Environmental impact and remediation of uranium tailings and waste rock dumps at Mailuu Suu (Kyrgyzstan)[1]

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Abstract: This paper describes the environmental situation in the former uranium mining and milling region of Mailuu Suu (Kyrgyzstan), the approach to environmental remediation of the waste facilities (tailings ponds and waste dumps) and the results achieved so far. It starts with an outline of the history of the environmental remediation project which has received international attention and is seen as pilot project for further remediation activities of former uranium mining and milling sites in the region. Apart from technical aspects, the paper draws conclusions with respect to the administrative environment, institutional capacity building and the local availability of resources needed to successfully implement a complex remediation project.

1. Introduction

The town of Mailuu Suu is located in the north-eastern part of the Fergana valley, in the valley of the Mailuu Suu river. The altitude of the area is between 900 and 1000 m a.s.l. The Mailuu Suu river reports to the Syr Darya river which, in turn, feeds lake Aral. Administratively, the area belongs to the Dzhalalabat province in the southern part of Kyrgyzstan, with a distance from the Uzbek border of around 25 km. Today, approximately 25,000 inhabitants live there, with a light bulb factory being the only employer of significance.

In and around the town, uranium was mined and milled from the late 1940's to the 1960's. Most of the waste dumps and tailings ponds are located in the valleys of the Mailuu Suu river and its tributaries Kara Agach, Kulmen Sai und Aylampa Sai. Their proximity to the riverbeds, strong seasonal floods of rivers, steep slopes of a mountaineous landscape, landslides and a pronounced seismicity[5] add up in varying degrees to the structural instability of a large part of the waste facilities. The area, typically covered with grass, is over-grazed which adds to the landslide risk and further reduces the water retention potential of the soil, increasing the frequency and magnitude of floods. Under these conditions waste material with elevated natural radioactivity is eroded and transported towards the denser populated parts of the Fergana valley and, further on, across the border to Uzbekistan, adding a politically sensitive cross-border aspect to the problem.

Investigation of the environmental and health impact of the uranium mining and milling wastes began after international attention had been drawn to the situation. Since then, numerous efforts have been undertaken to understand the environmental impact and develop appropriate remediation solutions, which have been financed by international organizations such as the European Commission's TACIS program and the World Bank. In the following sections, the various investigation and remediation approaches and the current status of the remediation works will be presented and discussed. Currently, the design of remedial measures has almost been completed, and implementation of the most urgent measures is in progress.

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The rest of this paper starts with a brief overview of the uranium mining and milling legacy at Mailuu Suu (Section 2), and provides a summary of the numerous projects over the past 15 years to tackle the environmental situation (Section 3). The main results of the investigation programme and environmental impact assessment are presented in Section 4. Section 5 discusses the selection procedure of the preferred remediation options for the most important waste sites, and Section 6 presents results achieved and remaining challenges. As design activities, permitting procedures and the implementation of physical works are still in progress at the time of writing. this paper describes the situation at Mailuu Suu as of Autumn 2007.

2. Legacy of uranium mining and milling at Mailuu Suu

In the area of Mailuu Suu, uranium mining and milling was carried out between 1946 and 1967 as part of the Soviet nuclear programme. Exploration and development of the uranium deposit of Mailuu Suu began in late 1945, being one of the first in the Soviet Union's political reach. The deposit in Carnotite is of relatively low grade. Only scarce information on the ore characteristics, grades, production volumes and mining methods is available, though. Archives in Uzbekistan and Russia still have to be made fully accessible.

Underground mines were operated under a surface of around 36 square kilometers, subdivided into 5 mine fields, and accessible via 3 shafts and several adits. These operations resulted in 13 mine waste rock dumps left at the surface. Their total volume is around 0.9 million m³. They are largely uncovered, and partly exposed to erosion by the tributaries of the Mailuu Suu river.

The ores were processed in 2 plants at Mailuu Suu (later, ores were shipped to Kara Balta, west of Kyrgyzstan's capital Bishkek), together with ores from Eastern Germany (Erzgebirge area), China, Bulgaria and Czechoslovakia (Jachymov). The processing residues were stored in 23 tailings ponds with a total volume of around 2 million m³.

