Environmental Risk Reduction for Contaminated Sites at the Khaidarkan Mercury Mine

Remediation Synthesis Report

Prepared for UNEP Chemicals

by

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The report was produced as an outcome of an expert mission to Kyrgyzstan in September 2009 bringing valuable experience from Almaden and Idrija mercury mines, and advice from US EPA and Zoi Environment. It should be recognized that this is a synthesis report that is intended to provide an overview of the current situation. More detailed information on data gaps, monitoring needs and specific activities are to be provided in an extended version.

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1 Context

The world's governments agreed at the United Nations Environment Programme Governing Council in 2009 to prepare a legally binding instrument on mercury to protect human health and the environment from mercury. In doing so, the Intergovernmental Negotiating Committee that will negotiate the instrument is to develop a comprehensive and suitable approach to mercury, including provisions to reduce the supply of mercury taking into account the circumstances of countries. Negotiations are to conclude in 2013.

After the closure of major mercury mines in Almaden (Spain) and Idrija (Slovenia), the Khaidarkan mine in Kyrgyzstan is the last remaining major supplier of primary mined mercury to the international marketplace.

This report outlines options for remediation of selected potentially contaminated areas around the Khaidarkan mine site and town, including sludge pond, slag heaps, and tailings pond. Remediation approaches that are sketched out in this document are based on the initial assessment by international and local experts. Remediation measures will have several important benefits. The implementation of risk reduction measures will provide near term jobs and economic opportunities to local workers and enterprises with longer term regional / local environment and health benefits.

It is recognized that a more detailed planning document complemented with risk analysis, environmental impact assessment (EIA), environmental monitoring and activities raising public awareness should be established as part of the overall future remediation process.

In order to support the planning, implementation and assessment for remediation works, the Spanish National Technology Center for Mercury Decontamination is planning to conduct a risk analysis at Khaidarkan and develop a monitoring program, including training for local counterparts, in 2010 which will provide the basis for concrete interventions and their adjustment as required

2 Sources of contamination

After more than 60 years of primary mercury mining at Khaidarkan and lack of technical and environmental measures a large number of contaminated sites occurred which are now the sources of mercury emissions. These sources are joined by non-point source emissions arising from atmospherically deposited mercury in the area. In order to address the issue efficiently, it is necessary to prioritize sites according to relevant criteria such as level of hazard, expected risk, feasibility and benefit of potential interventions, and cost.

2.1 Sludge pond

2.1.1 Site description

The sludge pond is considered one of the most problematic areas in Khaidarkan by the expert group and town authorities. Further analysis of contaminants, in particular methylmercury, is required to determine actual risk more precisely.

The sludge pond is a flat, low-lying area where residues from the mercury purification during the smelting process are collected. The sludge contains grained material that has been transported to the area via canals as a suspension and subsequently drained onto the site. The area is about 4 ha and reportedly partly lined with concrete. Samples taken from waste stream leading to sludge pond indicate highly elevated mercury concentration (solids 1-2 kg Hg/tonne, liquids ~14mg Hg/l). The total amount of mercury-rich waste stored is estimated to be around 90000 tonnes. Surface water naturally accumulates on the sludge material which constitutes a risk for methyl mercury formation. The site is located next to the main road leading to Khaidarkan town in the eastern part and is frequented by herders whose livestock drink and feed around the site. Vegetables are cultivated nearby. There are no fences or covers that prevent access, erosion and drainage.

The sludge pond is potentially a source of atmospheric mercury emissions and mercury discharges to surface and groundwater. It is feared that contamination of cattle and related products such as meat and milk occurs via this site.

2.1.2 Possible remediation approaches

Should it prove true that the deposited material displays highly elevated concentrations of mercury or other contaminants, as preliminary sampling indicates, it may be necessary to remove the sludge and store it in a safer location. The sludge could be excavated and mixed with cement slurry which would be backfilled into secure empty spaces in the underground mine, if possible in areas with no underground water. Addition of stabilizing agents (e.g. sulpide, polysulphide) should be considered before treatment with cement (if there is elemental mercury or other soluble mercury compounds present). Otherwise elemental mercury remains mobile and could pose a risk when groundwater enters the deposited waste. Considerable experience with this technique exists at the mercury mine in Idrija.

Alternatively, the material could be treated in the metallurgical plant to remove mercury from the sludge and to facilitate environmentally sound disposal. This option could prove to be cost-efficient given that it will not involve additional equipment and will use simple excavation and transport to the smelter. It should be noted that reprocessing this waste could result in several tons of marketable mercury and atmospheric emissions if the smelter is not operated properly.

