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Hydrogeochemical Groundwater Monitoring in Mailuu-Suu, Kyrgyz Republic

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Reduction of hazards posed by Uranium mining tailings
in Mailuu-Suu, Kyrgyz Republic

FINAL REPORT

Federal Institute for Geosciences and Natural Resources

Hannover
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Final report

Reduction of hazards posed by Uranium mining tailings in Mailuu-Suu, Kyrgyz Republic
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Summary

Under soviet governance, intense uranium mining and processing activities have been carried out in Mailuu-Suu valley from 1946 until 1969. The resulting ~3 Million m^3 dump and tailing material has been deposited provisionally in close vicinity of rivers and instable slopes. Due to common landslide events in the tectonically active area, the radioactive mining residues are potentially exposed to erosion and mobilisation processes with the result of a downstream contamination up to the densely populated area of the Fergana valley.

In collaboration with the ongoing 'Disaster Hazard Mitigation Project' of the World Bank, BGR explored the impact of uranium-containing residues on the local water resources and recommended appropriate monitoring and mitigation measures. Until the end of the project period (06/2008), World Banks activities have been accompanied by hydrogeological expertise of BGR.

The following major outcomes in frame of the BGR activities are:

- Radiation exposure caused by radioactive mining residues is confirmed to be a local hazard and a threat for everybody who trespasses the tailing bodies. During last decades, the contamination of water resources with radionuclides and other contaminants has become the major hazard for citizens and livestock in the Mailuu-Suu valley.
- Superficial dumps and tailings impoundments are the most obvious contamination sources, but also other sources contribute to the contamination pattern. Flooded mining structures are considered to enhance contaminants mobilisation within the associated deep aquifer.
- At 50 distinct sampling locations, surface, seepage and ground water has been sampled repeatedly. Except of the northernmost part of Mailuu-Suu, chemical composition of almost all sampled waters suggests influences by uranium mineralisation or the remnants of mining activity. Overall, more than 50% of the investigated water samples exceed international accepted chemical and radiological threshold values.
- Dissolved uranium dominates the contaminants pattern even in groundwater several kilometers downstream of potential pollution sources. Own geochemical and radiochemical studies indicate uranyl-carbonate complexes as the prevalent species of dissolved uranium. These stable and neutral to negative charged complexes lead to extensive migration of dissolved uranium even under slightly reducing conditions.
- Only "process" water delivered by the central water supply is recommended for consumption without restrictions. Other sources need to be checked prior using for drinking water purposes. Currently, no analytical laboratory in Kyrgyzstan is able to determine uranium with sufficient accuracy. Appropriate analytical equipment and training of laboratory staff is needed for future monitoring and mitigation activities.
- The contamination situation in Mailuu-Suu will fluctuate with time due to ongoing mobilization and migration processes. Therefore, continuous monitoring of the local

water resources, including surface water, shallow and deep groundwater, is crucial for a future safe drinking water supply.

- Field equipment was delivered to the Kyrgyz Ministry of Emergency Situations (MoE) in order to supply the Sanitary-Epidemic Station (CEC) in Mailuu-Suu which is the responsible institution for local water quality issues. In collaboration with CEC in Mailuu-Suu, a local monitoring group was established and has been trained to continue water monitoring activities beyond the BGR project duration.
- 11 groundwater monitoring wells have been installed to supplement existing sampling sites in frame of a monitoring network in the Mailuu-Suu valley. Additional monitoring wells are recommended to enhance identification of contamination sources and characterisation of deep aquifers.
- An empiric decision support approach has been suggested to CEC in order to suspect possible water contaminations based on simple in-situ parameters. Please note, that this method does not substitute professional laboratory water analysis.
- A public information event was presented in Mailuu-Suu to inform about the local contamination risk and practical mitigation measures. An accompanying brochure was handed out to citizens and authorities. Furthermore, a press conference was held to transfer the major outcomes of the project nationwide.
- Regarding strategies for risk mitigation of the Mailuu-Suu citizens, continuous monitoring of contamination sources and available water resources as well as restoration and extension of the existing central water supply network is recommended. Small scale treatment measures of contaminated water sources are considered to result in local benefit only.

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Abbreviations

AMSL	Above Mean Sea Level
BGR	Federal Institute for Geosciences and Natural Resources
BMZ	Federal Ministry for Economic Cooperation and Development
CEC	Sanitary-Epidemic Station
CSRL	Central Scientific Research Laboratory, Kara Balta
DHMP	Disaster Hazard Mitigation Project of the World Bank
i	Hydraulic gradient
ICP-MS	Analytic instrument for determination of trace metals in water
K_f	Permeability [m/s]
m/d	Flow rate unit of groundwater
µg/L	Concentration unit, e.g., of a contaminant in water
mSv/a	Unit of the radiation dose the human body receives in a year
MoE	Ministry of Emergencies of the Kyrgyz Republic
n_{eff}	Effective porosity
PIU	Project Implementation Unit of the DHMP at the MoE
V_A	Distance velocity of groundwater [m/s]
WHO	World Health Organization
ZSR	Centre for Radiation Protection and Radioecology, University of Hannover
PRB	Permeable reactive barrier (treatment technique for contaminated water)

1. Introduction

As a result of bilateral negotiations between Germany and the Kyrgyz government, the German Federal Ministry for Economic Cooperation and Development (BMZ) commissioned the Federal Institute for Geosciences and Natural Resources (BGR) in order to monitor the quality of water resources in Mailuu-Suu as an accompanying activity to the World Bank's ongoing "Disaster Hazard Mitigation Project". The BGR project "Reduction of hazards posed by Uranium mining tailings in Mailuu-Suu, Kyrgyz Republic" has begun in January 2006 with an initial duration of 18 months. An extension until June 2008 ensured the reinforcement of the project goals.

