of MES. Assessment of risks I, II, III, V; Fig 1.1. (Results are demonstrated in Section 5.2 and Table 5.2).

3. Analysis of facts and assessment of risk using data of foreign experts (NEAP).
Assessment of risks I, II, III, V; Fig 1.1 (Results are demonstrated in Section 5.3 and Table 5.3).
4. Own assessment of an anthropogenic risk (Risk II, Fig 1.1) by analysis of information gathered from various reports, papers and personal communications.
(Results are demonstrated in Section 5.4.1 and Table 5.4).
5. Own assessment of a level of risk (Risk I, Fig 1.1) spreaded by natural hazards: landslides, mudflows and earthquakes by analysis of data obtained from corresponding maps. (Results are demonstrated in Section 5.4.2 and Tables 5.5-5.7).
6. Calculation of a cumulative risk (Group I, Fig 1.1) posed by natural and anthropogenic factors. (Results are demonstrated in Section 5.4.3 and Table 5.8).
7. Calculation of a cumulative risk (Group I and II) from global data array including information from maps, reports, personal communication, etc. (Results are demonstrated in Section 5.5 and Table 5.9).
8. Creation of a map of risks posed by mining sites in Kyrgyzstan. (Results are demonstrated in Fig. 5.4)
9. Assessment of political risks arisen from the likely environmental disasters including the destruction of tailings impoundments and spreading mining wastes to bordering countries downstream.

Since environmental catastrophes assessed by the risks I and II inevitably lead to spread of hazardous materials from mining sites, levels of risks III and V will be close by magnitude to ones which belong to Group I. Therefore, it is possible to calculate cumulative risk levels by averaging risks from Groups I and II (Fig.1.1).

Ranking of the mining sites according to threat they pose due to impacts of anthropogenic and natural origin was carried out on the basis of qualitative

assessments. Since the quantitative estimation of risk levels lies outside the scope of this thesis due to an insufficiency of reliable data three magnitudes of risk: low, intermediate and high were distinguished and used for assessment. In order to have more precise assessment the risk levels in some cases were defined as "high/intermediate" or "very high". Table 2.1 characterises distinctive features of three main risk levels.

Table 2.1 Definition of risk levels

Level of risk from hazards	Description
High	High probability of the destruction of the large impoundments or dumps and rapidly spreading of their content. Serious threat to people's lives or the environment. Spread of mining wastes to wide areas. Radioactivity or toxicity of wastes of a high level. Serious political consequences arisen from the transboundary pollution.
Intermediate	Destruction of the tailings impoundments is hardly possible - only in the case of severe earthquake or unfavourable combination of hazards. Wastes may be represented by substances of high toxicity or radioactivity, but no direct threat of dam collapse. Intensive spread of the wastes without destruction of the dam.
Low	No immediate risk of destruction. Probability of moderate spread of wastes through water, dust, etc.

Source: Adapted from Torgoev 1999, pers.comm.

CHAPTER 3

3. INFORMATION ABOUT THE MINING INDUSTRY IN KYRGYZSTAN

Mining is like a search-and-destroy mission.

*Stewart L. Udall, 1976
Agenda for Tomorrow*

3.1. General information about Kyrgyzstan

Kyrgyzstan is a small, mountainous country in the north eastern Central Asia with a population of 4.3 million people (Fig. 3.1). The total area of the country is 198, 500 sq. km and it stretches 900 km from east to west and 425 km from north to south. Kyrgyzstan borders China, Tajikistan, Uzbekistan and Kazakhstan.

More than 94% of the country is located 1000 m above sea level and about 40% - 3000 m above sea level: the average altitude of the territory is 2750 m. Three of the highest peaks of the Tien-Shan – Pobeda (7439 m), Lenin (7134 m) and Khan-Tengry (6995 m) are located in Kyrgyzstan. In general, there are 14 peaks higher than 6000 m. Stretched-out chains of 88 mighty ridges belonging to Tien-Shan mountains (“celestial mountains”) tower above mountain valleys spreading from east to west.

Ridges and mountains of the Kyrgyz Tien-Shan are usually divided into 6 groups: Central Tien-Shan (Sary Djaz, Kakshaal-Too), North Tien-Shan (Kyrgyzskii, Talasskii), Internal Tien-Shan (Susamyr-Too, Naryn-Too, At-Bashi), Western Tien-Shan (Ferganskii, Chatkalskii), South Tien-Shan (Alaiskii, Turkestanskii).

Some 23 large mountain valleys and numerous smaller ones separate the mountain ridges. The most spacious and populous is the Fergana valley located mainly in Uzbekistan and partly in Kyrgyzstan. Another one is partly occupied by Yssyk-Kul Lake, which is matchless in the world with its depth(668 m) and volume (1738 km³.) (Otorbaev et al 1994).

The specific element of the relief of the country is the strongly pronounced gradation of landscapes: semi-desert, valley, foothill, sud-alpine, alpine, tundra and glacial.

The territory of the country is covered by a dense net of more than 30 000 rivers and streams springing from numerous snowflakes and glaciers. In the inner part of Tien-Shan alone there are 3732 glaciers covering 3481 sq. km and in Central Tien-Shan 707 covering 1687 sq. km. correspondingly. In general, the area of glaciation reaches 6578 sq. km. Glaciers and snowflakes accumulate enormous amount of fresh water.

The largest rivers in Kyrgyzstan are: Naryn, Chatkal, Sarydjaz and Talas. Due to their origin the rivers and streams are characterised by low water temperature and highly turbulent and transparent flow in the mouth. Downstream, while flowing through crumbly rock, the streams turn turbid.

Some 76.5% of the country's territory belongs to the area feeding the Aral Sea basin, 10.8% to the Yssyk-Kul lake, 12.4% to the Tarim and 0.3% to the Balkhash lake (Petrushina 1995). The main river of Kyrgyzstan is the Naryn. It originates in the eastern part of the country, collects water from a vast area of Tien-Shan and converges in Fergana valley with another large river Kara-Daria

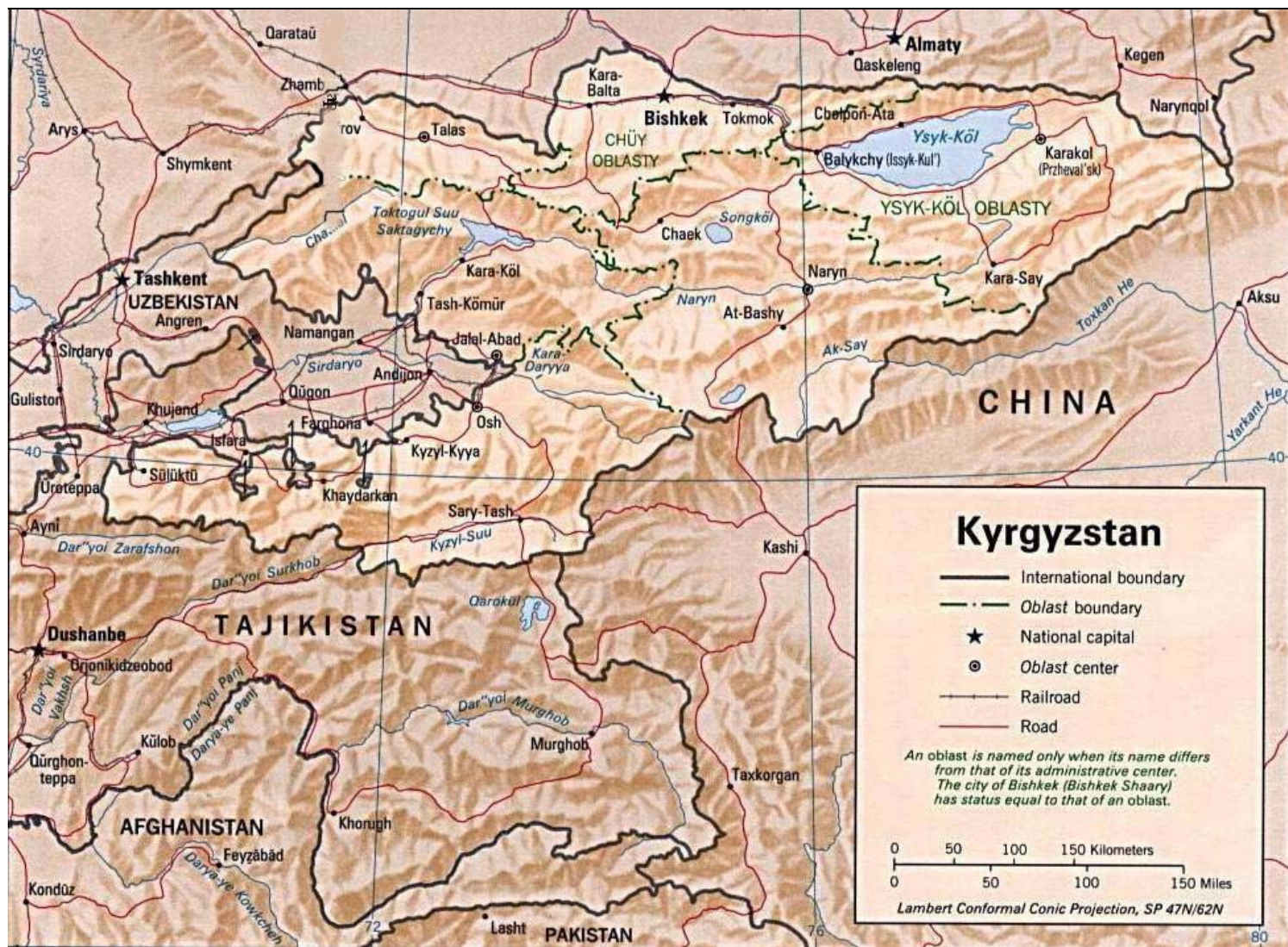


Fig.3.1. Map of Kyrgyzstan (shaded relief).

Source: Adapted from CIA 1996

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forming Syr-Daria, the second largest river of Central Asia. Naryn's length is 807 km, its average flow rate 432 m³/s and the average gradient 3 m/km. Thus, it has substantial hydroelectric potential, partly used by 5 power stations.

Along with rivers there are more than 2000 lakes covering about 7000 sq. km and located at high altitudes. The largest lake is Yssyk-Kul ("hot lake") – one of the largest lakes of Central Asia.

In accordance with its climatic, geographic and economic distinctions the territory of Kyrgyzstan is commonly divided into North and South. However, due to official administrative division taking into consideration population density, living conditions, peculiar features of historical and economical development, and difference in natural resources use the country is divided into six *oblast* (administrative district): Chui, Naryn, Yssyk-Kul, Jalal-Abad, Osh and Talas.

3.2. The mining industry in Kyrgyzstan

It is evident from numerous archaeological remains that mining has been known within the present territory of Kyrgyzstan since ancient times (Torgoev and Charski 1997).

The first industrial deposit of radioactive ore in the Russian Empire – Tuya-Muyun – was discovered in the foothills of the Alaiskii range, South Kyrgyzstan in 1904 (Pogodin and Libman 1977). Over a period of 6 years of exploitation of this deposit by Fergana Society for Rare Metals Mining about 820 tons of the ore was processed into uranium and vanadium compounds.

Development of mining industry in Kyrgyzstan is associated with discovery of a number of large deposits of antimony and mercury in the south of the country. To satisfy urgent needs of the USSR in strategic metals before the World War II two

large combines, Kadamzhai Antimony Combine and Khaidarkan Mercury Combine, were launched in 1936 and 1940 correspondingly.

The next impulse in the up-growth of mining in the country was given soon after the war in connection with nuclear weapons development. Nuclear industry of the former USSR began at the end of the 40's / beginning of the 50's being originally oriented towards military programs. This was the time when first Soviet uranium mines located in Kyrgyzstan have been commissioned. In 1955 Kyrgyzstan was the largest uranium manufacturer in the former Soviet Union (Torgoev and Charski 1997).

Later, along with known mercury and antimony deposits, new deposits of rare-earth, coal, tin, and gold was discovered. The country became one of the leading manufacturers of mercury, antimony and gold in the former Soviet Union.

Nowadays, because of the economic difficulties, decreasing market demand, and exhausting of the basic deposits of mercury and antimony gold-mining is coming to the fore. Table 3.1 illustrates production output of mining industry in Kyrgyzstan over a period of 6 years.

Table 3.1 Production output of mining industry in Kyrgyzstan

	1992	1993	1994	1995	1996	1997
Oil, th. Tons	113.0	87.6	88.2	88.5	84.0	-
Natural gas, mln. M ³	72.4	41.6	39.0	35.7	25.6	
Coal, th. Tons	2,151	1,721	746	463	432	-
Antimony, tons	13,810	9,778	9,588	7,053	6,002	4,401
Gold, tons	1.21	1.14	1.53	1.49	1.58	16.86

Source: Mindeco (1998)

The most reasonable hope is inspired by the discovery in the country of large deposits of gold. Starting from 1992, there has been a boom in gold-mining industry

in the country. Currently, a number of large gold manufacturers operate in Kyrgyzstan. According to Financial Time's Gold 1998 Survey Kyrgyzstan ranks as the world 19th largest gold producer with the fastest growth rate of the gold-mining industry in CIS. The largest manufacturer of gold in Kyrgyzstan is Kumtor Operating Company, which extracts gold from Kumtor deposit containing 360 tons of gold. Kumtor is the largest western-managed mining project in Central Asia. The Kumtor gold mine produced 502,176 ounces (14.237 tons) of gold in 1997 (Cameco Operating Company 1997) and 645,161 ounces (18,280 tons) in 1998 (Cameco Operating Company 1998). In the beginning of XXI century it is planned to reach annual 25-30 tons output of gold (Doolotaliev 1998).

3.2.1. Mining and economics

According to data provided by National Committee on Statistics of KR, industry made up 16.6% of GDP in 1997, and in that year it grew by 39.7%, due to non-ferrous metallurgy and fuel industry (NCS 1999). In 1997, non-ferrous metallurgy has reached the highest level in 5 years. Its share is currently one-third of all industrial production, which is as much as four times as of 1992.

Nowadays, industrial potential of the hard-rock mining industry of Kyrgyzstan is represented by a number of mining combines:

- Kara-Balta Mining Combine – currently manufactures gold from the concentrate of Kumtor gold deposit ; moreover, it process uranium ore and extract molybdenum;
- Makmal Combine – mining and production of gold from 1986;
- Kumtor Combine – has been commissioned in 1997 and currently it manufactures gold concentrate;

- Kadamzhai Combine – was established in 1936 as the only antimony manufacturer in the former Soviet Union. It consists of Kadamzhai & Terek-Sai mines and Kadamzhai ore processing factory. The basic products are antimony and antimony trioxide;
- Khaidarkan Mercury Combine – was established in 1940 to extract mercury from Khaidarkan deposit. Currently it is one of the largest mercury enterprises in the world.
- Kyrgyz Mining Combine – is a manufacturer of rare-earth metals and mono-crystalline silicon.