The operations at Mailuu Suu were closed between 1964 and 1968. Closure of the facilities was carried out according to Soviet standards: processing plants were mainly demolished (or used otherwise), underground workings secured and backfilled. In contrast to the waste rock dumps which were mainly left without any notable remediation, tailings were partly reshaped and received a mineral cover, even though many covers are incomplete and/or have been damaged.

The waste storage facilities differ significantly in their volume and footprint, but also in physical and chemical characterstics, in their exposure to fluvial erosion, seismic events and landslides, and thus in their significance in regard of environmental and health risks. While some of the 36 waste facilities are dry, with gentle slopes and stable, far away from both human settlements and rivers, others have been dumped within a steep, narrow riverbed where erosion carries away a significant portion of the wastes every year, or are nearly water saturated which reduces their structural stability under seismic events typical for the region, and could lead to a sudden release of pulpy radioactive tailings into the hydrographic system after dam failure.

3. History of the environmental remediation project

After closure of the operations in the late 1960's, the legacy of uranium mining and milling at Mailuu Suu fell into oblivion until it received increasing international attention in the early 1990's. In 1992-94, the first reports on sites of the Soviet nuclear fuel cycle appeared [1]. In negotiations with the Russian government (1994) Kyrgyzstan raised the issue of environmental remediation of former uranium mining sites for the first time. In 1996-1998, a survey of the uranium mining legacy in the CIS was funded by the EU Commission's TACIS programme [3], which identified Mailuu Suu as one of the foci of urgent environmental action. At around the same time, Kyrgyz media started to cover the situation in Mailuu Suu [2].

Soon, Mailuu Suu became synonymous with the devastating environmental impact of environmentally unregulated uranium mining and milling in the former Soviet Union, with the common exaggerations of risk perception. Gerhard Schmidt, of the renowned Öko Institute in Darmstadt, Germany, warned in 1998 that „leaks from wastes could make water in the Fergana valley unfit to drink“ [4]. The Blacksmith Institute listed Mailuu Suu among the "World‘s 10 Most Polluted Places“ (in 2007, it is still among the Top 30 [5]). The New Scientist (2002) stated that „flooding of Soviet uranium mines [i.e., Mailuu Suu] threats millions“ [6]. The massive media coverage has led to considerable public and political attention which helped to secure funding from numerous sources to solve the environmental problems at Mailuu Suu. Activities include, but are not limited to, the following:

- From 2000 to 2003, the EU Commission, through its TACIS programme, funded an in-depth investigation of the environmental situation and a feasibility study to develop appropriate remediation solutions [7] („Remediation of Uranium Mining and Milling Tailing in Mailluu-Suu-District, Kyrgyztan“). This project which also included urgent stabilisation measures of the tailings dam no. 3, was carried out by a consortium led by SCK-CEN (Mol, Belgium) and still represents the most comprehensive data base for subsequent efforts.[6]
- Since 2004, IDA (World Bank Group) has created the DHMP (Disaster Hazard Mitigation Project) which implements environmental remediation and public information and awareness activities in Kyrgyzstan. The DHMP is implemented by the Project Implementation Unit (PIU) within the Ministry of Emergencies (MoE).
- The IAEA Technical Cooperation Project RER9086 deals with the consequences of past uranium mining and milling practices. The countries that participated in these efforts are Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan [8].
- In the context of the DHMP, an Environmental Impact Assessment (EIA) was carried out by a Consortium of Jacobs Gibb and HCG Environment [9]. This EIA, together with a suite of associated assessments and reports (e.g., on seismology, water impacts, social assessment) were to provide the necessary information for the Environmental Assessment (EA) as required by the World Bank procedures.
- In 2005, the Consortium Geoconsult (Austria) - WISUTEC Wismut Umwelttechnik (Germany) was contracted for Component A of the DHMP, which deals with the design and supervision of remedial measures for the uranium wastes in the Mailuu Suu region.
- Starting in 2006, the German Federal Institute for Geosciences and Natural Resources (BGR) has funded a monitoring programme in order to improve the knowledge of the water impact of mining and milling residues on the water resources [10].
- In 2007, the German Federal Ministry of Environment and Nuclear Safety (BMU) devoted funds to a consulting, capacity building, training and know-how transfer project carried out by WISUTEC in order to complement the predominantly technical focus of Subcomponent A of the DHMP.