Overall goal was the development of a concept for a long-term groundwater-monitoring in Mailuu-Suu enabling the responsible authorities of Kyrgyzstan to observe the drinking water in Mailuu-Suu in terms of chemical and radiological contamination[1]. Therefore, BGR sampled and investigated seepage, surface water and groundwater at 50 locations within Mailuu-Suu valley in varying seasons to achieve a substantial data basis which allows an assessment of the contamination degree of local water resources.

With the Centre for Radiation Protection and Radioecology (ZSR, Leibniz-University of Hannover), BGR assigned internationally approved expertise in order to characterize relevant radionuclides in the sampled water resources and to assess the radiologic risk potential originating from contaminated drinking water wells.

Recommendations by BGR aim to protect the inhabitants of Mailuu-Suu from further uptake of uranium and other contaminants via the drinking water path. Though the focus of the project was on the hydrochemical quality of the groundwater resources in Mailuu-Suu, also the surface water (e.g., creeks, rivers) need to be examined, because the water bodies potentially communicate with each other and contaminants may migrate between them.

In frame of the project, the cooperation partner MoE and the World Bank asked BGR to extend its activities on observing the surface water quality in Mailuu-Suu to cover further components of the World Bank Disaster Hazard Mitigation project. Generally, BGR expressed its willingness to support the Kyrgyz efforts for Mailuu-Suu in frame of a future World Bank project.

This report represents the final findings during the project period. Herewith, the geological and hydrogeological frame is summarized, as far as known by own field observations and the limited information sources. A characterization of the contamination pattern is followed by the presentation of already conducted as well as still recommended mitigation measures in order to enable the decision holders to handle the situation appropriately. The present report is based on a manuscript by Dr. H. Jung, subsequently revised and supplemented by Dr. F. Wagner.

[1] In this report "contamination" is defined as an anthropogenic modification of the geogene water composition. Therefore, "contamination" does not necessarily express that specific threshold values fail.

2. Characterization of water resources in Mailuu-Suu

The extensive mining and processing activities in Mailuu-Suu from 1946 until 1969 represent a major interference into the hydrogeological and geochemical environment in both the subterraneous ore-bearing host rock due to mining excavations as well as the tailing and dump material with radiologic inventory. A consequence of the new geochemical environment may be the mobilization of potentially toxic elements such as uranium and the transfer among different compartments (e.g., hydrosphere → soil → biosphere) mainly using the water path. In case of consume of contaminated water and food may have a hazardous impact on the health of citizen and livestock in Mailuu-Suu.

Therefore, a clear understanding of the (hydro)geological setting of the local water bodies and their hydraulic connection is crucial for the assessment of the pollutants pathways and the degree of contamination. Therefore, the following sub-chapters are dedicated to the geological and hydrogeological frame of the Mailuu-Suu valley.

2.1 Geological setting

The consolidated and unconsolidated rocks occurring in Mailuu-Suu valley comprise sedimentary rocks of mesozoic and neozoic age. The mountainous area north of the valley consists mainly of sedimentary strata of jurassic age. The age of the rocks is decreasing southward and therefore, sedimentary rocks of cretaceous and tertiary age cropping out. Locally quaternary unconsolidated sediments of generally alluvial origin have been deposited in the river valleys. The detailed map of the Mailuu-Suu valley attached as Appendix visualizes geological as well as structural elements.

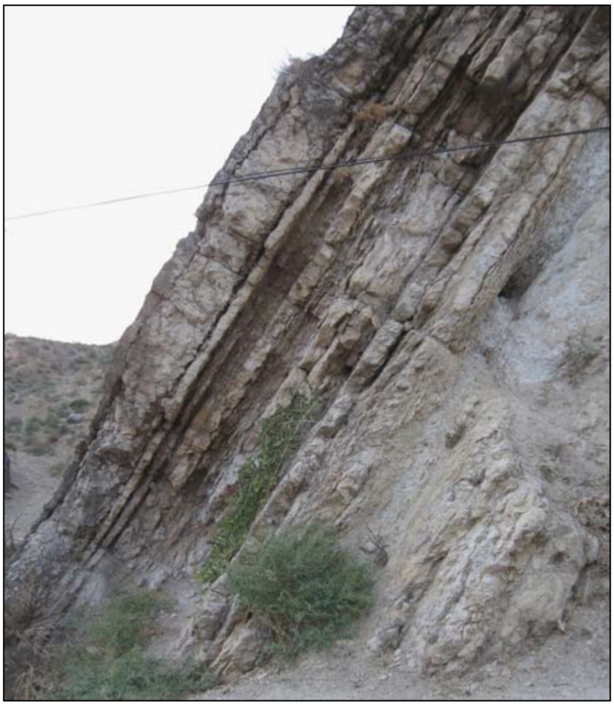

Figure 1: Limestone sequence of upper cretaceous age, typical host rock for uranium ores deposits in Mailuu-Suu.