According to Masayoshi (1999) Kyrgyzstan currently faces the following topical issues in its mining industry:

- a) structure of the mining industry management basically remains the same as in the Soviet Union period;
- b) the state's policy on mining promotion is ineffectively implemented;
- c) lack of funding for geological exploration and development;
- d) need for using high technologies in mining operations;
- e) privatisation of mining industry as a strategic sector.

3.3. Environment protection in Kyrgyzstan

Environment protection issues in Kyrgyzstan are supervised by a number of governmental agencies and ministries:

- Ministry of Environment Protection
- Ministry of Health

- Ministry of Agriculture and Water Resource
- The Ministry for Emergency Situations and Civil Defence
- The State Agency on Forestry
- The State Agency for Geology and Mineral Resources
- The State Agency on Use of Land

The key institution that shapes and carries out environmental policy in Kyrgyzstan is the Ministry of Environment Protection (MEP). The major responsibilities of the ministry are:

- developing and enforcing environmental standards and regulations;
- co-ordination of the system of environmental management;
- assisting the government in shaping and implementing policies for environmental protection.

Structurally, the MEP consists of the following departments and regional units:

- Republican Fund for Environment Protection;
- National Centre for Ecological Strategy and Policy;
- Kyrgyzhydrometeorology (Kyrgyz Organisation on Hydrometeorology) ;
- Environmental Monitoring unit;
- Ecological Control and Inspection Department;
- State Inspection for Fish and Water Supervision;
- Regional Departments for Environment Protection;
- State reservations and protected natural territories unit.

The first law on Environment Protection was adopted in Kyrgyzstan as early as in 1991. Recently, a series of new laws on Environmental Protection has been

adopted by Jogorku Kenesh (Parliament of KR), namely: Environmental Protection Act, Clean Air Act, Forest Code, Animal Kingdom Act, Biosphere Territories Act, Radiation Security Act, and Environmental Expertise Act.

The law «On Mineral Recourses» (Mining Code) that has been amended in 1997 mainly reflects legislation in mining sector. The law establishes state proprietary rights for all the mineral resources. Government has a right to manage all the mineral resources of the country through:

- shaping and implementation of national policy for mineral resources
- development and implementation of investment policy
- protection of the environment during exploration, development and extraction of mineral resources, etc.

MES is responsible for the following activity (Moldobekov et al 1997) :

- preventive and forecast research aimed at decrease of risks associated with natural disasters, man-induced activity and military conflicts;
- improvement of stability of systems which may pose risk for people's health;

In 1999 MES was appointed as a heir of Kyrgyzaltyn (Kyrgyzgold) pertaining to tailings impoundments and dumps. Structurally, the MES currently includes the Centre on Rehabilitation of Tailings Impoundment and Dumps which is responsible for documentation on most of the tailings.

CHAPTER 4

4. MINING ACTIVITY AND RELATED ENVIRONMENTAL RISKS IN KYRGYZSTAN

When you create a mine, there are two things you can't avoid: a hole in the ground and a dump for waste rock.

Charles Park, quoted in John McPhee, Encounters with the Archdruid

4.1. Environmental risks related to mining in general

Mining is an activity aimed at obtaining solid minerals resources such as ores or fuels from the earth's crust. Ore is naturally occurring mineralised rock containing a valued metal that can be profitably mined on the surface of the earth or underground.

Mining activities occur in six consecutive stages (Ripley et al 1996):

- I. **Exploration**, which may involve geochemical or geophysical techniques, followed by the drilling of promising targets and the delineation of ore bodies;
- II. **Development**, i.e., preparing the mine site for production by shaft sinking or pit excavation, building of access roads, and constructing of surface facilities;
- III. **Extraction**, i.e. ore-removal activities that take place at the mine site itself, namely extraction and primary crushing;

- IV. **Benefication**, which takes place at a mill usually not far from the mine site; at this point a large of the waste material is removed from the ore;
- V. Further processing, which includes **metallurgical processing** and one or more phases of **refining**; it may be carried out at different locations;
- VI. Since every ore body is finite, a final **decommissioning** stage is required through which the disturbed area is returned to its original state or to useful alternative.

Major environmental issues for mining may be summarised as follows (Parsons 1998):

- Destruction of habitat and biodiversity at the mine site;
- Ecosystem biodiversity /habitat/ protection in adjacent land;
- Landscape /visual impact/ loss of land use;
- Site stabilisation and rehabilitation;
- Mine waste / tailings disposal;
- Sudden failure of tailings facilities;
- Abandoned equipment, solid waste, sewage;
- Air emissions;
- Dust;
- Climate change;
- Energy consumption;
- Situation and changes in river regimes;
- Effluent discharges and acid drainage;
- Groundwater alteration or contamination;
- Hazardous wastes and chemical residues;
- Hazardous chemicals handling, safety, workplace exposure;
- Noise;

- Radiation;
- Workplace health and safety
- The impact of metals toxicity on the marketing of metals
- Cultural and archaeological values
- Public health and urban settlement issues around mines.

4.1.1. Land erosion

The land disturbance represents a serious problem at a mine and is mainly associated with the surface mining and disposal of tailings or waste rock. The deterioration of the land begins after removal of the vegetation cover. In the mountainous environment of Kyrgyzstan land erosion is very fast and characterised by intense landscape change.

4.1.2. Air pollution

Blasting operations and haul roads may be a source of dust. Also, there are fears that at high altitudes dust raising in the atmosphere may settle on glaciers causing alteration in the regimes of their melting. The main source of air pollution in uranium mining is radioactive radon escaping from abandoned mines, tailings impoundments and waste rock dumps. Metallurgical processing also has the strong potential to harmful emissions such as sulphur dioxide and heavy metals.

4.1.3. Water pollution

The are four primary ways that mining causes water pollution (Da Rosa and Lyon 1997):

1. Acid mine drainage: acid run-off that is formed when sulphide minerals and waste rock are exposed to air and water;
2. Toxic metals such as cadmium, copper, lead and zinc unearthed with the ore can spread through the environment easily;
3. Use of chemical agents to separate and recover minerals, for example cyanide;
4. Erosion and sedimentation: eroding mine waste mineral carried off site where it settles and causes the clogging of river beds.

4.2. Hard-rock mining wastes in Kyrgyzstan

Hard-rock mining is one of the most waste-intensive activities. The result of processing of several tons of ore is frequently only several grams of a target component. The activity of Khaidarkan Mercury Combine which has been processing 650 thousand tons of mercury ore containing 0.1 – 0.2 % of mercury annually to produce about 650-700 tons of pure metal can serve as an example of this idea (Mindeco 1998). Substantial quantities of wastes are generated in the form of mine wastes or mill tailings. Mine wastes represent ore having too low content of a target component to be economically sound, whereas mill tailings are residues left from the process of extraction or beneficiation. Tailings are often composed of the same toxic or radioactive components as waste rock. Moreover, they can also contain added processing chemicals such as acids, oils, etc. As a rule, tailings are composed of fine particles that are very mobile while exposed to the environment. Thus, taking into account that tailings contain toxic or radioactive materials which can be easily

released into the environment and their high mobility it can be inferred that they present a high potential hazard to the environment and human beings.

In the early period of the mining industry there was no concept of storing wastes generated in the course of mining activity in a safe place: instead, they were dumped directly into the rivers, which caused immeasurable harm to the environment. Later, this practice was discontinued and replaced by constructing special ponds, so called tailing impoundments, designed for depositing tailings (see Plate I).



Plate I. Typical tailings impoundment in the mountain environment in Ak-Tyuz

In relation to embankment construction and tailings deposition techniques two types of tailings impoundments can be distinguished: raised embankments and

retention dam (EPA 1994). According to the first type, a dam is constructed by piling up the coarse fraction of the tailing slurry itself. Such a construction does not represent engineered structure as it can be seen from Figure 3.1, and its stability depends to a great extent upon the regime of hydraulic deposition. The second type of tailings impoundment represents a dam made of earth and fragments of rock gradually filled with tailings.

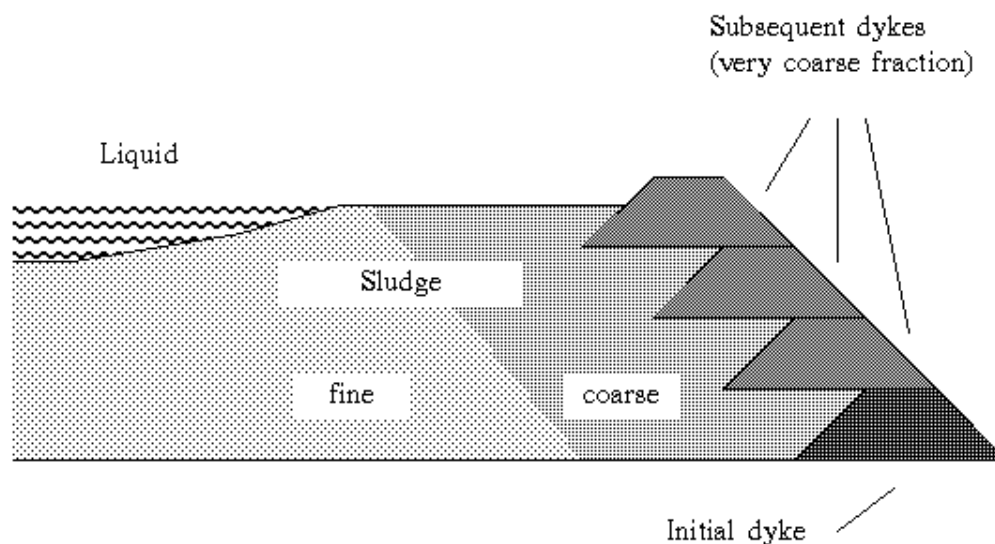


Figure 4.1 Typical construction of tailings dam
Source: WISE Uranium Project 1999a

It is necessary to note that wastes of the mining industry are represented mainly by solids in a form of waste rock or tailings, whereas wastes of non-ferrous metallurgy can be in solid, liquid and gaseous states. Since the mining and non-ferrous industries are currently facing deep economic crises and many mines and combines work at minimum load, liquids and gases are not emitted in large quantities and a massive threat comes from solid mining wastes.

According to the Concept for Ecological Security of Kyrgyz Republic (MEP 1998) the wastes of the mining industry constitute grave an ecological threat to

Kyrgyzstan and partly to Uzbekistan. At present, there are more than 130 sites containing wastes of the mining industry which take up more than 620 million m³ occupying 1950 hectares (MEP 1998). Solid wastes of the mining industry in Kyrgyzstan consist of radioactive materials, heavy metals, toxic elements, cyanides and acids. Taking up 754 hectares, some 49 tailing impoundments contain 75 million m³ of wastes, while the volume of waste rock from the coal and non-ferrous industries is estimated to be about 534 millions m³ taking out from usage 14,170 thousand m² of the land (MEP and MES 1999).

The most hazardous wastes are tailings and waste rock of the uranium mining. The quantity of generated uranium tailings in Kyrgyzstan is comparable with that in some developed countries of Western Europe as can be seen from Table 4.1.

In Kyrgyzstan the different radioactive tailings of concern include the following types of wastes (NEAP 1995):

- waste rock from the mining operations usually containing low-level of radioactivity;
- low grade milled residues, usually contained in tailings impoundments;
- waste residue;
- low grade coal of high ash content, originally mined due to content of uranium.

Table 4.1 Comparison of the amount of uranium mill tailings in Kyrgyzstan and Europe

	Solids		Surface occupied hectares
	10 ⁶ tons	10 ⁶ m ³	
Germany	~ 170 ?	-	~ 650 ?

Czech Republic		~ 45 ?	~ 607 ?
Hungary	20	-	200
Romania	3.4	1.7	35
Bulgaria	16	-	-
Sweden	1.5	1	25
France	45	-	-
Kyrgyzstan	>39.0	-	-
Mailuu-Suu	2.3	1.97	-
Min-Kush	>2.0	-	-
Kara-Balta	34.5	-	-
Kadji-Sai	~0.5	.4	1

Adapted from: Diehl (1995); MEP and MES (1999); Aitmatov et al 1997a; SEC Geopribor 1995a

At present, there are 21 hard-rock and coal mining enterprises operating in Kyrgyzstan and about 70 exploiting non-metallic mineral products. In general, from the 50's to the present there were closed 18 mining combines including 4 uranium ones (Koshoev 1996).

Table 4.2 and the map (figure 4.2) summarise the basic mining and metallurgy processing sites located in the territory of Kyrgyzstan.

Table 4.2 Basic mining industry sites (operative and abandoned) in Kyrgyzstan

No. In Fig. 4.2	Site	Name of the mining / processing enterprise	Basic pollutants in mining wastes	Years of activity	Brief description of the site
1	Mailuu-Suu	Zapadnyi Mining and Chemical Combine	uranium and its decay series elements, lead, arsenic	1946-1968	Mining and processing of uranium from Mailuu-Suu, Shekaftar and Kyzyl-Jar. For the period of exploitation about 10 thousand tons of uranium was extracted. Comparable amount of uranium ore from other deposits in Eastern Germany, former Czechoslovakia, China, Bulgaria and Tajikistan was also processed and dumped into 23 tailing impoundments and 13 waste rock dumps. Among them 14 tailing impoundments and 12 dumps are located directly within Mailuu-Suu town boundaries (Koshoev 1996). According to Aitmatov et al (1997b) the volume of radioactive tailings at Mailuu-Suu uranium deposit amounts to 2 million m ³ (4 million tons).
2	Sumsar	Sumsar Ore Management	lead, cadmium, zinc, antimony	1950-1978	Sumsar Ore Management mined and processed complex-ore: zinc, copper, lead and cadmium. The tailings of mining and processing activity are emplaced into 3 tailing impoundments.
3	Shekaftar	Branch of the Zapadnyi Mining and Chemical Combine	uranium and its decay series elements	1946-1958	Underground mining of uranium ore from 6 mines. At present there are 8 radioactive waste rock dumps of which 7 are located within Shekaftar village.