4. Environmental situation and impact of the tailings and waste dumps

The numerous studies and investigations of the environmental impact which have been carried out over the past decade, most notably the valuable data collection of the TACIS project [7, 12], and the additional results obtained by the authors of this paper within the DHMP [14] have revealed a picture which wil be summarized in the following sub-sections.

4.1. Erosion

The most obvious and severe impact of waste facilities is due to the strong erosion of tailings and waste rock situated on the banks of the Mailuu Suu river and its tributaries. Erosion of wastes is caused both by rivers and creeks on whose banks the wastes have been deposited, and by the unhindered runoff of precipitation during strong rainfall events and snowmelt. Most striking examples are the waste dumps (WD) no. 1 and 2, and tailings ponds (TP) no. 2 and 13, see FIGURE 1.

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[6] A seamless continuation of the detailed work carried out by the SCK-CEN team was ensured by key experts of the 2000-2003 TACIS study who kindly provided invaluable background information to the authors of this paper [11].

FIGURE 1. Fluvial erosion of the dam toe of tailings pond no. 2 and 13 in the valley of Aylampa Sai, a tributary of the Mailuu Suu river.

While erosion does not lead to a critical radiological impact today (i.e., incremental effective doses due to the mining and milling residues stay far below 1 mSv/a), it is the uncontrolled nature of the dispersion of radioactive mining and milling residues and the unpredictable accumulation of radioactive material on floodplains downstream which causes strong concerns. The transboundary nature of fluvial dispersion may also lead to political strains with neighboring Uzbekistan.

Another obvious issue is the bad state of maintenance of water diversion channels and ditches. Most existing channels have collapsed or are otherwise damaged, which adds to the erosive action of surface drainoff during and after heavy rainfalls and snowmelt.

4.2. Seismic instability

Tailings pond (TP) 3 which is situated in the Mailuu Suu river valley, is unstable under seismic loads. TP 3 has been shown to be partially water saturated which is explained by springs beneath the tailings body. During the TACIS project [7], temporary stabilization measures in the dam area were carried out, and additional in-situ stabilization techniques have been discussed, but under long-term aspects relocation of the entire tailings pond is required.

Continuing erosion of loamy alluvial material from the hillslopes in the hinterland of TP 3 and its deposition on the tailings pond plateau leads to the build-up of a static load which further decreases the overall structural stability of the waste facility, see also FIGURE 2.

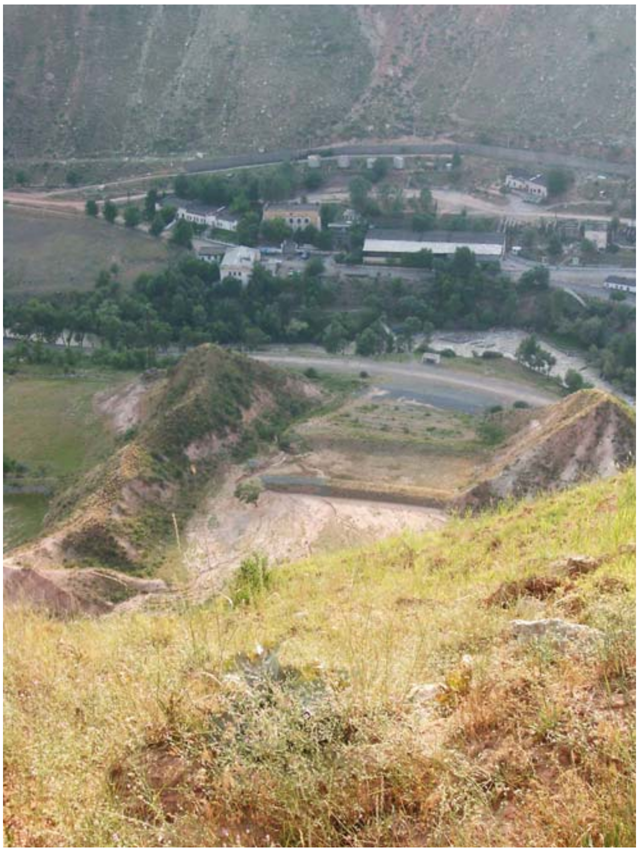

FIGURE 2. Tailings pond no. 3 seen from the cliff in its hinterland. Note the Mailuu Suu river behind the public road

4.3. Landslides and mudflows

For the waste dumps and tailings, landslides are an indirect hazard in that they may block riverbeds. The raising water level will then inundate the waste dumps and tailings dams situated upstream of the blockage and decrease their stability. The Mailuu Suu river is particularly affected. However, the extent to which landslide material can realistically block water courses and lead to the scenario described, is not entirely quantifiable yet. In order to achieve a more quantitative understanding of the impact of landslides, a landslide monitoring program has been developed by consortium member Geoconsult as part of the DHMP Component A.