The jurassic and cretaceous rocks consist mainly of fine grained limestone sequences with intercalated marl layers (Fig. 1). Rivers may face water losses due to karst formation. Whereas clayey horizons are less developed in cretaceous strata, they become more predominant in the sediments of tertiary age. In the city area of Mailuu-Suu, tertiary strata have a dominant sandy component, while further northwards in the area of the village Kara-Agach they mainly consist of red clays. Especially in these clayey strata landslides are very common, which are initiated by earthquakes and heavy rainfalls.

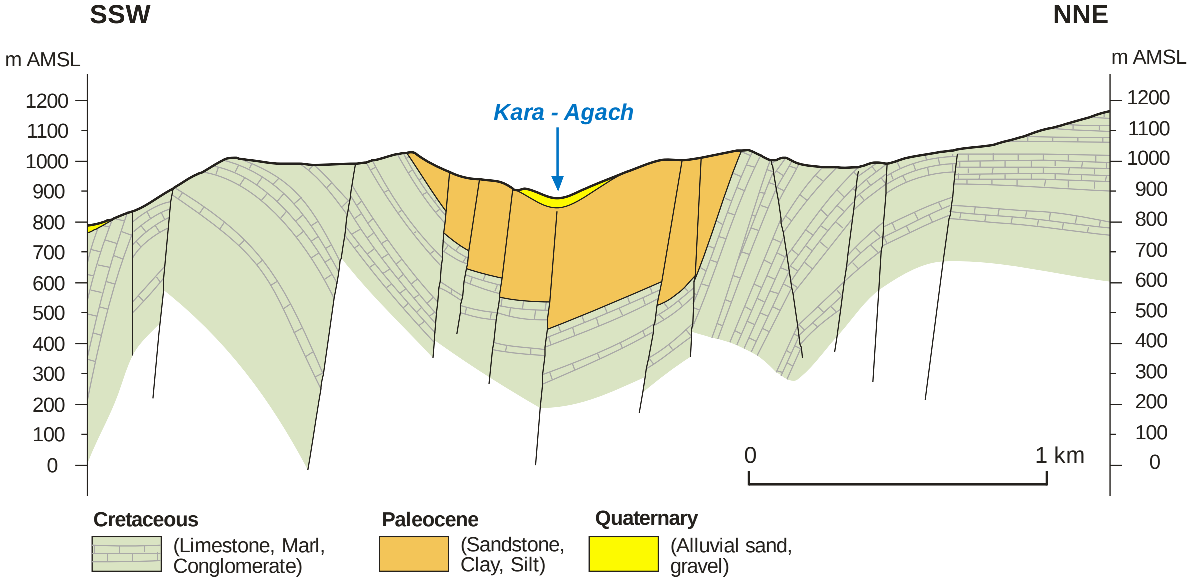

Figure 2: Section A through cretaceous and old-tertiary strata north of Mailuu-Suu (location see fig. 14) showing the folded structure of the underground in the area of the central syncline (height 2x exaggerated).

In morphologic depressions like river valleys of the Mailuu-Say and Kara-Agach young sediments of quaternary age can be found. With a maximum thickness of up to 30 m, they consist mainly of gravels and sand and are less compacted.

From the structural-tectonic point of view, the area was subject to a northward directed pressure towards the high mountainous area of central Kyrgyzstan (THOSTE, 1996). As a consequence folds have developed with WSW dipping fold axes. The north of the Mailuu-Suu valley including the central area of former mining activities is dominated by two main structural elements: (1) a central anticline, in which mainly strata of cretaceous age are cropping out, followed northward by (2) a central syncline (see Fig. 2), where clayey tertiary strata are exposed at the surface and are forming a morphologic depression.

The directions of faults are various (MoE, 2006), but at least north of the city the predominating main direction is WNW – ESE. Nonetheless, attention should be paid to the regional structural element of the southward Fergana-valley, which caused by its ongoing subsidence movement the SSW – NNE directed major fault. The trend of this fault is impressively underlined by

Figure 3: Crude Oil from cretaceous strata is leaking into the river Mailuu-Say.

the stream course of the river Mailuu-Say.

In the Mailuu-Suu valley, the mineralisation of uranium ores has developed mainly within the limy strata of the upper cretaceous and - to a lesser extend - in strata of the lower tertiary age (see following chapter). Furthermore, crude oil deposits are occurring in cretaceous rocks. As a consequence, reducing geochemical environment develop in the oil-bearing rocks, so that the stability of the uranium mineral *Pitchblende* is enhanced. The crude oil is still extracted in the valley of Mailuu-Suu, even an extension of the production volume is currently planned and drilling activities are rising. At view locations, crude oil is simply leaking into the Mailuu-Say River (Fig. 3), a natural phenomenon from which the valley as well as the city “Mailuu-Suu” derived its name: “Black Water”.