Table 4.2. - continued

No. In Fig. 4.2	Site	Name of the mining / processing enterprise	Basic pollutants in mining wastes	Years of activity	Brief description of the site
4	Ak-Tyuz	Kyrgyz Chemical Metallurgical Plant	rare earth, thorium	1942-present	Mining of rare-earth. Includes 4 tailings impoundments and 3 waste rock dumps. Content of tailings impoundments and dumps is radioactive because of thorium.
5	Kara-Balta	Kara-Balta Ore Mining Combine	uranium and its decay series elements	1952-present	Since 1952 Kara-Balta Ore Mining Combine has been producing "yellowcake" from uranium ore. Currently the combine refines gold from Kumtor gold deposit and processes uranium ore from Kazakhstan . It has the largest in Kyrgyzstan, well-run tailings impoundment.
6	Kadamzhai	Kadamzhai Antimony Combine	antimony, arsenic, barium salts	1936-present	The first large antimony mining and beneficiation complex in Kyrgyzstan. Also produces liquid steel, steel castings, non-ferrous castings, and cast iron moldings. At present, raw material is supplied mainly from Russia. In general, there are 5 tailings impoundments with total volume of 6.7 million m ³ of tailings.
7	Khaidarkan	Khaidarkan Mercury Combine	mercury, antimony	1940-present	Large manufacturer of mercury. Serious environmental problem is associated with the wastes of metallurgical processing and emission of mercury into the biosphere.

Table 4.2. - continued

No. in Fig. 4.2	Site	Name of the mining / processing enterprise	Basic pollutants in mining wastes	Years of activity	Brief description of the site
8	Min-Kush	Branch of the Zapadnyi Mining and Chemical Combine	uranium and its decay series elements	1950-1967	Min-Kush uranium deposit is located near Min-Kush town, which has a population of about 12,000. There are 4 tailings impoundments and 4 waste rock dumps at the site.
9	Kadji-Sai	Branch of the Zapadnyi Mining and Chemical Combine	uranium and its decay series elements	1948-1961	Uranium at Kadji-Sai was extracted from brown coal with a high-ash content. After the incineration the uranium was leached out from the ash.
10	Tuyua-Muyun		uranium and its decay series elements	1904-beginning of 30's	The first deposit of uranium discovered in Central Asia. Initially it was exploited for extraction of radium. Currently, there are 2 waste rock dumps, which are located near mines.
11	Kumtor	Kumtor Mountain Company	cyanide	1997-present	Kumtor is the largest western-managed mining project in the former Soviet Union. Tailings are deposited in tailings impoundment with earth-filled dam using synthetic liner.
12	Kan	Kan Ore Management	heavy metals	1950-1971	Kan Ore Management mined lead and zinc ore. Tailing impoundment has not been rehabilitated.
13	Makmal	Makmalzoloto	cyanide	1986-present	Second largest gold-mining enterprise in Kyrgyzstan.

Table 4.2. – continued

No. in Fig. 4.2	Site	Name of the mining / processing enterprise	Basic pollutants in mining wastes	Years of activity	Brief description of the site
14	Orlovka	Kyrgyz Chemical Metallurgical Plant	rare-earth	1942-present	Rare earth production began in 1966 and semi-conductor silicon since 1973. Currently manufactures rare earth oxides, rare earth (mainly of yttrium group).
15	Kyzyl-Jar	Branch of the Zapadnyi Mining and Processing Combine	uranium and its decay series elements	?	Location of the former uranium ore sorting plant. The territory is contaminated. No rehabilitation was made.

Source: Compiled on the basis of the following documents: Aitmatov et al 1997a, 1997b; MEP, and MES 1999; NEAP of KR 1995.

Figure 4.2 Mining areas and hot-spots in Kyrgyzstan.



Source: Adapted from CIA 1996; Mindeco 1998; NEAP of KR 1995

Solid mining wastes such as mill tailings and waste rock poses serious threat to the biosphere primarily because of their huge volume, even if concentration of toxic / radioactive substances in them is quite low. Mining wastes are not inert while exposed to the environment, instead they can release into the biosphere easily. A tailings impoundment or waste dump containing radioactive or toxic wastes may spread heavy metals and radioactivity in the following ways (Kornilov and Ryabchikov 1992; Da Rosa and Lyon 1997):

- migration of natural radioactive nuclides and toxic substances through trophic chains: vegetables, grass → animals → human;
- radioactive and toxic groundwater contamination due to seepage from tailing deposits;
- radioactive and toxic surface water contamination due to seepage from tailing deposits;
- release of radon into the atmosphere;
- the dispersal of radioactive or toxic dust from tailings
- tailing dam failure.

Moreover, there is one more way of the pollution / contamination spread, namely anthropogenic. Man-induced spread implies using tailings and waste rock for building of houses and construction of roads.

Waste sites generally may fail in one of two ways: a catastrophic failure, such as breach of the tailings dam, or a chronic low-level release, such as seepage over an extended period (Sumner et al 1995). Of all environmental risks posed by tailing impoundments the most grave is a dam failure. The most critical

element of any tailings impoundment is a dam. Stability of the tailings impoundments depends a number of factors: its design, location, presence of the geological and meteorological hazards in the region, etc. As a rule, major source of risk represents dams of older design.

Tailings impoundment dams can fail because a number of natural hazards as well as natural hazards in combination with anthropogenic factors. Figure 4.3. represents non-exhaustive variety of tailings impoundment failure reasons for Kyrgyzstan.

One of the most common reasons of dam failures is pond overtopping due to improper water discharge. In the mountain environment this problem may be also caused by sudden floods or mudflows. Secondly, mining wastes sites can be destroyed by landslides which are very frequent in some mountainous areas. Thirdly, an earthquake can certainly be a reason for a dam failure. This is especially valid for tailings impoundments located in areas of high seismic activity and at geological faults. The destruction of the dam may take place because of direct severe earthquake's shock or as a result of the chain of events: earthquake → landslide → dammed lake → wash-off of mining wastes site → dam break → dispersion of toxic or radioactive wastes with mudflows (Aitmatov et al 1997b). Tailings slurry liquification as a result of repeated seismic shocks makes threat from earthquakes quite realistic.

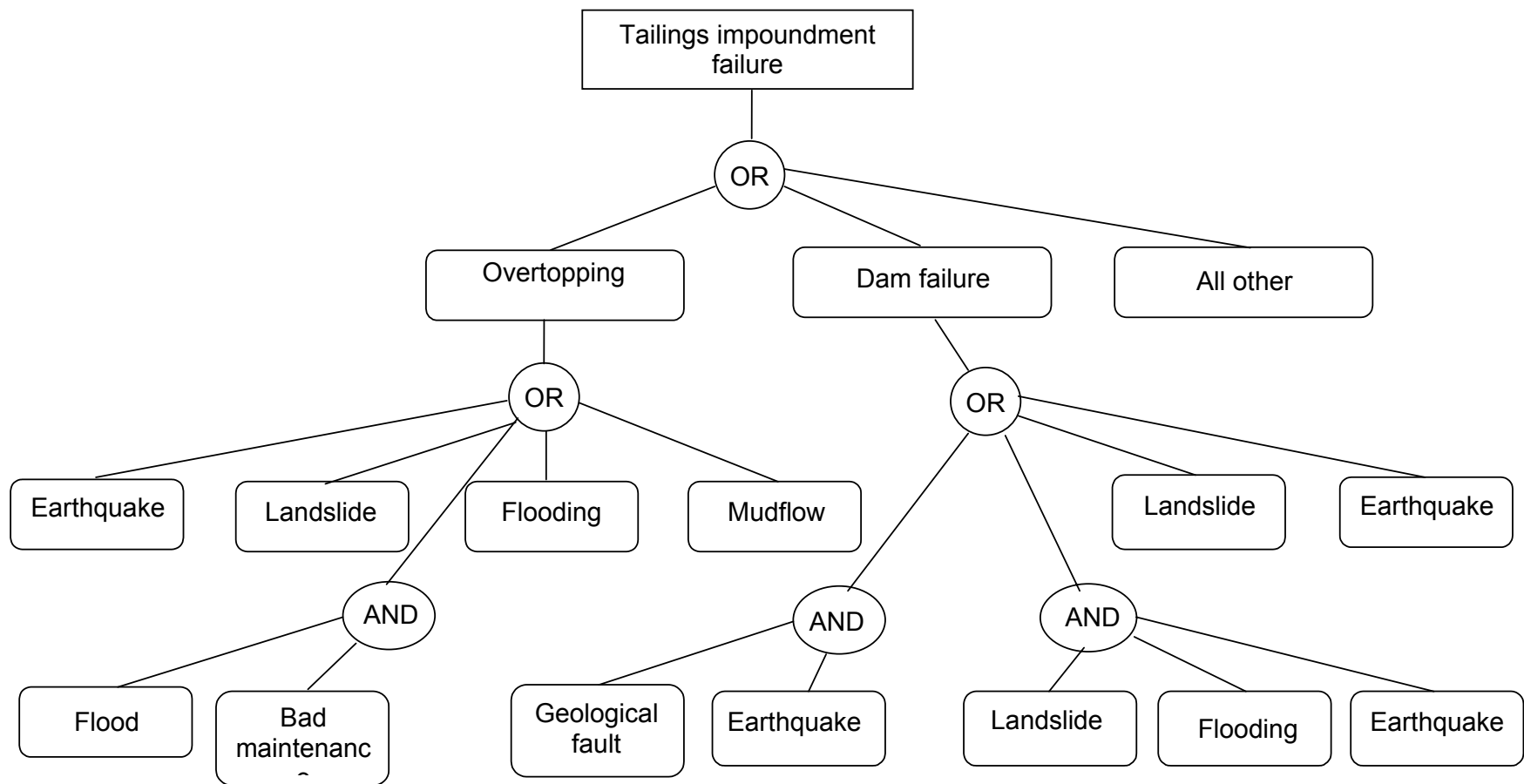


Figure 4.3. Simplified tailings impoundment fault tree : example of Kyrgyzstan

Source: Adapted from Louvar and Louvar 1998

Therefore, such a diversity of factors which can cause destruction of a tailings impoundment located in the mountainous environment, rapidity at which released tailings can be transported downstream and their high chemical availability determine that high level of risk associated with mining wastes in Kyrgyzstan.

4.2.1. Health risks associated with heavy metals

Three basic ways of toxic substances intake for a human being are as follows (Fergusson 1990):

- ◆ inhalation of air into the lungs;
- ◆ ingestion of food and water;
- ◆ transfer through the skin.

Figure 4.4 depicts several pathways of heavy elements into the human body.

Two most probable ways of heavy metals intake from mine wastes are inhalation and ingestion.

Inhalation intake takes place as a result of breath in dust blown from non-rehabilitated tailings impoundments by the wind. Situation with waste rock dumps in Shekaftar uranium mining site may serve as an illustrative example for that (SEC Geopribor 1995a). Since the surface of the dumps is non-vegetated small particles are dispersed into the atmosphere by the wind contaminating gardens, pasturage and houses. Similar problem can be observed in Kara-Balta (NEAP 1995) and in Sumsar tailings impoundment No. 3 (SEC Geopribor 1995a).

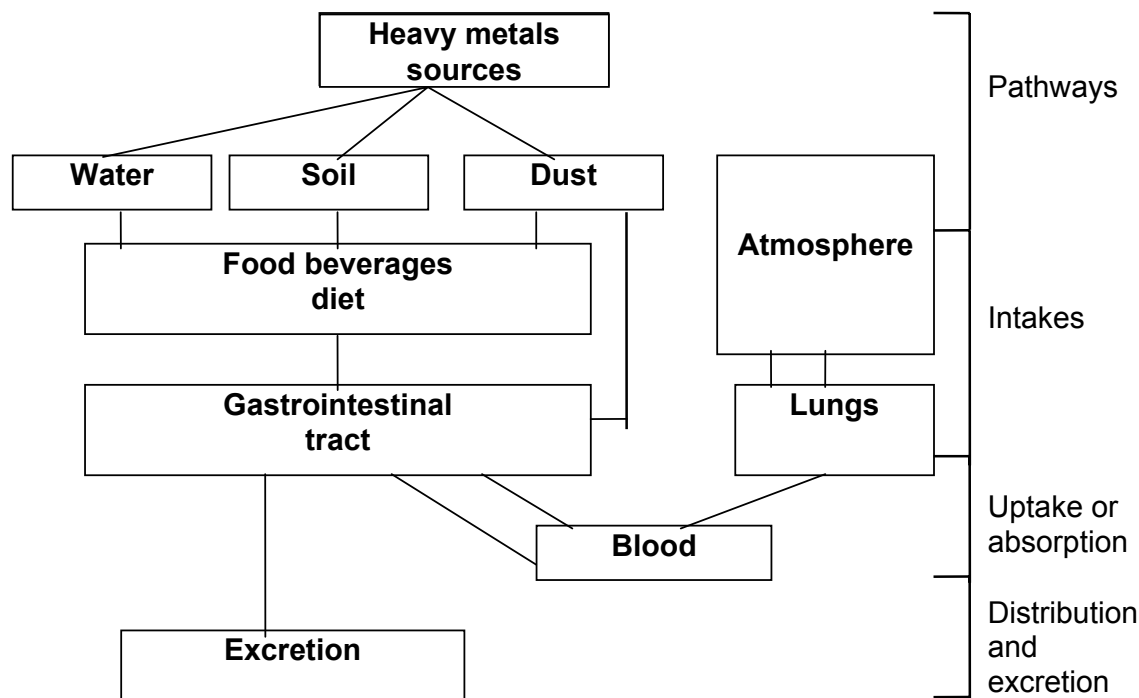


Figure 4.4 Transfer of heavy elements into the human body

Source: Fergusson 1990

Ingestion of heavy metals can take place in two different ways. Firstly, they can reach gastrointestinal tract directly from the water. Emergency situation with toxic heavy metals intake through the water in Sumsar can exemplify this way. Owing to catastrophic erosion of the dams of the complex-ore tailings impoundments in Sumsar the concentration of very toxic cadmium in the Sumsar Sai river was 320 times as high as maximum allowable concentration (SEC Geopribor 1995a; MEP 1998). Toxicity of cadmium will be discussed hereinafter in section 4.2.3. Emergency measures should be taken because of the fact that all downstream communities use Sumsar Sai River as a source of water. Secondly, heavy metals can be ingested through a food chain. Passing up the food chain

they tend to accumulate at higher trophic levels. In fact, cadmium, mercury, lead has a potential to biomagnify. However, an issue of heavy metals take up from tailings and their passing through a food chain into the human body is complex and requires additional research.

MH of KR in collaboration with other environmental institutions have carried out long-term research on the status of the environment and health risks in Kadamzhai region of Osh oblast. It has been concluded about increased concentrations of mercury and antimony in the environment. Immune system is the first target in case of long-term influence of these two toxic metals (Kasiev and Khamzamulin 1995).

The mortality among workers of Kadamzhai Antimony Combine and Khaidarkan Mercury Combine was a subject of research made by MH (Kasiev and Khamizulin 1995). It has been found that life expectancy for people working in basic workshops is 5-7 years less as compared with population of Osh oblast in general.