The impact of the so-called Tectonic landslide on the cliffs above TP 3 on the tailings pond stability is discussed differently [7, 13]). Whether the landslide will reach the tailings surface after activation, threatening the stability of the entire structure, depends on the quantitative results of the landslide monitoring program mentioned above.

Apart from their (indirect) impact on the uranium mining and milling wastes, landslides are a direct hazard to health and property of the population in the Mailuu Suu area. A better understanding and prediction of the mechanisms and effects of landslides is therefore in the interest of the general welfare of the region.

Mudflows which occur in valleys such as the Kulmen Sai creek valley, close to waste dump WD 2, are similar to landslides in that huge amounts of material are suddenly sliding down the valley. They must be taken into account in the design of sustainable remediation solutions, otherwise they may severely damage riverbank strengthening measures and other man-made structures.

4.4. Impact of waste facilities on water quality

The impact of the waste facilities on fluvial water is barely measurable. Even though a weak increase of the radionuclide concentration in the Mailuu Suu river can be observed [7, 14], the impact is far from causing a significant dose increment to downstream water users.

There are isolated occurrences of dam seepage water from tailings ponds which contain elevated concentrations of radionuclides. For example, the seepage of TP 16 contains around 24 mg/l uranium [14]. However, due to its remote location, there is no realistic usage scenario of the seepage (which can be further precluded by warning signs and diverting the seepage to the next creek in a controlled manner), so that there is no justification of further remedial action.

4.5. Radon and direct radiation

Apart from one waste dump (WD 5) and some isolated radiation hot spots due to damaged or incomplete covers, there are no sites which pose an acute radiological risk to the public.

WD 5 is located in a populated area with residential houses partly built on it. Long-term radon measurements using track-etching detectors indoors and outdoors have shown that effective doses received by the public living near WD 5 may come close to, or even exceed, the 1 mSv/a reference value. Here, remedial measures are clearly required. Complete removal of the dump has been recommeded and will be carried out.

Gamma-scans on the surface of waste facilities have revealed some isolated hot-spots of direct radiation, where the dose rate is well in excess of 1500 nSv/h. Examples are spots on TP 5, where the cover should be repaired, and WD 11 where obviously some low grade ore lies close to the waste dump surface. Typically, however, the ambient dose rate is well below 750 nSv/h [7, 14]. Even under conservative assumptions and use scenarios, effective doses stay far below 1 mSv/a, so that intervention cannot be justified.

4.6. Dust

Dust plays no significant role in the dose calculations. This is due to the fact that the tailings ponds are mostly covered with inert material, while the waste rock dumps are less prone to dusting (due to their coarser grain spectrum) and have a much lower activity concentration.

5. Remediation measures

5.1. General approach

Based on the environmental data which had been collected before the start of this project, and the additional investigations carried out during this project, and following an iterative evaluation and decision making procedure, all waste facilities in the Mailuu Suu area were categorized in one of the following groups, according to the intervention measures recommended:

1. no action required,
2. remediation measures are recommend, but are of lower priority (such as removal of a supernatant water pond on a remote tailings pond, or slope stabilization of very small objects),
3. intervention measures can and should be carried out quickly, requiring a relatively small budget, such as fencing or placing a simple cover on isolated radiation hot-spots,
4. temporary stabilization measures, mainly riverbank strengthening in river sections with strong erosions, are urgently required,
5. long-term solutions are needed to sustainably remove a major environmental and/or health risk, such as relocation of wastes to a safer disposal site.