2.2 Mining and processing of uranium ore

During the period 1946 and 1968 mining and processing of uranium ore minerals (Fig. 4) was carried out in Mailuu-Suu. In upper cretaceous sedimentary limestones towards lower tertiary (paleogene) strata three uranium containing horizons (L_1, L_2, M) have developed. They were mined in three mining claims comprising six underground mines covering a total area of 36 km^2. The mining activities were focusing on the central anticline and the area north of the river Kulmin-Say, the central syncline and the Kara-Agach area (compare to Appendix), even in the north of the city area of Mailuu-Suu, mining activities have been carried out (THOSTE, unpublished data).

The uranium deposits, primarily consisting of the uranium mineral *Pitchblende* („nasturan“; UO_2), are widely altered to *Carnotite* ($K_2(UO_2)_2V_2O_8 \cdot 3H_2O$) and *Tyuyamunnite* ($Ca(UO_2)_2V_2O_8 \cdot 5\text{-}8H_2O$). Since these vanadates are already oxidized and therefore contain the sexavalent uranium species (U^{6+}), they are supposed to be more resistant against superficial weathering processes under oxidizing environments. Contrarily, *Pitchblende* contains the reduced uranium species U^{4+} and is less resistant against weathering processes or oxygen containing fluids. Nevertheless, the high alkalinity of fluids in carbonatic host rocks may improve the mobility of the U^{6+} species due to the formation of mobile uranium-carbonyl complexes. In the mined ore also other uranium minerals such as *Orthobrannerite* ($U^{4+}U^{6+}Ti_4O_{12}(OH)_2$) and *Uranotallite* $Ca_2(UO_2)(CO_3)_3 \cdot 11H_2O$ have been found, even when they are less significant.

Figure 4. Uranium ore as collected on a waste rock dump. The original uranium mineral *Pitchblende* is oxidized to *Carnotite* and *Tyuyamunnite*.

Since original mining documentation are supposed to be

Figure 5. Tailings impoundment no. 3 with a newly constructed groundwater-monitoring-well in the front.

stored in Russia[2], only limited information about the constructed mine drifts, facilities and infrastructure is available. Generally, uranium ore has been mined up to a depth of 500 m below surface (OTTONELLO, 2003). The condition of the mining excavations are moderate and most probably they are flooded below the groundwater table. Furthermore, open pit mining has been reported, but no remains of these activities have been found so far.

The uranium-bearing rocks with an uranium content of max. >0.5 % but down to 0.03 %, the ore was still considered to be valuable for mining. Totally, roughly 10,000 tons of uranium was produced from mining activities in Mailuu-Suu.

Reports state that two different processing techniques were applied after grinding the ore. An older processing plant ("ISOLIT") used an acidic technique to extract the uranium from the ore by applying H_2SO_4, followed by subsequent neutralisation with limestone. Huge amounts of gypsum were generated during the neutralisation process, which were deposited in the tailings impoundments together residual host rock material (SCHMIDT, 1997). Another processing plant ("No. 7; SERBIA") applied a basic extraction technique (Na_2CO_3, H_2CO_3). Both processing techniques used $KMnO_4$ for precipitation of the dissolved uranium as the so-called 'Yellow Cake' U_3O_8 (ASSMANN & THOSTE, 2004) explaining the high manganese content of the tailing material. SCHMIDT (1997) as well as local information reported that the ISOLIT plant processed not only local uranium ores, but also ore material from other mining districts, such as from Kasachstan or even from the east-german ore mountains where transported to Mailuu-Suu . Nevertheless, THOSTE (pers. comm.) was the person in charge to examine this issue, but was not able to find any direct evidence.

Until 1960 only 40% up to 75% of total uranium content could be extracted from the mined ores. Therefore, the fine-grained (0.05 - 0.1 mm) and still slurry processing residues contain elevated concentrations of radionuclides and other heavy metals. The daughter product of the ^{238}Uranium decay ^{226}Radium was not caught by the processing

[2] Documents about the mining activities are said to be stored in Minatom/Moscow. The Central Scientific Research Laboratory in Kara Balta/Kyrgyzstan has no further data.

techniques applied, thus is supposed to be enriched in the tailings material. Preceding radiologic studies indicated that no isotopic fractionation took place while processing the uranium ore (BUNNENBERG, ZSR, pers. comm.).