4.2.2. Specific risks of uranium mining wastes

Uranium ore mining and uranium ore concentrate (yellowcake) production is an initial stage of the nuclear cycle. The wastes from these processes are composed of mining wastes and mill tailings of low and sometimes intermediate-level long-lived radioactivity as shown in Table 4.3.

In contrast to non-ferrous mining wastes uranium ones vary in presence of an additional risk factor – radioactivity. Radioactivity of the uranium tailings is less than the one of the original uranium ore: commonly tailings retains about 70% of the initial ore radioactivity (Uranium Institute 1991).

Impact on the environment and human beings is exerted through both uranium itself and its nuclear decay products. Major hazards of uranium mill tailings are demonstrated in the Figure 4.5.

Table 4.3 Major types of radioactive wastes.

Waste type	Level of radioactivity	Period of radioactivity
Mine wastes and tailings	Low	long-lived
Materials and equipment contaminated as a result of operation of nuclear facilities	Low	short-lived
Wastes arisen from nuclear fuel after they have been used in a reactor	high, intermediate, low	long-lived
Wastes resulting from dismantling nuclear reactor	low, intermediate	short-lived

Adapted from: Uranium Institute (1991)

Similar to toxic substances, there are three basic radiation exposure pathways to a human being and the environment:

- direct irradiation
- ingestion of radionuclides
- inhalation of radionuclides

It is generally believed that immediate risk, which comes from the direct radiation exposure from tailings, is not high. However, some scientists claim that there is no safe doses of radiation proving that carcinogenesis from ionising

radiation does take place at the lowest doses and rates (Gofman 1990). Additionally, it is necessary to take into account that due to lack of good selection technologies in initial period of the nuclear industry some of dumps and tailing impoundments may contain intermediate-level radioactivity.

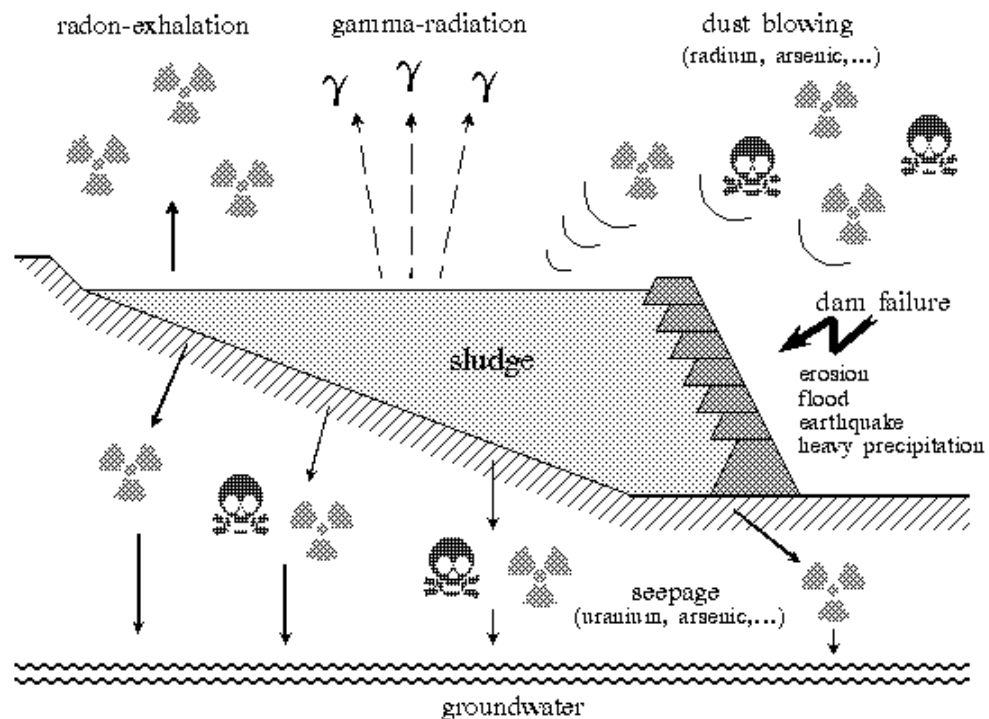


Figure 4.5 Uranium mill tailing hazards

Source: Diehl 1999

One of the characteristic features of the radioactive wastes is their long-term potential hazard. In fact, radioactive tailings contain all the elements from uranium-238 decay series including non-extracted uranium. Taking into consideration that thorium-230 decays at a half-life of 80,000 years, and radium-226 – 1600 years it could be concluded that mill tailings are hazardous for

thousands of years brining about the necessity for long term control over them. Radium, which has a long half-life presents the most hazardous radioactive constituent in uranium wastes. Besides being hazardous itself, radium produces radon, a radioactive gas causing lung cancer. Toxicity of radon will be discussed in detail hereinafter in section 4.2.3.

Environmental concern about uranium is its chemical toxicity and radiological hazard. According to the Environmental Contaminants Encyclopaedia (Irwin et al 1998) "Downstream of uranium mine tailings, the ecological concerns for natural uranium are minimal; they should predominantly relate to chemical toxicity and additional toxicity and acidification associated with co-contaminants in mill and mine tailings. Ecological concerns associated with radiation exposure of biota to natural uranium are minimal. Instead, environmental concerns about radiation exposure are primarily associated with an increased chance of cancer induction in humans due to inhalation of uranium in dusts and ingestion of soluble forms of uranium in water and food".

It has been mentioned above that the issue of long-term low-level radiation effect on the health is quite complicated. Two examples from uranium production in Mailuu-Suu, and rare-earth and thorium (radioactive element) production in Ak-Tyuz illustrate this point.

Research conducted by physicians from Institute of Oncology and Radioecology on 1213 people in Mailuu-Suu uranium deposit has demonstrated that (Kamarli 1999):

- number of people suffering various forms of cancer is 172.2 per 100,000 people that is almost double figure as compared with average data through the whole country (93.5 per 100,000).

- some 34.05% of all people under investigation suffer from pre-tumour diseases. Such a considerable amount may be explained by both bad nutrition and influence of radiation through trophic chains.

A comprehensive study was carried out by a team of scientists in Ak-Tyuz area in 1991-1992 to reveal consequences of thorium tailings dam failure (see section 4.5.2) (Kasiev and Khamzamulin 1995).

The conclusion of this study was: " Retrospective analysis of the level and structure of the mortality among people for 25 year has shown that in the first ten years after the breach of the tailings dam of Ak-Tyuz Benefication Combine in 1964 there was certain increase of mortality among inhabitants of the elder age group (50 y.o. and above) basically because of cardiovascular, respiratory, digestive diseases and cancer. However, in the following years this increase came to naught and, moreover, in the time of the research health indicators of the population of this area (Kichi-Kemin) turned to be better than those of neighbouring communities".

Nevertheless, the MH states in NEHAP that people living in proximity to the mining combines more frequently suffer from a number of specific diseases. According to MH and MEP (1997): "Long-term statistical data show the increase in the incidence of cancer, blood diseases and endocrine pathology".

4.2.3. Occurrence and toxicity of selected pollutants from the mining industry

This section includes toxicological and other relevant information about typical pollutants occurred in mining wastes in Kyrgyzstan.

All naturally occurring metals can be subdivided into 3 general groups according to their toxicity (Table 4.4). As can be seen from this table many metals occur in Kyrgyzstan: cadmium, zinc, thorium, lead, mercury, antimony, etc. can be attributed to the moderately or highly toxic group. That is why leaching these metals out of mining wastes and their subsequent release into water is very dangerous.

Table 4.4 Classification of naturally occurring metals according to their toxicity and availability in the hydrologic environment.

Non-toxic		Low toxicity		Moderate to high toxicity		
Aluminium	Magnesium	Barium	<i>Praseodymium</i>	<i>Actinium</i>	Lead	<i>Tantalum</i>
Bismuth	Manganese	<i>Cerium</i>	<i>Promethium</i>	Antimony	Mercury	Thallium
Calcium	Molybdenum	<i>Dysprosium</i>	<i>Rhenium</i>	Beryllium	Nickel	Thorium
Caesium	Potassium	<i>Erbium</i>	<i>Rhodium</i>	Boron	<i>Niobium</i>	<i>Titanium</i>
Iron	Strontium	<i>Europium</i>	<i>Samarium</i>	Cadmium	<i>Osmium</i>	<i>Tungsten</i>
Lithium	Rubidium	<i>Gadolinium</i>	Scandium	Chromium	Palladium	Zinc
	Sodium	<i>Gallium</i>	<i>Terbium</i>	Cobalt	Platinum	Zirconium
		Germanium	Thulium	Copper	Polonium	
		<i>Gold</i>	<i>Tin</i>	<i>Hafnium</i>	<i>Ruthenium</i>	
		<i>Holmium</i>	<i>Ytterbium</i>	Indium	<i>Ruthenium</i>	
		<i>Neodymium</i>	Yttrium	<i>Iridium</i>	Silver	

*Metals that do not normally exist as dissolved species in natural water or are very rare in crustal rock are in Italics

Source : Wood 1974

Mercury

Mercury is an element that occurs naturally in the environment in several forms. All forms of mercury are considered poisonous. EPA has listed mercury as one of 129 priority hazard pollutants. Kyrgyzstan is abundant with mercury deposits, part of which were heavily exploited. The technology of mercury extraction includes burning of the mercury ore with subsequent pollution of the atmosphere with such harmful substances as CO, SO₂, Se, NO₂ and mercury. Furthermore, mercury compounds may leach out from solid wastes of burning. Table 4.5 illustrates the concentration of mercury vapours in different locations in Khaidarkan.

Table 4.5 Concentration of mercury (mg/m³) in the atmosphere in Khaidarkan*

	1987	1988	1989	1990	1991	1992-94
Village	.017-.056 (186)	.01-.023 (76)	.0048 (16)	.0011 (4)	.00035	.00034- .00022
Hotel	.017-.032 (106)	.018 (60)	.03 (10)	.0014 (4.6)	.00034	.00032- .0002
Kindergarten	.016-.034 (113)	.015 (50)	.0032 (10)	.0016 (5)	.0016	.00035- .00024
Garage	.021 (70)	.018 (60)	.0038 (12)	.0014 (4.6)	.0014	.00034- .00023

Figure in brackets shows for how many times the concentration exceeds the maximum allowable concentration.

Source: Buyuklyanov et al 1998

As can be seen from the table the concentrations of mercury vapours are within allowable limit since 1991 when the production of mercury went down.

Effects of mercury on human beings may vary depending on the type of mercury compound. In fact, mercury concentrates in kidneys where it destroys blood-filtering function causing finally death.

Cadmium

Cadmium is included in the list of top 20 hazardous substances by the US Agency for Toxic Substances and Disease Registry and EPA. It is contained in tailings, sometimes in high-concentrations, of several complex-ore mines in Kyrgyzstan, i.e. Sumsar. In fact, there are three basic ways of cadmium exposure to human being from mining wastes: through the dispersion of toxic dust from the surface of a tailings impoundment located close to settlements, by leaking of cadmium ions into a water stream used as a source of water and with food through a food chain. Compounds of cadmium are harmful and toxic. Moreover, cadmium is very strongly retained while entering the body. Depending on levels and duration of cadmium, effects of cadmium on a human are as follows (Irwin et al. 1998):

- kidney damage - in case of exposure through dust or water;
- lung damage - while inhaling toxic dust;
- lung cancer - suspected human carcinogen by inhalation.

Arsenic

Arsenic occurs in some antimony deposits, tailings impoundments and waste rock sites in Kyrgyzstan. It is emitted during metallurgical processing of antimony ore in Kadamzhai Antimony Combine (Buyuklyanov et al 1998). Like cadmium, arsenic is also listed among 20 top hazardous substances by EPA and ATSDR.

High doses of arsenic causes in humans bone marrow suppression. Occupational exposure to arsenic may be significant in the non-ferrous smelting. The principal exposure pathway is inhalation, although ingestion and dermal

exposure are also possible. Some immunological and neural effects have been documented for arsenic but information is still incomplete.

Radon

Radon is a colourless, odourless radioactive gas associated with uranium mining and formed by the decay of radium, which is itself a decay product of uranium. Radon and its decay products may be transported over long distances from a mining site by the wind.

Radon contributes about half of the annual average radiation exposure of the different sources of radioactivity as can be seen in Fig. 4.6.

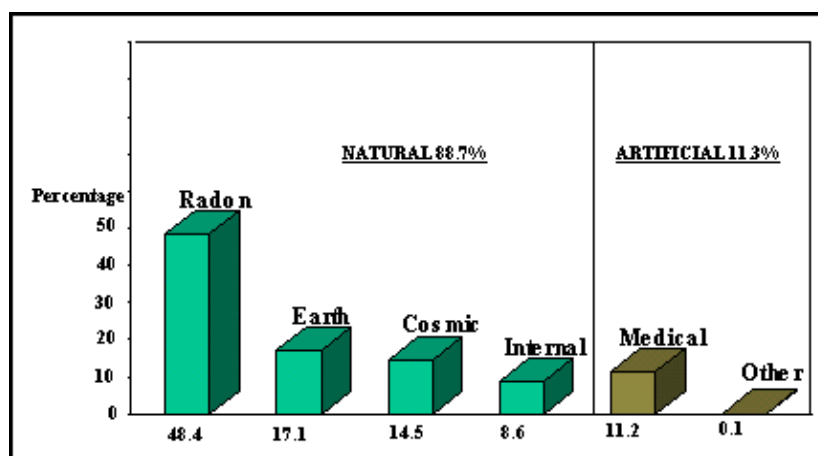


Figure 4.6 Annual average individual radiation exposure from natural and artificial sources.

Source: UNSCEAR 1993

Radon's main hazard is caused from inhalation of the gas and its highly radioactive daughters emitting alpha radiation. While breathing in radon daughter particles alpha radiation causes damage to lung tissue. A distinctive feature of radon daughter particles is their ability to attach themselves to dust or water mist

resulting in alpha radiation easy access to the deepest parts of the lung when inhaled. Comprehensive data from epidemiological research of the underground miners shows that radon is a human carcinogen (Conrath and Kolb 1995).

Low concentrations of radon emissions from uranium mill tailings and waste rock would not make any significant contribution to total radon dose. However, effects of radon accumulated in a cloistered space, such as a mine may be significant. Since in Mailuu-Suu access to many mines is not restricted people may enter mines easily and be effected by considerable doses of radon.

4.3. Classification of hazards influencing mining wastes

Two types of hazards which have an impact on mining wastes can be distinguished: anthropogenic (or technological) and natural as shown in Table 4.6.