After excavating the sludge, the area could be filled with low-mercury waste material, e.g. waste rock from areas that require physical stabilization. To enable re-cultivation, the area should be covered with an impermeable layer and topsoil followed by re-cultivation to avoid water ingress. A cover layer of clay, geotextiles, or synthetics maybe applied. Given that there are various clay deposits in the vicinity of Khaidarkan, this may be the most cost efficient solution.

If the mercury content in the sludge is below levels of concern, excavation could be avoided and a cover as described above would be applied directly. The capping will prevent exposure to livestock, limit water ingress, reduce dust generation and allow safe agricultural production in the area.

2.1.3 Estimated cost and employment generated

Environmentally sound and through project planning for this task will comprise in-depth analysis of mercury contamination levels throughout the waste site and characterization of pollution pathways for efficient risk reduction measures. This works will comprise drilling, sampling and laboratory analysis of the waste material and surrounding areas. It is estimated that this work can be concluded within a period of 2-4 months during warm weather. The results will determine appropriate measures relevant for determining the resources required to address this site.

Potential tasks comprise:

- Project planning and engineering
- Excavation and transport of waste material and contaminated soil over an area of 4ha to a depth of 1.5m
- Installation of a cement slurry mixing unit and pumping facility
- Transport of solidified waste into underground cavities
- Clay extraction, transport and application
- Topsoil application and re-cultivation (phytoamelioration)

Equipment such as excavator, bulldozer and trucks can be supplied by the mine, while plants for re-cultivation can be provided by the local authorities.

Estimated employment:	20 people over 6 months
Estimated cost[1]:	150 000 - 900 0000 USD

[1] Depending on the implemented approach, lower estimate refers to waste reprocessing and the upper estimate refers to backfilling. Cost estimates provided are based on rough calculations and experience elsewhere transferred into the Kyrgyz context. They strongly depend on local availabilities which could vary considerably at a remote location like Khaidarkan. The indicated figures will be subject to further improvement considering the international good practices and should be seen as approximations.

2.2 Slag heaps

2.2.1 Site description

Slags are smelting residues left over after the ore roasting process. Commonly these dry and rather coarse materials are backfilled into the mine shafts after exploitation to increase shaft stability, reduce land take and limit environmental impact. In Khaidarkan, no backfilling was conducted which resulted in 13 million tonnes of slag stored on 40 ha surface next to the town.

Significant risks related to the slag heaps area include:

- high slope angle, which can result in sliding (note that the area is prone to earthquakes);
- close proximity to the town, resulting in dust contamination of the residential area;
- possibility mercury leaching into surface and ground waters via precipitation
- possibility to generate gaseous mercury emissions entering the global cycle

The sheer quantity of slag stored in addition to the environmental risks listed is causing a general problem to landscape and limits options for land use in the area.

The mining company reports that slag contains low levels of mercury, however analysis conducted earlier in this project shows mercury concentrations around 0.2 kg Hg/tonne. If not mitigated, mercury evaporation from the slag constitutes a permanent emission source. Proposed risk analysis and monitoring planning by the Spanish National Technology Center for Mercury Decontamination is expected to characterize the waste in more detail to specify required action.

2.2.2 Possible remediation approaches

One option is to backfill the slag into the existing shafts. While at other mining operations, backfilling of this material is the most common and cost-efficient approach for reducing associated risks, the Khaidarkan management has raised concerns about using this method because of the mine water pumped from the shafts and used for irrigation in the valley. If the water level rises after mine closure and voids filled with slag become flooded, it is feared that irrigation waters become contaminated. Compared to sludge, the amount of slag that requires relocation is much higher (13 million tonnes of slag and 90 000 tonnes of sludge) so it is expected that not enough dry and safe voids for backfilling the material, as proposed for sludge, exist in Khaidarkan.

The area should undergo a detailed hydro-geological analysis. Such a study would determine whether a proper drainage system that deals with all water sources (meteoric water, springs) will need to be installed, and also if the water is polluted with mercury or other contaminants, in which case a water treatment facility may be necessary.

If concerns are confirmed, safe storage of this waste should be conducted in place. This would require reshaping of the slag to increase stability and to eventually allow for safe alternative land use options. By filling large depressions on the waste surface, water seepage through the waste material becomes limited and water impoundment on the surface is avoided.

Reshaping would be followed by capping with an impermeable layer (e.g. clay), topsoil, and re-cultivation to further limit water seepage, erosion and accessibility. This could eventually make this area environmentally safe and available for agricultural land use.

2.2.3 Estimated cost and employment generated

Cost and effort for remediation will depend on the approach chosen for this site. Potential tasks comprise of the following:

- Study and prioritization of slag waste areas for implementing risk reduction measures
- Project planning and engineering

The above studies are required. Cost for implementing risk reduction measures at the slag heaps will depend on the amount of slag requiring reshaping and capping. This will need to be decided based a physical and chemical analysis of the various slag heaps.