The tailings impoundments were provisionally deposited within 23 morphologic depressions (e.g., Fig. 5; compare map Fig. 6) and mining waste rocks were deposited in 13 waste rock dumps close vicinity to their origin. The tailings impoundments as well as the dumps have no base sealing (UN, 2001). In most cases, a gravel front with drainage tubes was installed at the foot of the tailings impoundments to control the seepage water outflow. Recently, the drainage system was found out of function due to clogging (UN, 2001). Nevertheless, some concrete discharge channels allow sampling of the collected seepage water (e.g., Tailing No. 5-7). Some bigger tailings impoundments were covered with a layer of 0.4 m gravel and 0.6 m clay on the top. The dams of tailings

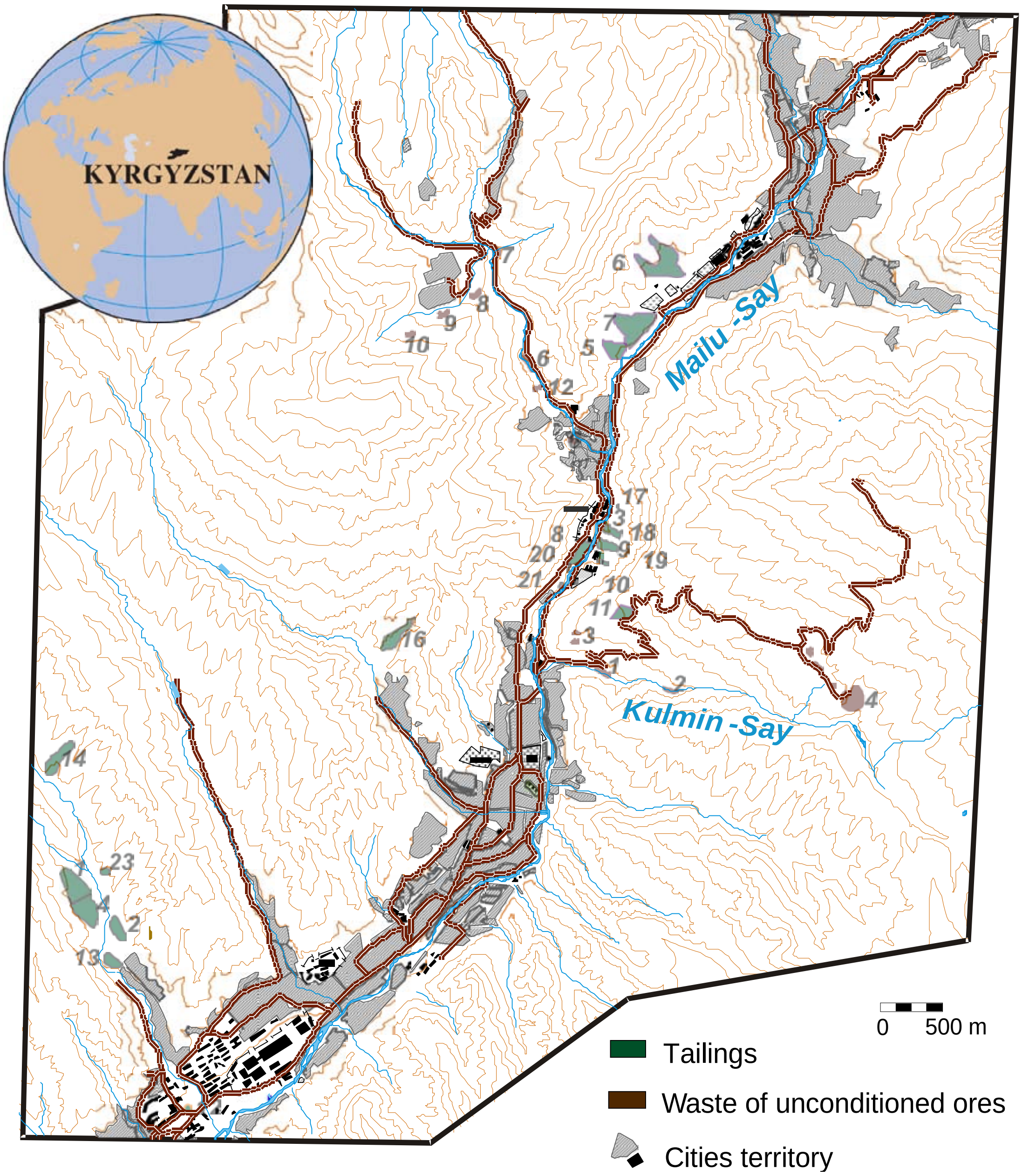

Figure 6. Topography and locations of potential contamination sources (tailings, dumps) in the northern valley of Mailuu-Suu (modified after Wagner et al., 2007).

impoundments no. 7 and 8 have been eroded by the river Mailuu-Say (KUPCHENKO, 2003) as well as dump No. 1 and 2 by Kulmin-Say River (see Fig. 6). Selected damaged facilities are currently under maintenance by the DHMP.

The tailings are object to leaching processes due to water-rock-interaction, which let contaminants migrate into the environment. Besides the tailings impoundments and waste rock dumps, possible sources of contamination represent also subsurface mining structures. It has been reported that huge amounts of tailing material has been re-deposited in flooded mining excavations (ASSMANN & THOSTE, 2004).

2.3 Hydrogeological setting

OSTROBORODOV et al. (2003) provides a composition of available information about the hydrogeological situation in Mailuu-Suu valley. In the following a summary is given with respect to an applied point of view.