As was already explained in Section 4, acute radiological risks play only a minor role in the decision process, at least with respect to the costly long-term solutions. The categorization was dominated by the obvious erosion and geotechnical risks. Nevertheless, the handling of radioactive material during the remediation measures requires the observance of guidelines and standards, among which the following IAEA standards are of particular relevance:

- RS-G-1.7 "Application of the Concepts of Exclusion, Exemption, Clearance",
- WS-G-1.2 "Management of Radioactive Waste from the Mining and Milling of Ores",
- RS-G-1.1 "Occupational Radiation Protection".

FIGURE 3 shows the formal procedure to categorize the objects according to their priority of being remediated.

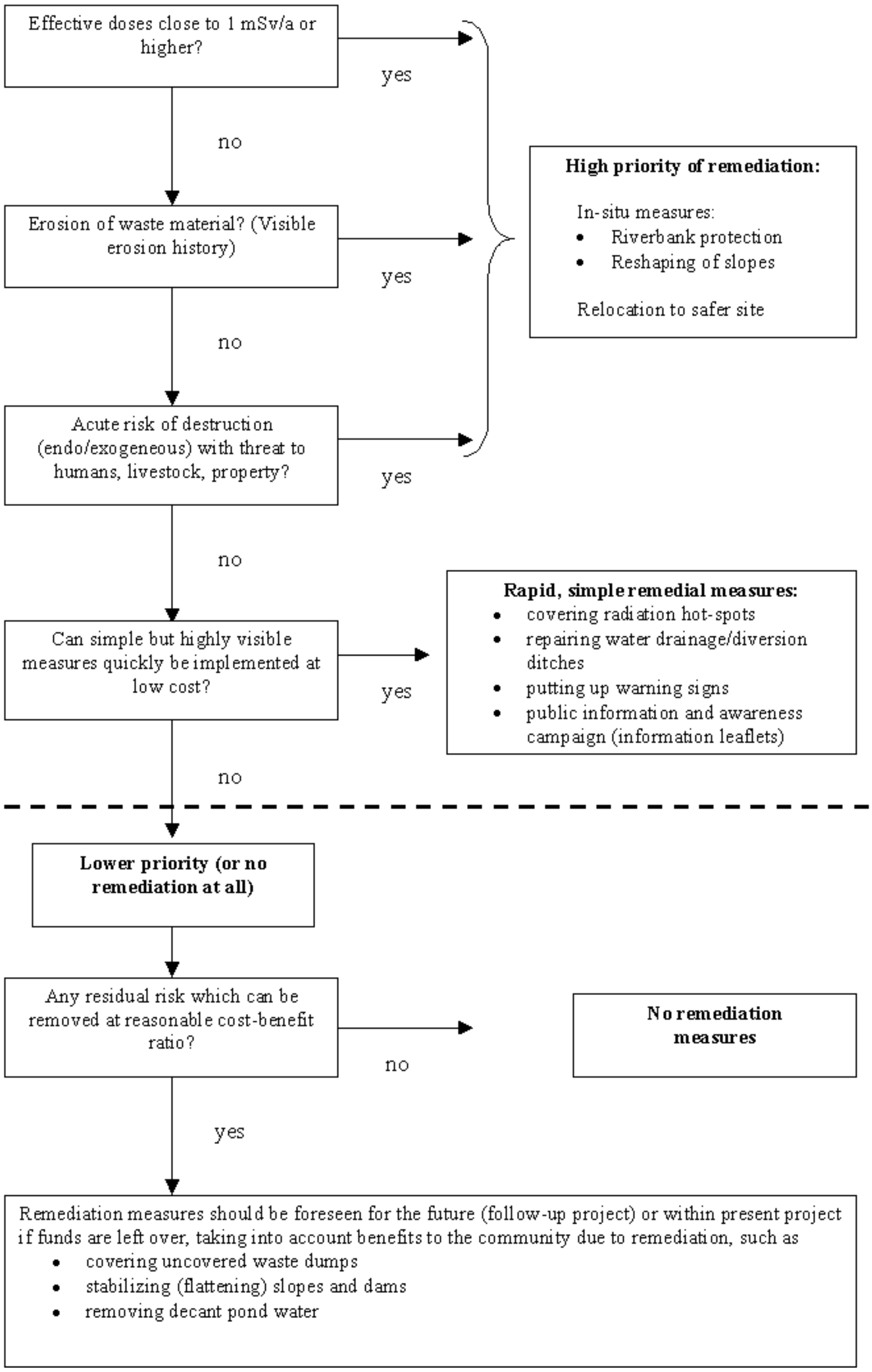

FIGURE 3. Decision procedure to categorize individual objects according to their priority