- Reshaping
- Capping, top soil application and re-cultivation
- Water drainage and treatment
- Establish sanitary-buffer zones

Estimated employment: 50 people over 5 years

Estimated cost: 3-5 million USD

2.3 Tailings pond

2.3.1 Site description

The tailings pond is located about 5 km west of the town and processing plant, with a surface of 22 ha. It is filled with fine-grained residues from milling and floatation processes (tailings) to extract fluorite, antimony and mercury from complex ore. The amount of tailings is about 400 000 tonnes with mercury content of around 0.1 kg Hg/tonne or below. Other contaminants such as arsenic and antimony are present in the tailings.

The tailings pond is neither covered on the top, nor isolated from the bottom which can lead to the release of dust or gaseous mercury to the atmosphere and/or the release of mercury containing effluents to surface and ground waters. There are no fences or other protection measures around the pond. There have been complaints by residents about dust formation during dry and windy periods.

The tailings are currently being considered by the plant administration for reprocessing to produce fluorite concentrate. Cover and re-cultivation of the tailings will only be possible if tailings are not reprocessed.

2.3.2 Possible remediation approach

In order to reduce atmospheric mercury emissions, contaminated dust generation, and water seepage from the tailings pond, it is recommended to apply a clay cover similar to the approaches described earlier for the sludge pond. In addition it will be necessary to ensure the dam stability. Therefore pond barriers would need to be reshaped and elevated.

Any water ingress would need to be avoided to ensure stability and minimize water pollution. In considering this, the tailings surface might require reshaping to avoid water ponding. Emergency notification systems should be installed at the tailing site to identify and quickly respond to any risk situations through a suitable monitoring is recommended which would ideally include piezometric groundwater measurements, chemical analyses of water quality and monitoring of geo-mechanical stability at the site.

2.3.3 Estimated cost and employment generated

The implementation of measures strongly depends on the mine operator’s future plans for the tailings pond since it cannot be used anymore after remediation. Therefore, this part is likely to be addressed in a later stage during a phased remediation approach. Related cost will depend on the level of technical complexity for the dam assessment and stabilization works.

Estimated employment: 20 people over 2 years

Estimated cost: 0.5-1 million USD

2.4 Other sites

2.4.1 Waste rock

Over hundred million tonnes of waste rock is deposited in a high position in the mountains north of the town which pose similar physical risks as the slag heaps in terms of stability, but it is likely that mercury levels are low in this material. Waste rocks may require reshaping to ensure long-term stability and safe land use. They can also be used as filling material for the excavated sludge pond or tailings.

2.4.2 Smelter area

With advanced economic transition in Khaidarkan, the smelter might become subject to decommissioning works. It is suspected that the area around the smelter is highly contaminated with mercury and other toxic elements. Therefore excavation and safe disposal of the soil and other items in the smelter area needs to be considered and planned in the course of the decommissioning works. Once mine transition is indicated, equipment dismantling and area sampling plans should be developed, followed by proposed remedial actions for the area.

2.4.3 Abandoned mine sites

Potentially dangerous environmental legacies of abandoned mercury sites formerly associated to the Khaidarkan mine, especially *Chauvay*, should eventually be addressed to extent possible using experiences and technologies applied in Khaidarkan.

2.4.4 River sediments

Next to atmospheric emissions, transport of mercury rich sediments via waterways is an important trans-boundary pollutant pathway. Given that Khaidarkan is located upstream of the Ferghana Valley and 8 km west of an Uzbek enclave, measures reducing potential trans-boundary environmental impacts should be considered.

Preliminary sediment analyses showed that the mercury content a few kilometers upstream the mine is about 7 mg/kg while a few kilometers downstream the result was 44 mg/kg, shaft water sediments had a mercury concentration of 160 mg/kg. It is assumed that the mercury legacy further downstream is considerable given the higher emission levels in the past.

3 Other measures that are linked to environmental risk reduction and remediation

3.1 Environmental Impact Assessment and cross-border study

According to the Kyrgyz legislation, the environmental impact assessment of the proposed risk reduction and remediation interventions should be conducted prior to the undertaking of actual activities on site. This will require a desk and a field study considering existing international experience. To ensure appropriate selection and application of remedial measures, practical cooperation with already closed mercury mines currently undergoing restructuring and remediation for knowledge transfer and experience sharing would be very desirable. Such cooperation could include expert visits and trainings on the site and abroad.