Hydrogeology of Mailuu-Suu is dominated by two general conditions: a young shallow aquifer is established in unconsolidated quaternary alluvial sediments. Therein, groundwater is migrating through the pores of un- or slightly compacted sands, clays and gravels. For the shallow aquifer permeabilities within the range of 10^{-4} up to 10^{-2} m/s may be estimated (PRINZ 1991). This is leading to the assumption that groundwater is flowing through the quaternary strata with a relatively high velocity. Quaternary strata are mainly present along the centre of the river valleys and in the city area. The groundwater flow direction follows generally the south-western dipping of the valley.

By contrast the solid and fractured rocks of tertiary and cretaceous age have usually permeabilities within the range of 10^{-6} up to 10^{-4} m/s. With decreasing lithologic pressure towards the surface the permeability may increase as well as karst formation in limestone rocks may locally enhance permeability. Nevertheless, groundwater in fractured rocks generally flows comparatively slowly with increasing depth. OSTROBORODOV et al. (2003) observed a time lag between precipitation and increased discharge of springs of about 1-2 months in the tertiary aquifer. Maximum discharges were registered in June and minimum discharges in November.

Surface water and groundwater are supposed to communicate with each other, supporting the exchange of solutes, including toxic constituents. During the season with snow melt and high precipitation, high groundwater table leads to exfiltration into the receiving river. On the other hand dry and hot summer leads to low discharge and precipitation and, therefore, river water may infiltrate into shallow aquifer (compare Fig. 7).

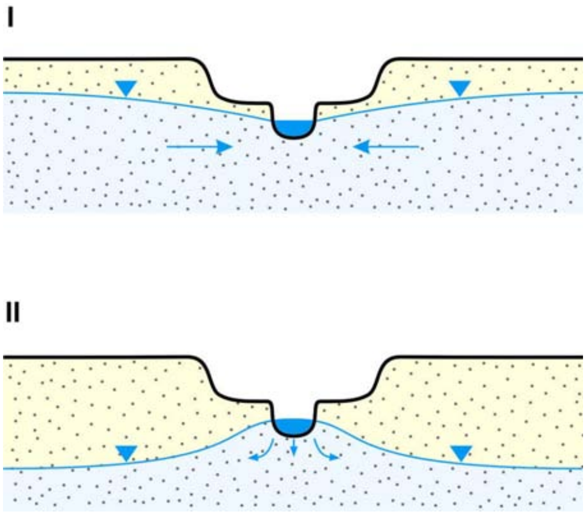

Figure 7: Due to seasonal variation of the groundwater level, groundwater may infiltrate into a river (I: spring), or river water infiltrates into shallow aquifer (II: late summer and autumn).

Especially cretaceous strata may reveal due to their high carbonate content also karst formation. By dissolution of limestone even sinkholes for river water can appear. In the valley north of the city area several locations are known by local people, where the river Mailuu-Say looses water due to karst formation. Also its tributary Kara-Agach flows through cretaceous strata facing sinkholes as a result of karst formation.

Another artificial impact on the hydrogeological situation in Mailuu-Suu is caused by the mining facilities and excavations in the subsurface. These structures open pathways in originally low permeable hard rocks, so that groundwater can easily migrate between several elevation levels. This is accompanied by a at least local change of the redox-environment by transporting oxygen saturated water into an originally anoxic environment. Presumably, flooded mining structures are feeding one spring observed at the basis of the mined mountain side (Fig. 8). Nevertheless, the impact of flooded mining excavations on the quality of deep as well as shallow groundwater should not be underestimated.

Contaminated groundwater is not only observed in the north of the city, where mining activities were carried out, but spreads also southward and south-eastward together with the general groundwater flow direction. Consequently, even in the quaternary aquifer in Kok-Tash, about 10 km south of the mining activities, a significant contamination by uranium can be observed (e.g., sample station 10: 7 µg/L).

The relationship v_A [m/d] = k_f * i * 86400 s / n_{eff} allows calculation of the distance velocity v_A of groundwater in the shallow aquifer, presuming appropriate permeabilities (k_f) and effective porosities (n_{eff}). A height difference of 150 m between the area of mine workings and the distance to the village Kok-Tash (10 km) is leading to a hydraulic gradient i of 0.015). The resulting groundwater velocities vary between 0.1 and 1.3 m/d (Table 1), by all means values which are considered to be close to reality.

Figure 8: Underground mining excavations, indicated by two adits south of ISOLIT-plant (left), affect a H_2S-degassing spring located directly downwards at the river Mailuu-Say by uranium-containing groundwater (right, station 7). Note also the crude oil leakage beneath the spring.

Table 1: Calculated groundwater velocities (v_A, *italic*) presuming different permeabilities (k_f) and effective porosities (n_{eff}) of the quaternary aquifer.