Generally speaking, the stability of mining waste sites is defined by the superposition of impacts from several natural or/and anthropogenic factors as depicted in Figure 4.7. Natural factors play a dominant role from the standpoint of their constant "pressure" on the mining sites towards their destruction and dispersion of their content. Mistakes made by the human beings also contribute to the equilibrium disturbance from the side of natural hazards. The only factor, which helps to balance the system, is maintenance of waste mining sites by humans. It is this deterrent that has been neglected lately. The result of this negligence may increase the risk of accidents caused by technological hazards.

Table 4.6 Basic hazards related to mining wastes in Kyrgyzstan

Natural hazards	Anthropogenic (technological) hazards
<u>Geological</u>	<u>Human mistakes</u>
Mudflow	Incorrect location of tailings or dumps
Landslide	Incorrect design of impoundments
Earthquake	Incorrect construction of impoundments
	Poor estimation of natural hazard impact
<u>Meteorological</u>	Using tailings or waste rock in building
Flooding	<u>Maintenance</u>
Wind	Lack of monitoring for mining wastes
	Easy access to tailings ponds

Compiled on the basis of Moldobekov 1998; Aitmatov et al 1997a, 1997b

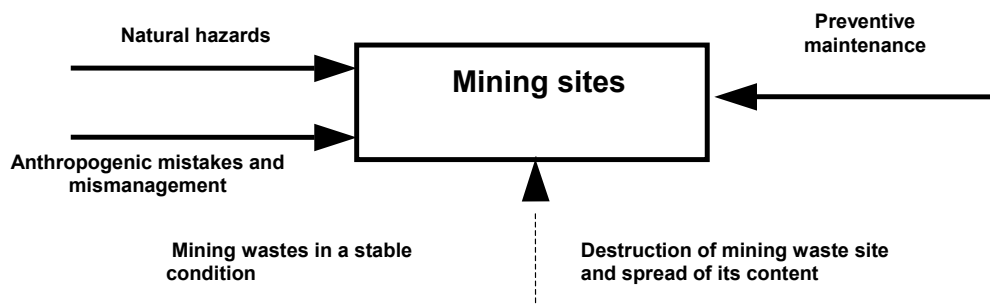


Figure 4.7 Balance of power for mining wastes fate

4.3.1. Anthropogenic hazards

Anthropogenic hazards imply man-induced accidents where the initiating event in a disaster arises from a human (Smith 1993). In terms of the influence on waste mining sites, two primer groups of anthropogenic hazards related to mining wastes in Kyrgyzstan can be distinguished:

- ◆ Mistakes made mainly in the past because of lack of knowledge about storage of mining wastes. Those include selection of incorrect location for tailings and dumps (at geological faults or places exposed to natural hazards impact), bad design of impoundments, ignorance of the impacts of intense mining activity on the high-altitude fragile ecosystems,
- ◆ bad maintenance of tailings or dumps (see Plates II and III in Appendix I) in the present or recent past due to economic difficulties, mismanagement, etc. This includes lack of adequate monitoring over mining sites, easy access of people to the tailing ponds, using radioactive or toxic mining wastes for building houses and roads, using territories of impoundments as a pasturage, etc.

4.3.2. Natural hazards

One of the characteristic features of the mountainous ecosystems, to which the territory of Kyrgyzstan belongs to, is their extreme friability and specific instability to technological impact. Strongly dissected relief, diverse climatic zones, complex geology and tectonics of the mountain environment result in much more intensive character of natural hazards as compared with the plain environment. That is why many natural hazards both geological and meteorological ones assumes a catastrophic character in Kyrgyzstan. It is necessary to emphasis that some natural hazards can detonate other ones. For example, earthquakes may trigger landslides or avalanches causing cumulative effect of destruction.

Effect of the natural hazards on mining waste sites may result in erosion or destruction at the worst of tailings impoundments or waste rock dumps with consequent spread of their toxic or radioactive content throughout vast territory.

Short-range forecast made by the experts from the MES (Moldobekov et al 1997) concludes that the territory of Kyrgyzstan in the nearest future may be subjected to strong impact from the following natural hazards: earthquake, landslide, mudflow, flood, avalanche and so on. Table 4.7 summarises consequences of largest natural disasters occurred in Kyrgyzstan over a period of ten years.

In 1994 some 411 natural disasters were registered in Kyrgyzstan (Koshoev 1996). Among them, avalanches – 223, landslides – 95, floods – 41 and other – 52. Subject of the most considerable impact from the natural hazards was southern part of the country: Jalal-Abad – 199 times, Osh – 60 and to a certain extent northern part: Chui –53; Yssyk-Kul -42; Talas – 40 and Naryn – 17.

Table 4.7 The largest natural disasters in Kyrgyzstan for 1985-1994.

Year	Type of natural disaster	Region	Amount of losses			Number of victims
			millions Kyrgyz soms	millions Russian rubles	millions US\$	
1985	avalanche	Jalal-Abad		22		
1986	showers, hail, mudflows	Osh, Jalal-Abad		0.5		
1987	showers, early frosts, snow	Osh		2.3		
1988	Showers, landslides, mudflows; Earthquake (5-6 points); Avalanche	Osh Jalal-Abad, Naryn, Chui; Osh		53 3.0 No data		38 people were killed
1989	showers, early frosts, snow	Osh		4.0		
1990	earthquake (6-7 points); floods	Yssyk-Kul Yssyk-Kul		20.0 13.0		
1991	mudflow	Chui		28.0	1.0	-
1992	showers, mudflows, landslides; earthquake (9-10 points)	Osh, Jalal-Abad Jalal-Abad, Talas, Chui, Naryn		4300 15000	21.5 75.0	53 people were killed; 60,000 homeless
1993	early frosts, snow	Chui, Osh, Talas	105	21000	26	-
1994	landslides	Osh, Jalal-Abad	180		18	115 people were killed; 27,000 migrants

Source: Moldobekov et al (1997)

Landslides

According to Encyclopaedia Britannica on-line (1999) landslide (landslip) is “downward mass movement of earth or rock on unstable slopes, including a number of forms that result from differences in rock structure, coherence of material involved, degree of slope, amount of included water, extent of natural or artificial undercutting at the base of the slope, relative rate of movement and relative quantity of material involved.”

Landslides are very common throughout southern part of Kyrgyzstan and southern coast of Yssyk-Kul Lake. Serious anxiety is expressed lately because of considerable increasing the frequency of landslides in a Mailuu-Suu region. Aitmatov et al. (1997b) state: " ...starting from 1990 landslide activity in Mailuu-Suu assumed a undamped, quasi-stationary character that can be explained by combination of a number of factors: man-induced disturbance of mountain slopes both underground and surface parts, steep slope relief, existence of geological faults, near surface bedding of water impermeable layers, high seismic activity of the region and character and frequency of precipitation"

Mudflows

There are a number of interpretations of mudflows, creep and earthflows. According to Encyclopaedia Britannica earthflow is “sheet or stream of soil and rock material saturated with water and flowing downslope under the pull of gravity; it represents the intermediate stage between creep and mudflow”.

Mudflows represent a distinctive feature of flood regime of mountain streams and rivers in Kyrgyzstan. Besides, mudflows can be generated in a consequence of damming and following breaching mountain lakes. As a rule, a

mudflow is of short duration and carries huge amount of mud and sometimes rock fragments. Breach of a lake dam causes formation of a mudflow of disastrous volume. In fact, there are 3103 rivers with mudflow potential in Kyrgyzstan(Central Directorate for Geodesy and Cartography 1987).

Formation of a mudflow depends on three groups of factors (Medeuov and Nurlanov 1996) :

- ♦ hydrometeorological – falling heavy showers as well as considerable stock of snow towards snow melting period and elevated temperatures;
- ♦ geological and geomorphological – steep mountain slopes and river-beds, availability of mudflow centres and river beds;
- ♦ anthropogenic – man-caused effect on the environment.

Heavy shower mudflows result in 80% of all mudflows, whereas snow melting in combination with rain is responsible for 15% of all the amount (Central Directorate for Geodesy and Cartography 1987).

Earthquakes

Earthquakes represent the primer seismic hazard being distributed worldwide in a naturally determined order. Around two third of all earthquakes are located in so called "Ring of Fire" which includes the territory of Kyrgyzstan. They are responsible for lives of millions of people, more than any other natural hazard.

Scale of earthquakes is estimated mainly by two techniques: magnitude and intensity. More frequent used technique - magnitude - is usually assessed on the Richter scale. From the empirical evidence it follows that the occurrence

of major disaster is usually associated with the shallow earthquake with a magnitude at least 5.5 (Smith 1993).

As it was mentioned above, earthquakes can trigger geological processes such as landslides, which may block rivers up in their beds forming impounded lakes. Afterwards, such lakes may break through resulting in mudflows – unexpected release of flows containing huge amounts of soil, stones and water. Another scenario is that the impounded lakes may flood the areas where tailings are located.

Moreover, earthquake may destroy a tailings impoundment dam directly causing practically instantaneous release of its toxic or radioactive content. Tailings dams built on geological faults are also pose grave threat of breach in case of earthquakes.

4.4. Accidents involving tailings in the mining industry

4.4.1. Accidents world-wide

A number of accidents with tailings dams took place world-wide in the past causing catastrophic damages to the environment and killing people.

On December 31, 1998, a phosphogypsum dam failure at Huelva, Spain, releases 50,000 cubic meters of acidic and toxic liquid to a tributary of Rho Tinto (WISE Uranium Project 1999b)..

On April 26, 1998, a lead-zinc tailings dam failure at the Boliden's Los Frailes mine near Seville, Spain, releases 4-5 million cubic meters of toxic tailings slurries and liquid into nearby Rio Agrio, a tributary to Rio Guadiamar. The slurry wave covered several thousand hectares of farmland, and it

threatens the Docana National Park, a UN World Heritage Site and Biosphere Reserve (WISE Uranium Project 1999b);

The collapse in September 1996, of a complex ore tailings impoundment dam, 4100 m above sea level, at the El Porco mine in Bolivia released 400,000 tonnes of toxic tailings (zinc, cadmium, lead, arsenic, etc.) into the Yana Machi river polluting 300 km downstream (Higham 1997).

On August 19, 1995 a gold tailings dam failure occurred at the Omai mine in Guyana venting 3 million m³ of cyanide wastes into Essequibo River (Jodah 1995).

In 1994, a gold tailings dam failure at the Harmony mine in South Africa killed 17 people after heavy rainfall (WISE Uranium Project 1999b).

In 1985, a fluorite tailings dam Val di Stava, Italy, ruptured and the resulting mudflow killed at least 199 people. Damage from the disaster was estimated in more than 4.7 millions USD (Alexander 1986).

In 1984, uranium tailings at Key Lake, Saskatchewan, Canada: spilled more than 87,000 cubic meters of contaminated liquid (WISE Uranium Project 1999b).

In 1979, a “state-of-the-art” uranium tailings dam burst at Church Rock, New Mexico, USA releasing about 1100 tons of radioactive mill wastes and around 370,000 cubic meters of contaminated water towards Arizona (Wasserman and Solomon 1982).

In 1978, a gold tailings dam failed at Arcturus, Zimbabwe, killing one child (WISE Uranium Project 1999b).

In 1977, uranium tailings at Grants, New Mexico, and USA: spilled 50,000 tons of slurry and several million liters of contaminated water (WISE Uranium Project 1999b).

4.4.2. Accidents in Kyrgyzstan

Koshoev (1996) states: “for the present there were no large-scale technologic catastrophes entailing heavy social and environmental consequences in Kyrgyzstan. However, it seems that it is a matter time, and the greatest danger arises from tailing impoundments of the mining industry”.

A series of accidents involving radioactive tailings took place in the past (Charski 1999 pers. comm.; Koshoev 1996; Charski 1999; SEC Geopribor 1995a):

In 1956 while constructing tailing impoundment in Min-Kush (South Kyrgyzstan) more than 60 thousands cubic meters of radioactive pulp break through a dam and contaminated Min-Kush river.

In 1958 there was an accident at tailing impoundment No.7 in Maili-Suu. As a result of this accident more than 500 thousands cubic meters of radioactive wastes were released into Mailuu-Suu River causing contamination of vast areas and spreading to densely populated Fergana valley in Uzbekistan.

In 1959, as a result of heavy rains the dam of Kara-Balta tailing impoundment was damaged and radioactive wastes contaminated surrounding areas.

In 1964, there was an accident at Ak-Tyuz tailing impoundment causing release of 680 thousand cubic meters of radioactive sand into Kichi-Kemin River

with subsequent contamination of the watershed with heavy metals and radioactive materials.

In 1977, heavy rain caused a mudflow, which swept away part of old tailings impoundment in Kadamzhai resulting in pollution of the river.

In 1994, tens thousand cubic meters of tailings were washed off into the river in Sumsar after dam was damaged by heavy rain.

CHAPTER 5

5. RANKING THE MINING SITES ACCORDING TO RISK LEVELS

Today's world is one in which the age-old risks of humankind - the drought, floods, communicable diseases - are less of a problem than ever before. They have been replaced by risks of humanity's own making - the unintended side-effects of beneficial technologies and the intended effects of the technologies of war. Society must hope that the world's ability to assess and manage risks will keep pace with its ability to create them.

J. Clarence Davies, State of the Environment: An assessment of Mid-Decade

This chapter aims at ranking mining sites located in Kyrgyzstan in the context of level of environmental risks they spread. The final conclusion about mining site priorities is arrived at while making comparative analysis of data obtained from different organisations involved and data on natural hazards interpreted from the maps and anthropogenic risk factors. Those organisations involved in geoenvironmental issues in Kyrgyzstan are: SEC Geopribor, MES and MEP. Additionally, several hot-spot mining sites were identified in the NEAP and Concept for Ecological Security of KR. Comparative analysis of those data, sometimes contradictory ones, makes it possible to come to more or less valid conclusion about levels of risk represented by tailings impoundments and waste

rock dumps in the country and provide recommendations on mitigation of environmental risks posed by hot-spots.

5.1. Information from SEC Geopribor

SEC Geopribor and Institute of Physics and Mechanics of Rock conduct research of natural and man-made disasters and current environmental issues related to the mountain environment. Experts of the SEC Geopribor have carried out a number of researches devoted to the geoenvironmental problems in the mining industry of Kyrgyzstan (Aitmatov et al 1997a; Aitmatov et al 1997b; SEC Geopribor 1995a; SEC Geopribor 1995b). The most comprehensive study has been carried on uranium mining wastes in Mailuu-Suu and Shekaftar, as well as uranium mining wastes in Sumsar. The data about status of tailings impoundments in Mailuu-Suu are summarised in Table 5.1.