Given the Khaidarkan valley's rivers and streams eventually drain into the densely populated Ferghana Valley, it is suggested that an EIA should also addresses trans-boundary environmental concerns arising from Khaidarkan. This should ensure appropriate remediation measures to reduce potential risks of trans-boundary pollution and minimize environmental impacts downstream. The initiatives on environmental impact assessment facilitated via Swiss cooperation and by the Finnish Environmental Institute could support the project knowledge base and implementation.

3.2 Public Awareness

In order to effectively reduce risks from mercury pollution, public awareness and occupational health issues need to be addressed. By improving the local population's awareness of mercury-related risks and understanding of emission sources in the area, exposure can be limited. In particular, it will be of great importance to raise awareness for mercury related risks during potential mine closure and remediation works as by experience mercury mobilization increases significantly (temporarily) during these works.

Moreover, improved knowledge on mercury related issues will facilitate informed decision making and consideration of non-mercury alternatives. For this purpose, a public awareness programme implemented by local environment and health authorities, NGOs and town administration would be most appropriate.

4 Conclusions and recommendations

Overall cost is estimated between 4.6 and 8.8 million USD over 5 years for these high priority activities. It is recommended to adopt a phased approach in addressing all relevant issues at Khaidarkan. This phased approach would prioritize action where considerable risk can be reduced in a cost and time efficient manner. Thereby capacity can be built in context with local conditions and according to the resources available.

In order to take on responsibility for identified risks, efforts in monitoring and remediation can begin now in anticipation of an economic transitioning process at the mine site. Significant risks can be reduced in preparation or in parallel to a process involving mercury mine closure and transition to alternatives. In this context, it is recommended to further expand the environmental analysis and to conduct a remedial action at the sludge pond described under 3.1 in the short term. The high mercury load expected at the site, the prominent contamination pathways and the limited extent of waste (compared to others) have strong promise to achieve the significant environmental, health and economic benefits from the required investment.

Addressing slag heaps, tailings, contaminated water stream sediments and waste rock sites will be more difficult and technically challenging, but will have a great impact on improving the environmental situation in Khaidarkan as well as the regional and global impact. For works related to slag and tailings remediation, mine transition should have started or ideally be concluded and primary mercury mining should be terminated for technical and environmental reasons. The related works will provide considerable employment for several years which would further facilitate economic transition.

There is little experience in Kyrgyzstan in the field of environmental remediation. Local experts and institutes will require assistance in planning and implementing these works. Skills and experience that would be built in the course of implementing remediation actions could facilitate similar works in Khaidarkan and elsewhere in Kyrgyzstan, e.g. at abandoned mercury mines or uranium tailings sites.

Annex

Summary table of interventions and costs

Types of activities for planning and implementing the remediation measures	Estimated employment	Lower cost estimate, USD	Upper cost estimate, USD	Timeframe	Potential funding and facilitation
High priority and short term measures:					
Risk analysis and environmental impact assessment of the proposed technical environmental remediation measures	10	50 000	100 000	6 months	Government Donors (including the Spanish National Technology Center for Mercury Decontamination, the Finnish Environmental Institute, , learning from experience Swiss-funded cross-border EIA project in Central Asia, Italy's REHRA project, others)
Detailed planning and engineering design (for the entire site)	10	100 000	300 000	6 months	Government Donors, the World Bank
Sludge pond remediation	20	150 000	900 000	6 months	Khaidarkan Mercury Plant, Government Donors, the World Bank, the ISTC
Public awareness and health risk prevention	5	50 000	120 000	1 year	UNEP (public awareness brochure), UNIDO, OSCE (Osh Aarhus Center)
Remediation training, capacity building and exchange of good practices	5	50 000	80 000	1 year	Government Donors (Spanish National Technology Center for Mercury Decontamination, Slovenian Research and Information Centre on Mercury, others)
Establishment of an environmental monitoring system	10	250 000	450 000	1 year	Government Donors (Spanish National Technology Center for Mercury Decontamination, Finnish Environmental Institute), NATO's SPS programme, the ISTC
Project coordination	5	100 000	200 000	2 years	UNEP, UNITAR
SUB-total for high priority short term measures	**65**	**750 000**	**2 150 000**		
Slag heaps	50	3 000 000	5 000 000	5 years	Khaidarkan Mercury Plant, learning from experiences of the World Bank (environment remediation and risk reduction projects in Mailisuu, other sites), the Asian Development Bank (CACILM, land degradation)
Tailings pond	50	500 000	1 000 000	2 years	Khaidarkan Mercury Plant, learning from experiences of the World Bank
Water streams pollution, sediments clean-up	20	350 000	600 000	3 years	GEF, Switzerland
TOTAL for all measures	**185**	**4 600 000**	**8 750 000**		

Possible timeline for proposed activities