	$K_f = 1 * 10^{-5}$ m/s	$K_f = 5 * 10^{-4}$ m/s	$K_f = 1 * 10^{-4}$ m/s
$n_{eff} = 0.1$	*0.13 m/d*	*0.65 m/d*	*1.30 m/d*
$n_{eff} = 0.15$	*0.09 m/d*	*0.43 m/d*	*0.90 m/d*

A conceptual hydrogeological model for the mining area in the north and the city area of Mailuu-Suu is providing a synthesis of the observations in field (Fig. 9). The groundwater flow direction in the fractured underground of tertiary and cretaceous age may locally vary due to a complicated fracture scheme, but as a resulting direction groundwater flows will be directed towards the fold axes dip (e.g., NWW in the mining area). The conceptual hydrogeological model indicates contamination of the quaternary strata within the city of Mailuu-Suu, because they receive influx of uranium containing groundwater, where cretaceous strata are exposed and in contact to quaternary strata. The proportion of this pathway to the total contamination of quaternary aquifer, such as contributed by direct input from dumps and tailings is still not known.

Presumably, mobilization and transport of uranium and other contaminants to the superficial compartments were initiated since mining started und will persist until suitable remediation measures by the World Bank project are completed. In case of a successful prevention of further mobilisation of pollutants should different effects to the environment:

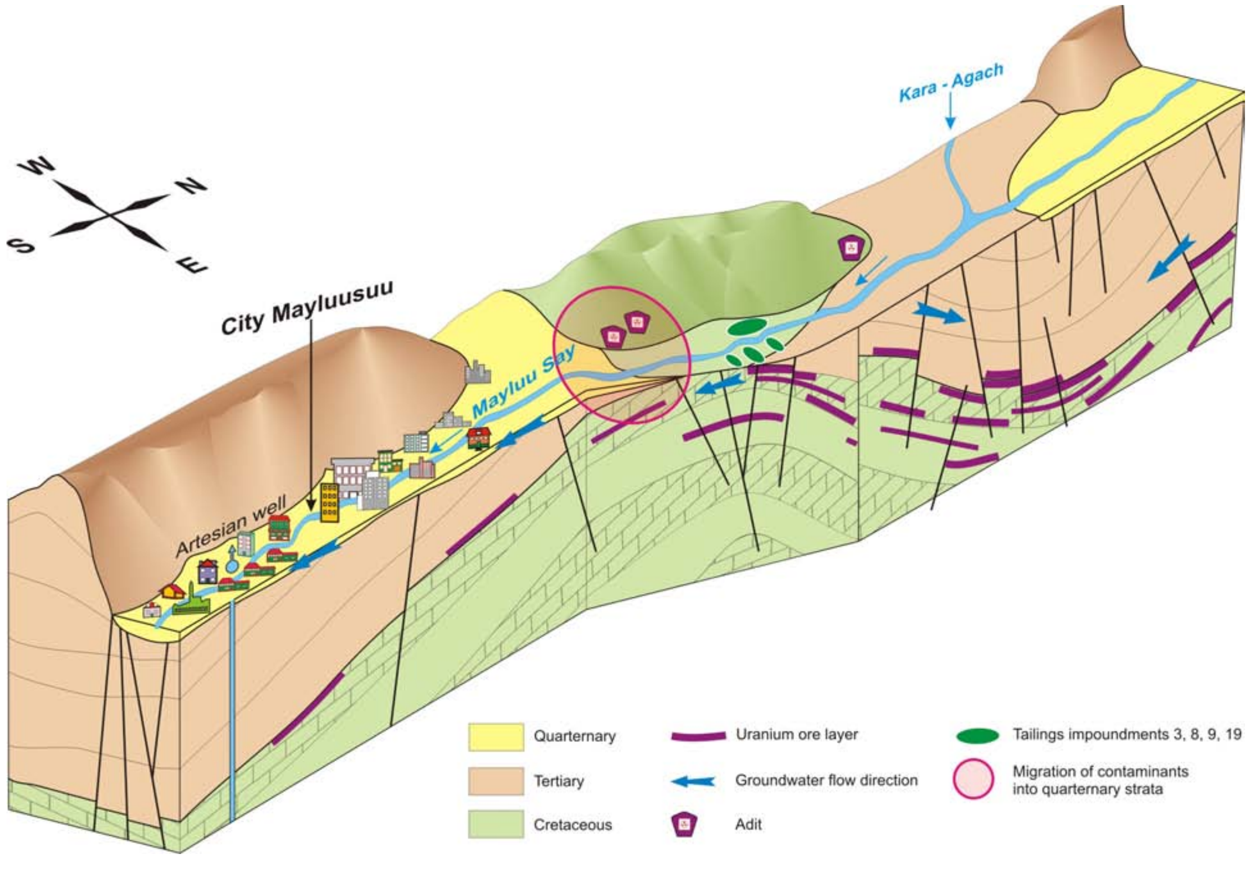

Figure 9: Section B (location see Fig. 10) illustrating groundwater flow and possible contamination paths. Cretaceous strata are cropping out north of the city Mailuu-Suu. Therefore, contaminants mobilized from ore layers and flooded mining excavations within cretaceous strata are able to migrate directly into the quaternary aquifer (red circle).

the contamination degree of lotic (=running surface) water will rapidly decrease, while decontamination of affected aquifers as well as contaminated soil and sediments may need many years due to sorption and retention processes.