As can be seen from the Table 5.1 (Aitmatov et al 1997a) the most hazardous is tailings impoundment No.3. It contains highly radioactive wastes, which were intended for further reprocessing. Initially this tailing impoundment was built as temporary without proper design. Due to low stability of the impoundment it can be easily destroyed by an earthquake of a magnitude of 7-9 or the landslide which is formed above the tailings impoundment (SEC Geopribor 1995b).

Critical condition of tailings impoundments in Sumsar is another serious mining waste issue according to report of SEC Geopribor (1995a). Tailings impoundment No.1 and 2 are close to be failed and currently represent sources of permanent pollution of Sumsar-Sai river with heavy metals.

According to Dr. I.Torgoev, director of SEC Geopribor (Torgoev 1999 pers. comm.) there is another hot-spot mining site - Ak-Tyuz - which is also assessed by him as of "high" risk level.

Table 5.1 Hot-spot tailings impoundments in Mailuu-Suu according to SEC Geopribor

No. * of TI	Type	Amount of tailings ths. tons	Total radioactivity of radionuclides Bq	Exposure rate of gamma irradiation uR/hr		Risk factor	Notes
				inside	outside		
3	Raised embankment	176	$1.86 \cdot 10^{14}$	30000	550	Landslide	most dangerous
5	Raised embankment	128	no data	2000	350	Flooding	erosion of the dam
7	Raised embankment	960	$1.38 \cdot 10^{14}$	2000	90	Flooding	accident in 1958
8	Dry storage	144	no data	no data	150	Landslide, Flooding	in a river bed
9	Dry storage	184	no data	1200	60	Landslide	increased concentrat. of radon
10	Dry storage	92	$5.3 \cdot 10^{11}$	1300	200	Landslide	increased concentrat. of radon
18	Non- organised Storage	4.8	no data	2000	8000	Landslide, Flooding	in a river bed
19	Non- organised storage	9.5	no data	no data	40	Landslide	

*- No. of TI is a number of a tailings impoundment in Mailuu-Suu according to classification accepted in the mining industry in Kyrgyzstan.
Source: Aitmatov et al 1997a

Other hot-spots of intermediate and low risk level identified by experts of the SEC Geopribor include waste rock dumps in Shekaftar, tailings impoundments and dumps in Mailuu-Suu that are not represented in Table 5.1., tailings impoundments and dumps in Kadamzhai and Khaidarkan, uranium tailings in Kadji-Sai and the tailing impoundment in Kumtor.

Table 5.9 provides the assessment of risk levels made by SEC Geopribor for a number of mining sites in Kyrgyzstan.

5.2. Information from MEP and MES

Table 5.2 summarises hot-spot mining sites according to data of the MES (Moldobekov et al 1997). It is necessary to note that according to the MES this forecast relates only to risks of dam failures caused by landslides, mudflows and floods, whereas earthquakes of high magnitude may have an impact on other mining wastes as well. As can be seen from this table the most dangerous situation is in Mailuu-Suu and Sumsar (Jalal-Abad oblast) where there is a risk of dam failures due to geological and meteorological hazards. The scenario for rehabilitation of tailings impoundments composed by experts from MEP and MES (MEP & MES 1999) stresses the importance of preventive measures to mitigate anthropogenic hazards.

Kadji-Sai is another hot-spot site, which is located in immediate proximity to Yssyk-Kul Lake and ranked among the most dangerous by expert of MES (Abdykaparov 1999, pers. comm.). The dam of Kadji-Sai tailings impoundment was extensively damaged by heavy rains and the content of the impoundment may easily leak into the environment.

Table 5.2 List of the tailings impoundments facing a risk of dam failures

No.	Region	River basin	Object at risk	Type of risk	Recommendations
1	Jalal-Abad oblast, Nookat region	Mailuu-Suu	-Tailing impoundments No.5 & 7 containing radioactive wastes	Flooding	Detailed investigation on the dams, definition of the risks. Taking preventive measures, including extraordinary ones
2	Jalal-Abad oblast, Nookat region	Mailuu-Suu	-Tailing impoundments No.3,9,10 containing radioactive wastes	Landslides	Detailed investigation on the dams, definition of the risks. Taking preventive measures, including extraordinary ones
3	Jalal-Abad oblast, Chatkal region	Sumsar	-Tailing impoundments No.1 &2 containing hazardous wastes - Tailing impoundment No.3	Erosion of the dam by flooding and mudflows Transfer of radioactive dust	Detailed investigation on the dams, definition of the risks. Taking preventive measures, including extraordinary ones

Source: Moldobekov et al 1997

Risk assessments for the tailings impoundments and waste dumps studied by MEP & MES are given in Table 5.9.

5.3. Information from NEAP

Table 5.3 summarises the results of discussion of mining waste hot-spots according to data represented in NEAP of KR. As can be seen from Table 5.3 the NEAP does consider neither Mailuu-Suu nor Sumsar. Instead, close

attention is paid to mining sites, which are missed in research of SEC Geopribor.

According to the NEAP (1995) the most serious hazard is associated with uranium mining wastes in Min-Kush. The risk is posed by the tailings impoundment which is located above the town of Min-Kush with a population of 12,000. In case of major seismic disturbance or flooding the stability of the dam may be called in question.

Risk assessments according to experts who composed the NEAP of KR are given in Table 5.9 located in section 5.5.

Table 5.3 Hot-spots related to mining activity according to NEAP¹

Site	Primary Product	Problem	Significance
Kara-Balta Combine	Uranium oxide Molybdenum Rhenium Gold	(i) Transshipment of hazardous materials; (ii) Suspected leaking of the toxins into groundwater; (iii) Radioactive dust blown from tailings surface.	(i) Possible accident (ii) potential wide-spread low-level ecosystem and human-health degradation
Former uranium mine: Min-Kush settlement	Uranium ore	(i) Unmonitored radioactive wastes located within a seismically unstable, flood plain area; (ii) site located within the watershed for the Kekemer river and Toktogul reservoir.	Potential health impacts on proximate communities including Min-Kush (12,000 pop.), and village (2,000 pop.) on mine property
Former uranium mine: Kadji-Sai settlement	(i) Uranium ore in association with brown coal; (ii) Current coal extraction by private enterprise.	(i) Site is proximate to Yssyk-Kul lake - insufficient containment of run-off exists, and unmonitored run-off from waste occurs; (ii) Lake waters and bottom mud contain low-level radioactivity; (iii) contaminated metal from old mine machinery is being salvaged and sold; (iv) unregulated private sale of radioactive coal for fuel occurs.	Broad-scale public health and ecosystem impacts associated with radon
Former uranium mine: Tuyuk-Suu	Uranium ore	Radioactive tailings dump, including toxic chemicals and reagents.	Erosion is threatening to carry materials to Tuyuk-Suu river with associated broad-scale, low level impact.

¹ This table is intended to be representative of the type and extent of current problems associated with mining wastes - it is not intended to be all-inclusive.

Site	Primary product	Problem	Significance
Kadamzhai combine (settlements of Kadamzhai and Terek-Sai)	Antimony and antimony oxides	Waste concentrates associated with sulphides and arsenic (As, SO ₂ , and NO ₂) released into atmosphere. Metals - Au, Zn, Ag and Pb - also associated wastes. Migration of toxic effluents into groundwater.	Public health impacts including weakened immune systems ²
Haidarkan combine ³ (settlements of Khaidarkan, Chauvay and Uluu-Too)	Mercury, mercury compounds, and calcium fluoride mined from wet surface and underground operations	(i) Toxic effluents containing antimony, mercury and mercury compounds infiltrating groundwater and migrating to the Chauvay river; (ii) water pumped from the wet mine is preferantly used in local agriculture; (iii) Stack emissions (CO, SO ₂ , Hg, F and No _x) exceeded standards.	Mercury compounds locally mobile in vegetation, 29% of local residents found to have mercury in their systems; 26% of the workers suffer immune system deficiencies. Potential broad-scale ecosystem impacts.
Orlovka Combine (The Kyrgyz Mining & Metallurgical Plan) settlements of Orlovka, Kashka, Ak-Tyuz village, Ilyich State Farm, and Kichi-Kemin village)	Rare Earth including thorium, lanthanum, cerium, erbium, gadolinium, holmium, dysprosium, etc.; zinc and lead	Thorium-bearing wastes, cadmium, molybdenum, PB, Cu, Zn, Be and others.	Contamination of 20 km ² by radioactive waste waters, human health impact through cultivation of the land (grain and potatoes) and building materials; toxic levels of lead and other heavy metals found in children
Makmalzoloto Combine (Makmal)	Gold: both vein and open pit	Saturation of the dumps containing cyanides	

Source : NEAP 1995

² Local consultant's report

³ Also referred to as Khaidarkan (local report)

5.4. Ranking risks associated with natural and anthropogenic hazards

This sub-chapter presents an own map-based analysis of anthropogenic and natural hazards and the risks they pose for major mining sites in Kyrgyzstan.

5.4.1. Anthropogenic risks

During the Soviet period all complex ore and uranium mining enterprises in the territory of Kyrgyzstan were subordinated to the USSR Ministry of Non-ferrous Metallurgy and Ministry of Medium Machine Building correspondingly and were uncontrollable by Kyrgyz government.

After gaining political independence in 1991, Kyrgyzstan inherited from the Soviet Union both large-mining combines and the environmental and economical problems related to them. One problem encountered was how to manage considerable amounts of mining waste, given the catastrophic economic depression. In fact, for some years, tailings impoundments and dumps, especially former ones, were uncontrolled and thus exposed to erosion and man-induced activity (Aitmatov 1999, pers. comm.; Charski 1999, pers. comm.).

It was not until 1994 that mining tailings were consigned to State Concern Kyrgyzaltyn (Kyrgyzgold) and later in 1999 to MES. The MES established a special department - the Centre on Rehabilitation of Tailing Impoundments and Mining Wastes, which is responsible for issues, associated with mining wastes.

Due to the fact that mining and processing of uranium ore took place in the early years of nuclear industry, there was a serious underestimation

concerning environmental risks associated with the radioactivity of wastes. As was mentioned in Chapter 4, the location of tailings sites have been frequently determined by current benefits without taking into account long-term stability of impoundments as well as hydrogeological and seismic conditions, and tectonics.

For example, reasons for considerable environmental pressure in Mailuu-Suu and Shekaftar can be explained by the following mistakes of anthropogenic origin (Torgoev and Charski 1997):

- Incorrect selection of deposition sites for mining wastes. Waste rock dumps and tailings impoundments were located in close vicinity to the settlements inviting radon danger. Additionally, often they were located in overflow lands of mudflow rivers and streams thus being a source of permanent radioactive contamination.
- Poor geological research and impoundments design. Location of tailings impoundments at geological faults, without consideration for hydrogeological conditions and meteorological hazards have resulted in high probability of dam faults.
- Ignoring the effect of man-induced activity on long-term stability of the fragile mountain ecosystem. Large-scale anthropogenic press on a small area of the fragile mountain ecosystem in a short period of time served to disturb the balance and to accelerate of a number of geological processes.

Preventive maintenance of the tailings facilities is of prior importance. According to the joint Scenario prepared by MEP and MES (1999) most of the

tailings impoundments and waste rock dumps in KR are not fenced and do not have warning signs which allows people unobstructed access to the facility's property. Additionally, the property of tailings impoundments is frequently used as a pasturage (see Plate III in Appendix I) or roadway. In several cases installed protective fencing was simply dismantled by locals and used for their private purposes (Schmidt 1997).

Similarly, serious misgivings can be expressed about using waste rock as a material for the construction of houses or roads as is the practice in Mailuu-Suu (Schmidt 1997) or Shekaftar (SEC Geopribor 1995a).

After collapse of the Soviet Union some documentation on tailing impoundments has been found to be missing or located in different countries (Russia, Tajikistan). At present, MES is trying to setup a comprehensive database on the tailings by collecting documentation from different organisations (Abdykaparov 1999, pers. comm.)

Table 5.4 gives an estimation of the levels of anthropogenic risks posed by different hot-spot mining sites in Kyrgyzstan.

Table 5.4 Risks to mining sites associated with anthropogenic factors

	Name of mining complex	Description of anthropogenic risks	Level of risk
1	Mailuu-Suu	Incorrect design and location of several tailing impoundments and waste rock dumps. Underestimation of anthropogenic impact on the fragile mountain environment. Free access to tailings. Direct threat of dam faults for several tailings impoundment.	High
2	Sumsar	Incorrect design and location of tailing impoundments and waste rock dumps. Bad maintenance of drainage and protective systems of the impoundments. Direct threat of permanent heavy pollution of water sources.	High
3	Shekaftar	Incorrect location of waste rock dumps. No direct threat to the radioactivity spread.	Intermediate
4	Ak-Tyuz	Uncontrolled and unmonitored tailings impoundments. No fencing and warning signs. Low-level radioactive tailings. Threat of collapse of the tailings impoundments No. 4 in case of flooding due to bad maintenance.	Intermediate
5	Min-Kush	Uncontrolled tailings impoundments. No fencing and warning signs. Local people digging dumps looking for contaminated abandoned equipment made of metal.	Intermediate

Table 5.4. - continued

	Name of mining complex	Description of anthropogenic risks	Level of risk
6	Kan	Tailings impoundment and waste rock dumps are not rehabilitated and fenceless. Tailings are used by local people for construction.	Low
7	Kadamzhai	Well-run tailing impoundments. Pollution of the air and water during metallurgical processing	Low
8	Khaidarkan	Well-run tailing impoundments. Waste waters from metallurgical processing contaminate groundwater.	Intermediate
9	Kumtor	Well-run tailing impoundment.	Low
10	Kadji-Sai	Mistakes during rehabilitation. Necessity to conduct repeated rehabilitation.	Intermediate
11	Kara-Balta	Well-run tailing impoundment.	Low

Source: Compiled on the basis of Aitmatov et al 1997a; 1997b; NEAP 1995; SEC Geopribor 1995a; 1995b