Of the 36 objects (13 waste dumps and 23 tailings ponds), 12 were found to need no intervention measures, and 10 where remedial action was of lower priority. For the remaining 14 objects remediation was recommended with high priority in the first place. A second level of prioritization was needed to define a set of remedial measures which fit into the current budget and time frame of the DHMP. In the following sub-sections, we will focus on those measures which have been approved by the PIU for implementation within the current World Bank funded project. They are summarized in TABLE 1 and explained in more detail below.

TABLE 1. Summary of remediation measures which are implemented during the current project, and further recommended measures of lower priority

	Implementation during current project	**Lower priority**
WD 1	Relocation to WD 2	
WD 2	Reshaping of wastes (including material from WD 1), Riverbank strengthening	
WD 4	Warning signs	
WD 5	Relocation to TP 6	
WD 6	Riverbank strengthening	
WD 7		Relocation to safer site
WD 8		Retention wall
WD 11	Hot-spot cover	
WD 12		Relocation to safer site
TP 1, 4, 20-23		Riverbank strengthening
TP 2, 13	Temporary riverbank strengthening	Relocation to safer site
TP 3, 18	Relocation to TP 6	
TP 5	Riverbank strengthening, Repair of drainage ditches, Warning signs, Hot-spot cover	
TP 7	Riverbank strengthening, Repair of drainage ditches	
TP 8		Relocation to safer site
TP 14	Repair of drainage ditches, Warning signs	Removal of supernatant water pond
TP 16	Repair of drainage ditches, Warning signs	

It must be noted that the categorization of waste objects was an iterative process which took place in a highly dynamic project environment. Apart from technical considerations, the need to start physical, visible activities was a strong driver. On the other hand, due to the pilot nature of this project and the often conflicting national and international approaches and standards, the entire decision process has suffered from delays and setbacks which require considerable flexibility from all parties involved, not least the consultant. In this respect, training, consultation and know-how transfer efforts accompanying the technical project have become ever more urgent, which has finally led the German Ministry of Environment and Nuclear Safety to fund this additional component (see Section 3).

5.2 Simple, rapid and less expensive intervention measures

These measures include

- placement of inert cover material of sufficient thickness on hot-spots of the gamma dose rate,
- repair of drainage ditches and water diversion channels,
- putting up warning signs,
- a public information and awareness campaign.

Cover on radiation hot-spots: The gamma dose rate was measured on tailings ponds by the TACIS project [7] and on waste dumps by this team [14]. A soil cover was placed on waste facilities which are easily accessible to the public (more remote sites received warning signs, see below) and where the gamma dose rate on isolated hot-spots exceeded 1500 nSv/h. The thickness of the cover was calculated based on the experience of the Wismut project and numerical simulations of the attenuation of gamma radiation by natural covers [15]. Erosion protection considerations were also taken into account. The simple cover consists of two layers (from bottom to top):

- 30 cm compacted mixed-grained sandy-silty soil (loam)
- 20 cm compacted loamy gravel mixture, consisting of gravel (80...85%) and loam (15...20%).
- The top layer is covered with mawn grass which improves erosion control and assists quick revegetation.

Drainage and water diversion ditches: It is good engineering practice to divert surface water from tailings and waste dumps [16]. This improves the geotechnical stability of these structures and reduces the contact of undisturbed surface runoff with contaminated material which may lead to increased contaminant release through the water path. Existing channels are cleaned and repaired, in some cases new channels are built. The cross section and slope of the channels corresponds to the hydraulic conditions. Of the various variants compared by the consultant, superficial ditches lined by natural materials such as stones, wood or plants were chosen.

Warning signs: Signs which make the public aware of radiation risks, warn against using material and water are erected, according to international practice [17]. Locations of warning signs are gamma dose rate hot spots (>1500 nSv/h) at remote waste sites where a cover is not justified, and along seepage channels with elevated radionuclide concentrations in the water which should not be used for human consumption, irrigation and cattle watering. Spacing between warning signs is around 150 m. The signs are visible from both sides, the typographical design of the signs is clearly legible also to the visually disadvantaged (large letters, high contrast), and contains the use and access restrictions as well as the contact addresses of the Ministry of Emergencies for further information.