5.4.2. Geologic hazards

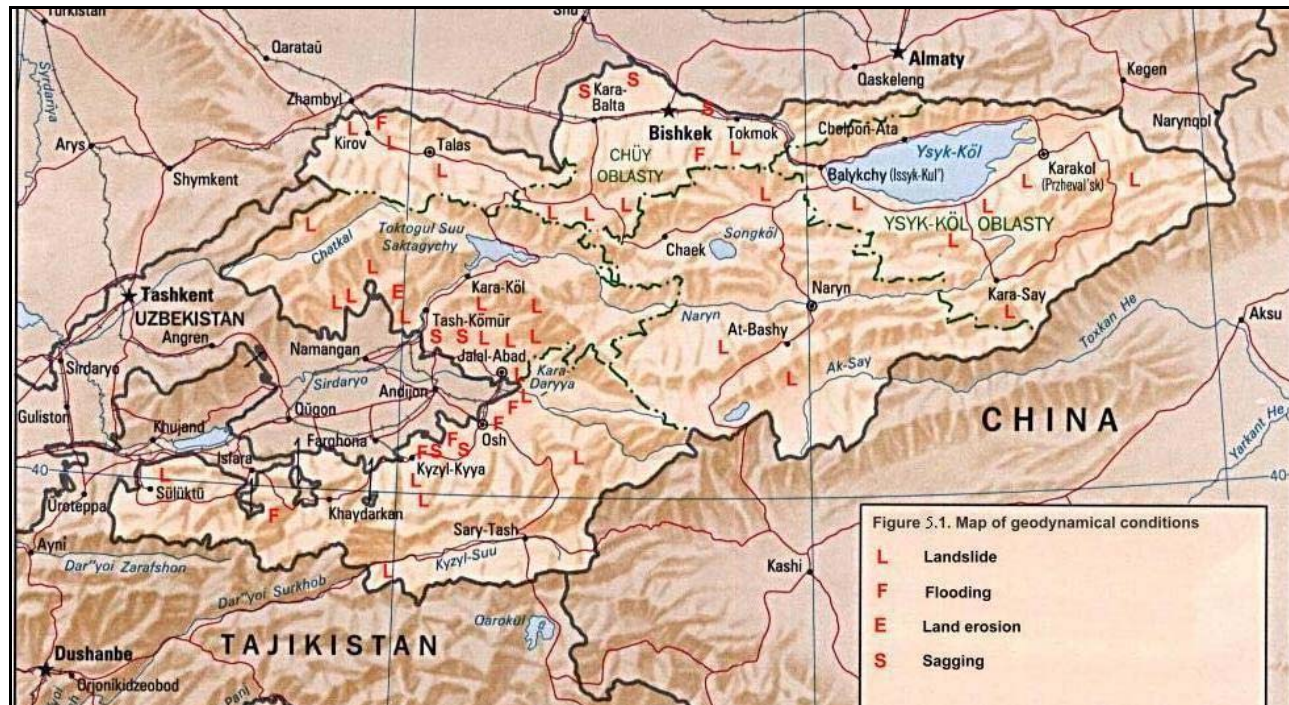
Geologic hazards include faults, earthquakes, landslides and mudslides. Along with anthropogenic hazards they pose considerable risk for mining waste sites. The gravest threat associated with natural hazards is their tremendous destructive power. Landslides, mudflows and earthquakes are the most frequent geological hazards, which have an impact on mining sites.

Landslides

Figure 5.1 shows a map of landslides and some other natural hazards in the territory of Kyrgyzstan. As can be concluded from this map landslide activity is distributed heterogeneously throughout the territory of Kyrgyzstan. The most frequent landslides can be observed in the west - south part of Kyrgyzstan (regions adjoining Kyrgyz - Uzbek border) and partly in Chuy Valley and Yssyk-Kul Lake. As was mentioned above, at some sites (Mailuu-Suu) the anthropogenic effect of mining was so intense that it caused considerable acceleration of landslide activity.

Table 5.5 provides the results of analysis of the map of geodynamical conditions concerning the level of risks for mining hot-spots arising from landslides.

Figure 5.1 Map of geodynamical conditions



Source: Compiled on the basis of CIA 1996 and State Agency for Geology and Mineral Resources 1999

Table 5.5 Risks to mining sites incurred by landslides

	Mining site	Landslide activity	Level of risk
1	Mailuu-Suu	Very high. Combination of natural and anthropogenic factors.	High
2	Sumsar	Low	Low
3	Shekaftar	Intermediate. Slopes are predisposed to landslide activity	Intermediate
4	Ak-Tyuz	Low	Low
5	Min-Kush	Low	Low
6	Kan	Low	Low
7	Kadamzhai	Low	Low
8	Khaidarkan	Low	Low
9	Kumtor	No	Low
10	Kadji-Sai	Low	Low
11	Kara-Balta	No	Low

Source: Interpreted from the map of geodynamical conditions (Fig.5.1)

Mudflows

Figure 5.2 displays a map of mudflows at the territory of Kyrgyzstan. It demonstrates areas where mudflows are generated, frequency of mudflows and also mudflow river beds. As can be seen from this map, the most frequent are mudflows at Uzbek-Kyrgyz border, at foothills of Chui Valley and in areas adjacent to Yssyk-Kul Lake. Areas out of range of mudflow activity due to soft slopes are flat countries of Chuiskaya, Talasskaya and Kochkorskaya valleys.

Table 5.6 summarises map analyses of the level of risk for mining hot-spots, which comes from mudflows.

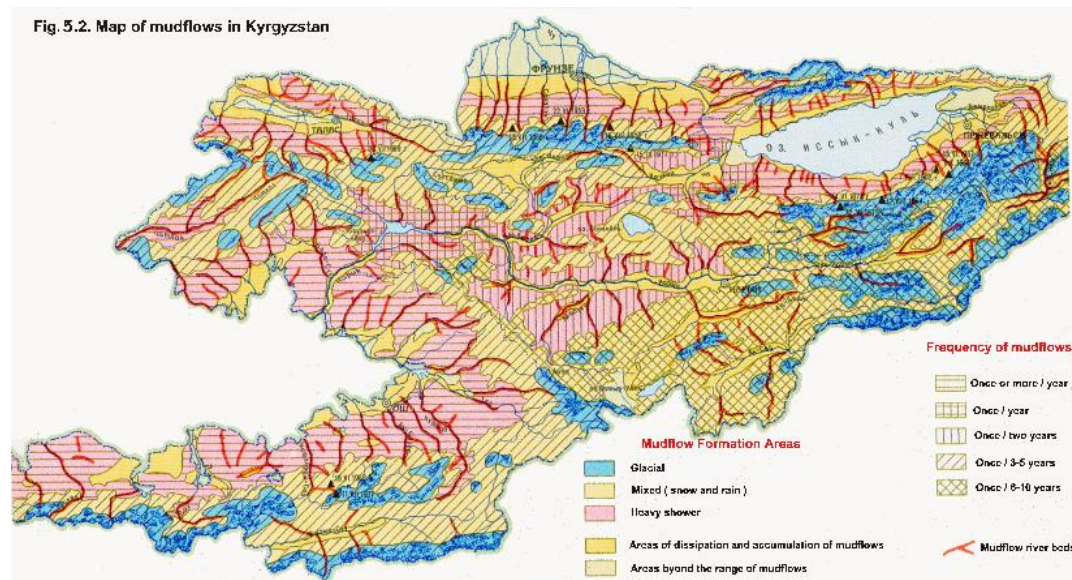
Table 5.6 Risks to mining hot-spots incurred by mudflows

	Name of mining complex	Area of mudflow formation	Frequency	Risk level
1	Mailuu-Suu	Shower	> 1 / year	High
2	Sumsar	Shower	> 1 / year	High
3	Shekafter	Shower	> 1 / year	High
4	Ak-Tyuz	Shower	> 1 / year	High
5	Min-Kush	Shower	> 1 / 2 years	Intermediate
6	Kan	Shower	> 1 / year	High
7	Kadamzhai	Shower	> 1 / year	High
8	Khaidarkan	Shower	> 1 / year	High
9	Kumtor	Glacial	> 1 / per 6-10 years	Low*
10	Kadji-Sai	Shower	> 1 / year	High
11	Kara-Balta	-	-	No

Source: Interpreted from the map of mudflows (Fig.5.2)

* Valid for the present conditions. In case of on-going trend to warming and melting of glaciers it is possible intensification of glacial mudflow processes. As a rule, glacial mudflows are more destructive as compared with shower ones (Medeuov, and Nurlanov 1996).

Figure 5.2 Map of mudflows



Source: Central Directorate for Geodesy and Cartography 1987

Earthquakes

The territory of Kyrgyzstan belongs to seismically active zones (Fig. 5.3). Earthquakes with the magnitude of 6-7 points are rather frequent and there are records of the catastrophic earthquakes occurred in the past. The most severe earthquakes were Belovodskoe in 1885, Vernenskoe in 1887, Chilikskoe in 1889, Keminskoe in 1911 and more recent Sary-Kamyshskoe (8 points) in 1970, Isfara-Batkinskoe (8 points) in 1977, Tupscoe (7-8 points) in 1990 and Suusamyrscoe (9 points) in 1992 (Koshoev 1996).

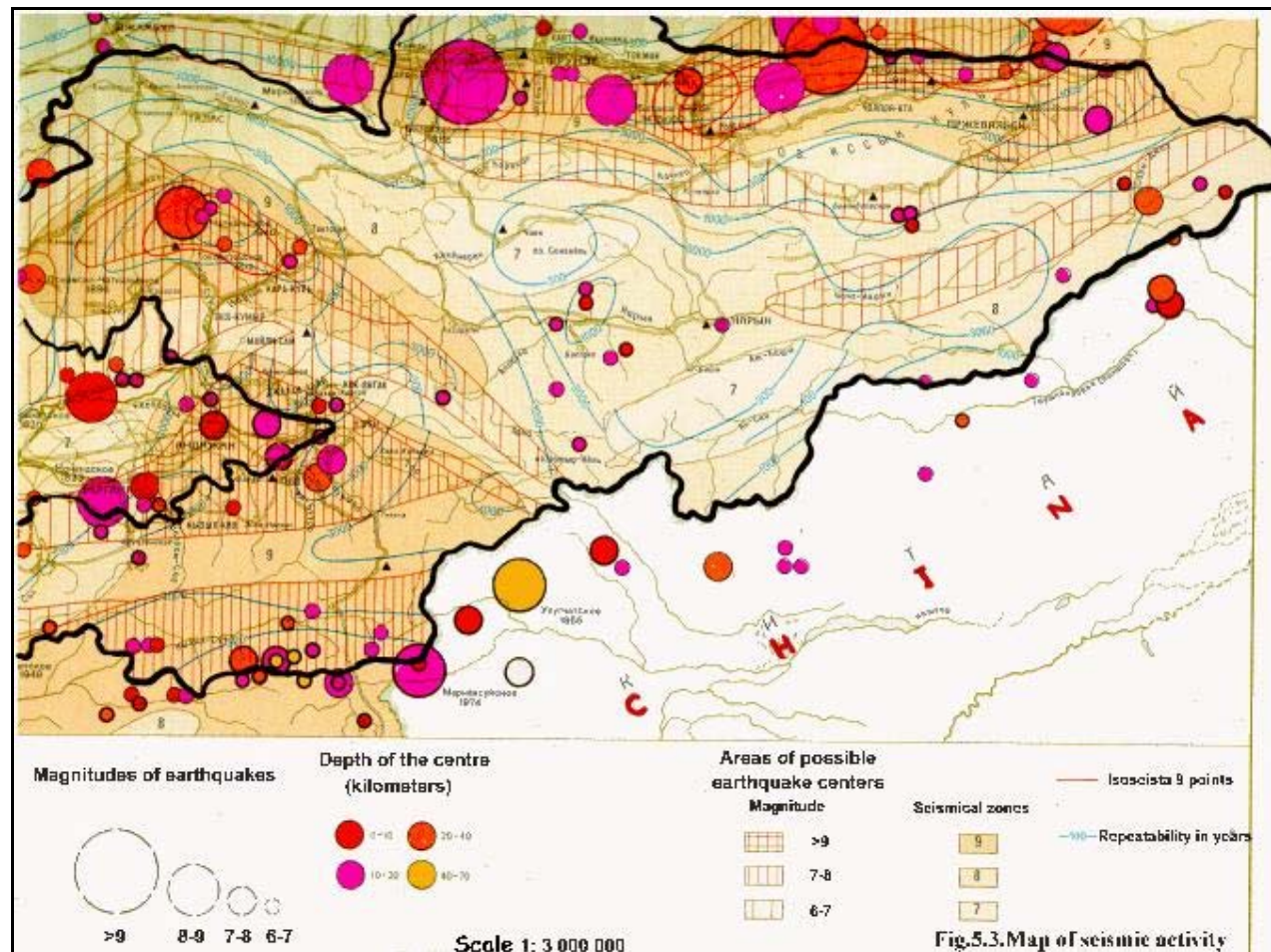
Table 5.7 summarises estimation of the level of risks to mining waste sites posed by earthquakes based on the analysis of the map of seismic activity.

Table 5.7 Risks to mining hot-spots sites incurred by earthquakes

	Name of mining complex	Seismic activity, points	Risk Level
1	Mailuu-Suu	8-9	High
2	Sumsar	8-9	High
3	Shekaftar	8-9	High
4	Ak-Tyuz	9	High
5	Min-Kush	7	Intermediate
6	Kan	8-9	High
7	Kadamzhai	8-9	High
8	Khaidarkan	8-9	High
9	Kumtor	7-8	Low
10	Kadji-Sai	8	Intermediate
11	Kara-Balta	9	Low

Source: Interpreted from the map of seismic activity (Fig.5.3)

Figure 5.3 Map of seismic activity



Source: Central Directorate for Geodesy and Cartography 1987

5.4.3. Cumulative levels of risk associated with natural and anthropogenic hazards

Table 5.8 summarises results of analysis of natural and anthropogenic hazards risks related to mining sites at the territory of KR. Cumulative levels of risk obtained by averaging levels of risk for natural and anthropogenic hazards for each mining site will be used further to estimate total risk levels from all sources of information in Table 5.9.

Table 5.8 Cumulative levels of risk arisen from anthropogenic and natural hazards

	Mining site	Level of man-induced risks	Level of landslide risks	Level of mudflows risks	Level of earthquake risks	Cumulative level of risk
1	Mailuu-Suu	High	High	High	High	High
2	Sumsar	High	Low	High	High	High
3	Shekaftar	High	Intermediate	High	High	High
4	Ak-Tyuz	Intermediate	Low	High	High	Intermediate
5	Min-Kush	Intermediate	Low	Intermediate	Intermediate	Intermediate
6	Kan	High	Low	High	High	High
7	Kadamzhai	Low	Low	High	High	Intermediate
8	Khaidarkan	Intermediate	Low	High	High	High
9	Kumtor	Low	Low	Low	Low	Low
10	Kadji-Sai	Intermediate	Low	High	Intermediate	Intermediate
11	Kara-Balta	Low	Low	No	Low	Very low

Source: Compiled on the basis of Tables 5.4-5.7

5.5. Risk levels and priority of mining sites in Kyrgyzstan

The final table (table 5.9) and Fig. 5.4 summarising results of the ranking of the hot-spot mining sites gives a clear picture of priorities in solving the problem of wastes of the mining industry in Kyrgyzstan. Estimation of the level of risks spread by a mining site was carried out on the basis of averaging risk levels obtained from different sources of information as well as assessment of risks coming from natural and anthropogenic hazards. The results obtained can be used for working out detailed action plan for all the mining sites in Kyrgyzstan.

Considering the results of the risk assessment given in Table 5.9 it may be concluded that the overwhelming majority of the impoundment embankments and dumps in Kyrgyzstan constitute a grave threat to the environment and people's health. As can be seen from various assessments and magnitudes of the cumulative risk levels the most serious risk ("high") is represented by the uranium tailings in Mailuu-Suu and complex-ore wastes in Sumsar. Another group of "intermediate / high" levels of risk includes radioactive wastes in Shekaftar, Ak-Tyuz, Kadji-Sai and polymetallic tailings in Kan. An "intermediate" level risk is posed by tailings impoundments in Kadamzhai, Min-Kush and Khaidarkan. And, finally, from "low" to "low /intermediate" risks are spreaded by the huge tailings impoundment in Kara-Balta and new operating tailings pond in Kumtor.

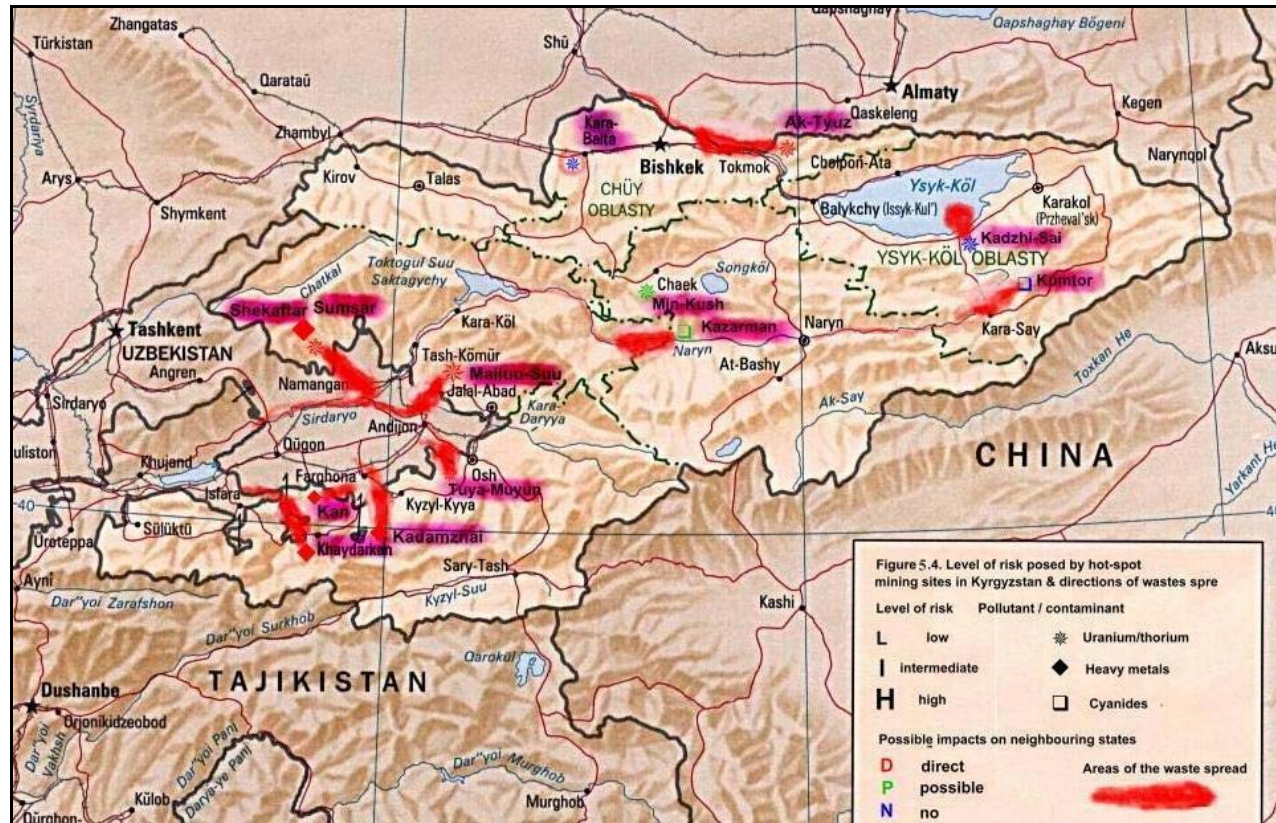
Table 5.9 Ranking of the mining sites in Kyrgyzstan according to risks they pose

No	Site	Risk level according to SEC Geopribor	Risk level according to MES and MEP	Risk level according to NEAP	Risk level according to analysis of risk factors	Cumulative risk level And priorities inside a mining complex	Notes
1	Mailuu-Suu	very high	high	no data	high	High TI No. 3,5,7,8,9,10,18,19 (Aitmatov et al 1997a); TI No. 3,5,9,10 (Moldobekov et al 1997)	Possible transboundary problems with Uzbekistan
2	Sumsar	very high	high	no data	high	High TI No.1,2 (MEP and MES 1999) TI No.1,2,3 (Moldobekov et al 1997)	Possible transboundary problems with Uzbekistan
3	Shekaftar	high	Intermediate	no data	high	Intermediate / High WR No.5 (SEC Geopribor 1995a)	
4	Ak-Tyuz	high	Intermediate / high	no data	intermediate	Intermediate / High TI No.4 (MEP and MES 1999)	Possible transboundary problems with Kazakhstan
5	Min-Kush	no data	Intermediate	intermediate	intermediate	Intermediate TI "Tuyuk-Suu" (MEP and MES 1999)	
6	Kan	no data	Intermediate	no data	high	Intermediate / High TI (Koshoev 1996)	
7	Kadamzhai	low / intermediate	No data	intermediate	intermediate	Intermediate Operative and old tailings impoundments. Toxic effluents from metallurgical processing. (NEAP 1995; SEC Geopribor 1995a)	Possible increased tensions with Uzbekistan

Table 5.9 - continued

No	Site	Risk level according to SEC Geopribor	Risk level according to MES and MEP	Risk level according to NEAP	Risk level according to analysis of risk factors	Cumulative risk level And priorities inside a mining complex	Notes
8	Khaidarkan	low / intermediate	no data	intermediate	high	Intermediate Operative and old tailings impoundments. Toxic effluents from metallurgical processing. (NEAP 1995; SEC Geopribor 1995a)	
9	Kumtor	intermediate	no data	no data	low	Low / Intermediate Tailing impoundment (SEC Geopribor 1995a)	
10	Kadji-Sai	intermediate	high	intermediate	intermediate	Intermediate / High Tailings impoundment (Koshoev 1996; SEC Geopribor 1995a; NEAP 1995)	
11	Kara-Balta	no data	low	low	low	Low Tailings impoundment (NEAP 1995)	

Figure 5.4 Levels of risk posed by mining wastes in Kyrgyzstan



Source: Adapted from CIA 1996

CHAPTER 6

6. POLITICAL RISKS OF ENVIRONMENTAL ACCIDENTS AT MINING HOTSPOTS

*Environment is one-tenth science and
nine-tenth politics.*

*Anonymous British delegate, UN
Conference on Human Environment,
Stockholm, June 1972*

Wastes of the mining industry in Kyrgyzstan create potential dangers for neighbouring countries. Basically, this relates to Kazakhstan, Uzbekistan and Tajikistan, though China may be influenced to a slight degree as well. As can be seen from Figure 4.2, mining combines as well as tailing impoundments and waste rock dumps associated with them are distributed non-uniformly along the territory of Kyrgyzstan. Many of them are located in the immediate vicinity to the Kyrgyz-Uzbek border. They include the currently operative Kadamzhai Antimony Combine and the Khaidarkan Mercury Combine as well as former tailings and waste rock located in Osh and Jalal-Abad oblast: Shekaftar, Sumsar, Tuya-Muyun and Kan. Additionally, combines located not in the close vicinity to the border but upstream of the rivers which belong to the Aral Sea basin can also have an impact on the environmental situation in Uzbekistan. An illustrative example of an accident having an impact on a neighbouring country is that accident occurred at Mailuu-Suu tailing impoundment No.7 in 1958, when about 600 thousand m³ of radioactive pulp were released into Mailuu-Suu River contaminating vast territories downstream, including fertile

Fergana Valley in Uzbekistan (Torgoev and Charski 1997). It is necessary to note that in Soviet times uranium industry was a top secret. The population had no information about the adverse effects of radiation on health and no investigation was made on the influence of this accident on the health of people. But presently the situation may be absolutely different.

Another risk factor is that Fergana Valley is a heavily populated agricultural area. Contamination of fields with heavy metals or radioactive materials may adversely effect the health of the population and make it impossible for them to sell their agricultural products. Taking into consideration the critical economic situation in the region and that there are aggravated tensions between Kyrgyz and Uzbeks, two dominant nations living in the South Kyrgyzstan, after a violent conflict in 1990 for land, it can be concluded that any grave environmental accident in Kyrgyzstan may detonate another inter-state conflict. That is why the Uzbek authorities express their concern over the environmental situation with respect to mining wastes in Kyrgyzstan (Finnish Environment Institute 1998).

The second interstate mining hot-spot is located near the Kyrgyz-Kazakh border in Ak-Tyuz. In case of a tailings impoundment accident similar to that which took place in 1964, when huge amounts of mill tailings polluted the territory of Kyrgyzstan and Kazakhstan, tailing will be spread along Kichi-Kemin and Chu rivers. Chu River serves as a border between two countries and finally missing in the desert in Kazakhstan. The areas along the river are quite densely populated in Chuiskaya Valley and water is used for irrigation. However, it will be reasonable to suppose that there is quite low risk of intensive pollution the Kazakh territory because of a number of factors:

- Tailings from Ak-Tyuz contain rare-earth and thorium. However, the concentration of toxic and radioactive components are quite low;

- Environmental risks coming from Ak-Tyuz are of intermediate level;
- The flow rate of Chu River is quite big and concentration of the toxic elements in the river will be substantially decreased;

Thus, there is no any ground to consider mining wastes in Ak-Tyuz as a source of interstate conflict between Kyrgyzstan and Kazakhstan.

Summing up, it can be concluded that mining wastes located in Kyrgyzstan close to Fergana Valley may be estimated as potentially dangerous from the point of political implications. The closest attention should be paid to uranium mill tailings in Mailuu-Suu.

CHAPTER 7

7. CONCLUSIONS AND RECOMMENDATIONS

The end crowns the work.

Russian proverb

The aim of this thesis has been to rank mining sites located in Kyrgyzstan according to the levels of risk they spread as well as to classify natural and anthropogenic factors which have an impact on mining sites in the mountainous environment. Another goal was to determine political risks associated with grave environmental accidents involving spread of radioactive / toxic wastes to the territory of neighbouring countries.

As a result of this thesis the following original contribution was made:

- Information from various sources associated with environmental and health impacts of mining sites in Kyrgyzstan was first compiled and analysed;
- Overwhelming majority of the mining sites were ranked according to risks they pose on the basis of this information;
- A number of hot spot mining sites were originally identified on the basis of the cumulative risk assessment;
- A map of the mining site risk levels was first created;
- Levels of political risks related to probable transboundary pollution from hotspot mining sites were assessed.

While analysing facts obtained from different sources and interpreting data from the maps it was found that :

1. Tailings impoundment dam failures in the mountain environment is the most disastrous way of toxic / radioactive substance release from mining wastes sites.
2. The most serious environmental risks from the point of destruction in Kyrgyzstan are posed by a number of uranium tailings impoundments (No. 3, 5, 7, 9, 10) in Mailuu-Suu and complex-ore tailings impoundments (No.1 and 2) in Sumsar. The most dangerous is tailings impoundment No.3 in Mailuu-Suu which contains high level radioactive wastes and is currently under the risk of destruction. Content of tailings impoundments may be spread throughout the vast area influencing thousands of people in case of the worst scenario.
3. Intermediate / High level risks are posed by a number of tailings impoundments and waste rock dams in Shekaftar(uranium), Ak-Tyuz (thorium) and Kan (heavy metals). In case of lack of proper monitoring and bad maintenance those sites may be placed in high risk group in future.
4. A number of mining combines: Khaidarkan, Kadji-Sai, Kadamzhai, and Min-Kush face intermediate risk level in relation to their dumps and impoundments.
5. Low and low / intermediate risks have been attributed to tailings impoundments and waste rock dumps in Kumtor, Kadji-Sai and Kara-Balta. Risks posed by these sites may also be re-considered in case of change of the condition of their maintenance.

6. Stability of the tailing impoundments and waste rock dumps depends on two groups of hazards: natural and anthropogenic. Impacts of natural hazards on mining wastes sites are distributed non-uniformly throughout the time, but can be statistically predicted, despite some natural hazards (landslides) tend to be more frequent because of increased anthropogenic pressure lately. The only way to decrease risks of radioactive / toxic materials spread is to minimise an anthropogenic factor (mistakes) and to improve situation with the maintenance.
7. Two types of anthropogenic risks can be distinguished in Kyrgyzstan: mistakes of tailings impoundment location and design made in the past, and bad maintenance of tailings impoundments and waste rock dumps in the present.
8. Spread of the radioactive / toxic mining wastes to the territory of the neighbouring countries (mainly Uzbekistan and Kazakhstan) may lead to increased interstate tensions. The most dangerous in the context of the political consequences are mining wastes, especially uranium, located close to densely populated Fergana valley.

Recommendations

1. Taking into consideration that tailings impoundment and waste rock dump safety should be maintained over a long term (hundreds or thousands of years) to avoid far reaching, disastrous consequences, as well as permanent threat of natural hazards which even tend to increase in some locations (landslides), it is necessary to re-establish tailings impoundment monitoring and control system.

2. It is necessary to take immediate measures on rehabilitation of the tailing impoundments and dumps at the most risk of complete destruction which are located in Mailuu-Suu and Sumsar including their re-deposition.
3. It is strongly recommended to adopt and enact a law regulating different aspects of long-term stabilisation and control of radioactive mill tailings similar to that adopted in the US: Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA)
4. Establishing electronic database embracing comprehensive information about all mining wastes sites is a must. In addition, computer network should be developed making it possible to update the database on the basis of current monitoring information.
5. It is necessary to study a possibility of reprocessing of tailings impoundments content using new technologies.
6. In the frame of International Year of Mountains (year 2002) it is recommended to initiate research on the adverse environmental effects of mining on the fragile mountainous ecosystems.
7. In co-operation with neighbouring countries (mainly Uzbekistan and Kazakhstan) it is necessary to work out action plan for the worst scenarios associated with mining wastes.
8. It is necessary to decrease to the lowest possible level anthropogenic risks related to toxic / radioactive material usage as construction materials as well as restrict free access to tailing impoundments and waste rock site territory.

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