Public information and awareness campaign: Informing the public about the current situation is good practice in the field of radiation protection. Following a recommendation of the ICRP [18], general information on the level of exposure should be made available if the likely effective dose received by members of the public is on the order of, or below, 1 mSv/a (for doses exceeding 1 mSv/a, the ICRP recommends more detailed information on ways to reduce the exposure of the public, but this situation does not occur at Mailuu Suu). One-page information leaflets which are distributed to all households have been developed with the following content:

- Short description of the waste sites and the risks to human health and environment
- Short description of the remediation measures undertaken to mitigate risks at the waste sites
- General restrictions on land-use of the tailings and waste dumps
- Precautions which should be taken seriously
  - no use of seepage or drainage water for drinking and cattle watering
  - no use of waste dump and tailings material for construction
  - no agricultural use of tailings and waste dumps

5.3 Erosion protection

As was discussed above, erosion of mining and milling wastes and their uncontrolled dispersion in the environment is of greatest concern and requires urgent action. Erosion protection measures are carried out either as rapid intervention with a temporary scope (the wastes shall eventually be relocated to a safer disposal site), or as permanent, sustainable solutions. The strongly eroded tailings ponds 2 and 13 in the Aylampa Sai valley fall into the first category, while the waste dumps 1 and 2 (Kulmen Sai valley) and 6 (Kara Agach valley) fall into the second.

The general approach to erosion protection is adapted from the experience of the Austrian consortium member Geoconsult in alpine environments. The technical measures include the use of gabions and Reno mattrasses, energy dissipators and similar structures known from alpine rivers.

At WD 6, it was possible to design the riverbank strengthening measures in a way to avoid any contact of workers with radioactive waste rock, by confining the construction works to a narrow strip on both sides of the riverbed sufficiently far away from the waste rock toe. This approach also helped to simplify and speed up the permitting process.

On the contrary, sustainability of erosion protection measures in the Kulmen Sai valley at WD 1 and 2 required that WD 1 with a volume of about 150,000 m³ is relocated to WD 2 (around 1 km upstream) and the entire waste rock body is reshaped so as to achieve a long-term stable surface contour, before the riverbank can be enforced and stabilized. An additional complication comes from the mudflows which threaten the entire structure and must be kept at bay by a special mudflow diversion dam. The amount of radioactive material to be moved and the risk that material may be spilled into the Kulmen Sai river necessitated the development of detailed Environmental Management, Monitoring, Radiation Protection and Health & Safety Plans.

The design of erosion protection measures for the dam toes at TP 5 and 7 which are both located on the western bank of the Mailuu Suu river depends on the results of an elaborate geotechnical investigation programme of the landslides which may block the Mailuu Suu riverbed. The description of the investigation programme developed by consortium partner Geoconsult and the related modeling approaches is beyond the scope of this paper.

5.4 Relocation of waste facilities including tailings pond no.3

For 7 tailings ponds and waste rock dumps, relocation to a safer disposal site would be the most sustainable solution (see TABLE 1). Within the current project, the decision has been taken to relocate TP 3 (125,000 m³ including part of the abutments and bedrock), the small adjacent TP 18 (3,000 m³) and WD 5 (53,000 m³) from the Kara Agach settlement to a safer site.

A constraint of the selection process was that no virgin land should be used for waste disposal, which left only sufficiently large waste facilities for further consideration. There were a number of options for final disposal sites, which included TP 15, located on the high plains several kilometers east of the Mailuu Suu river and which is the safest option with respect to fluvial erosion.

The preferred final disposal site and the optimal relocation technology are inseparably intertwined, as are the relocation of two waste types (coarse waste rock from WD 5 and fine tailings from TP 3) and the waste encapsulation and cover design. The decision for the preferred option was a complex, iterative process which took the following criteria into consideration:

- Cost
- Long-term stability
- Technical feasibility and technical risks
- Impact on public traffic
- Acceptance by the public and regulators

TP 6, a tailings pond north of the towns of Mailuu Suu and Kara Agach, on the western bank, with a flat plateau of around 6 hectares, was chosen as final disposal site. Being located high enough to be protected from erosion by the Mailuu Suu river, it is easily accessible which leads to a major cost advantage over other options. The drawbacks of TP 6 (need to repair a bridge for haulage, construction of an access road from Kara Agach to TP 6 to haul WD 5 material, landslides affecting the haul road section on the eastern bank of the Mailuu Suu) are manageable.

In the feasibility phase, shear vane investigations were carried out on a grid of roughly 20 x 20 meters mesh size. They provided a precise quantitative picture of the inhomogeneous, partly water saturated tailings [19] which is one of the technological challenges of the project. Alluvial material from the existing cover on TP 3 will be mixed with the wet, soft tailings to provide a material which transportable by trucks.

Of a wide variety of relocation technologies which, among others, also included hydraulic transport, trucks with watertight moulds and tarpaulin covers were selected. Hydraulic transport would have required an additional step of removing the excess water at the disposal site. Concerns about the disruptive effect of massive truck movements on public transport, safety risks associated with the transportation of radioactive material on public roads, stability of the abutments at the present location of TP 3 and water management are addressed in the design.

With its favourable hydraulic and geotechnical properties, the waste rock from WD 5 is suitable as dam material for the final disposal site and is integrated into the cover design. The final cover will consist of a store and release system [20] (thickness of 100 cm on the dam slopes and 150 cm on the plateau, of which the lower 50 cm will be compacted) and a vegetation cover.

6. Results achieved, remaining challenges and conclusions

The overarching objective of the remediation project in Mailuu Suu is to protect the population of the Mailuu Suu area and riparian users downstream including Uzbekistan, from the risks caused by the residues of former uranium mining and milling activities. It can be concluded that the practice and experience developed during other remediation projects on uranium mining and milling sites not least including the Wismut project in Eastern Germany, combined with the erosion protection and landslide management experience from alpine regions, can be applied and site-specifically adapted to the situation in Mailuu Suu, to achieve this objective.

The results achieved so far are:

- The temporary riverbank strengthening measures at TP 2 and 13 and the stabilization of the Kara Agach riverbed at WD 6 have been completed. The quick measures described in Section 5.2 (covering radiation hot spots, water diversion channels, warning signs and information leaflets) are in progress, as are the relocation of WD 1 to WD 2 and the subsequent reshaping and riverbank protection at WD 2.
- The access road from Kara Agach to the new disposal site of TP 6 is under construction. Relocation of WD 5 to TP 6 will begin early in 2008, using this newly built road.
- For relocation of TP 3 and 18 to TP 6, the design and EIA have been submitted to the MoE for review (including the road bridge overhaul).

The scarcity of suitably equipped and qualified contractors for topographical surveys, geotechnical investigations and (radio-) chemical laboratories, the lack of experience among regulators and a slow flow of information between the stakeholders are limiting factors and have clearly been underestimated in the preparation phase and by the authors of this paper.. A sufficient local skill base of field investigation and analytical methods is absolutely required to carry out the current remediation tasks, particularly if environmental projects are to be carried out in the future with national resources.

The need of training, know-how transfer and capacity building activities has become increasingly obvious during the implementation of the technical project. The remediation project at Mailuu Suu is the first of its kind in Kyrgyzstan and is seen as a pilot for other remediation projects in the region. This requires the optimal involvement of regulatory authorities, governmental and local agencies, NGOs, and the local population, in order to create a common understanding of the environmental situation, technical approaches with their benefits and drawbacks, and the institutional capacity requirements including a clear definition of responsibilities and the necessary permits and licenses requested under many, often conflicting, national regulations.

Modern international technical standards and approaches (e.g., related to cover systems on radioactive residues) are different from national standards, which, in turn, often reflect outdated Soviet standards. This may significantly delay permitting procedures and consume valuable resources. Training of decision makers and regulatory authorities can help to create a better informed environment for decisions and permits. For example, monitoring and health/safety requirements issued by the local or even national authorities often differ from what is seen as appropriate based on international best practice, given the moderate level of radioactivity and realistic exposure scenarios. Early transfer of know-how and best practice, well before the physical works commence, is therefore essential to avoid costly interruptions of the works.

Finally, local contract management and construction supervision skills are essential in order to implement remediation measures according to international standards (e.g., the FIDIC standards of construction contract management).

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