2.3.1 Hydrochemical characterization of local water bodies

Several artesian wells (stations 3, 17, 25, 29) in Mailuu-Suu are tapping deep aquifers under high hydraulic pressure. Possibly, the clayey tertiary strata locally act as a low permeable "sealing" layer and possibly prevent groundwater recharge from surrounding mountains to migrate into younger aquifers. Some outcrops of cretaceous rocks as discussed above are exceptions, where several springs certify the local discharge of cretaceous aquifer into river and shallow groundwater.

According to OSTROBORODOV et al. (2003) deep aquifers are developed in tertiary and cretaceous rocks, which cannot be associated to the local artesian wells because of lacking well drilling data. Only based on hydrochemical data, three genetic groups can be distinguished (Fig. 10). Therefore, artesian groundwater tapped north of Mailuu-Suu (including village Sarabiya) is dominated by calcium, magnesium and bicarbonate, whereas the artesian groundwater from wells located in the central part of Mailuu-Suu is characterized by its high sodium and sulphate content. A special standing of the latter deep groundwater type is underlined by its low $\delta^{18}O$ and $\delta^{2}H$ fractions (Fig. 11, blue triangle), indicating a catchment area which differs in space and time in comparison to

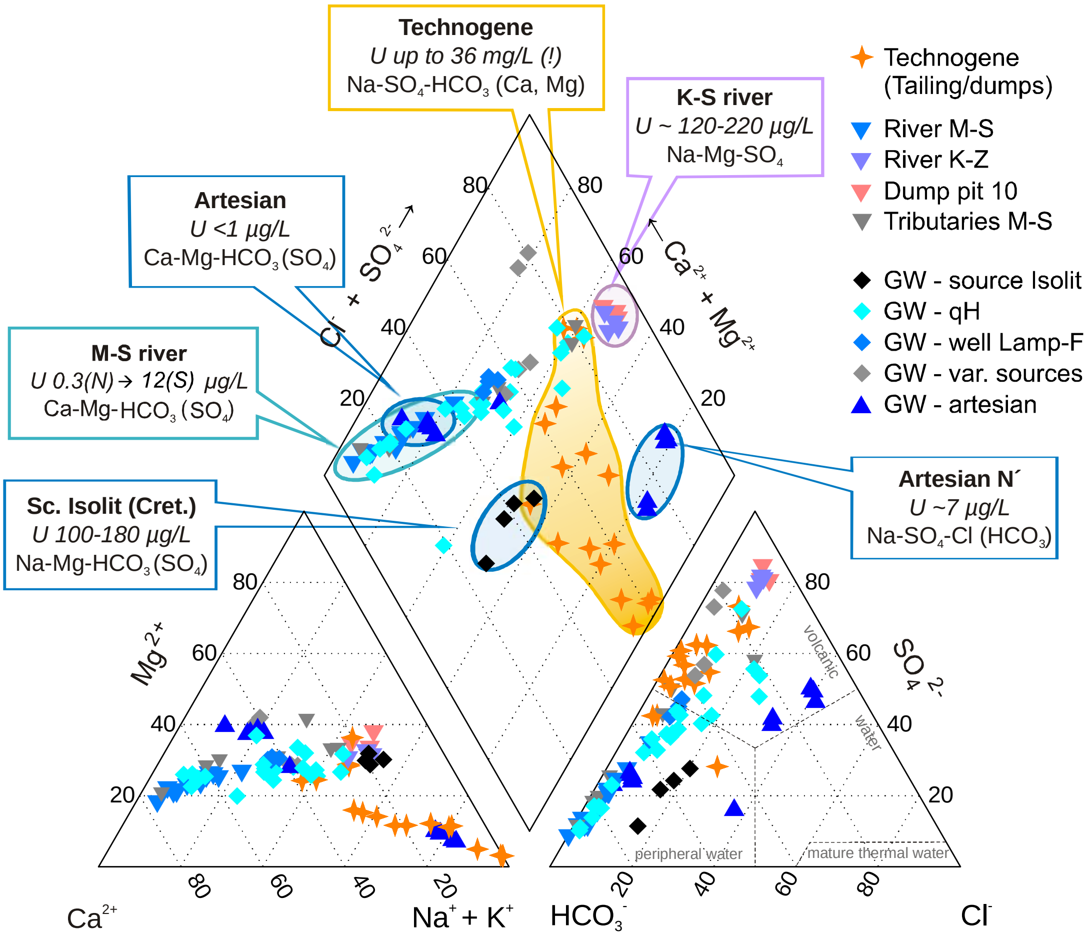

Figure 10. Major anion and cation composition of sampled water visualized in a piper-diagram provides a clustering of water samples with similar genetic history (Wagner et al., 2007).

other local deep and shallow groundwater types. A third type of deep groundwater represent some springs (e.g., source ISOLIT, station 7), which are obviously pouring out of cretaceous rocks and are associated with the occurrence of crude oil (Na-Mg-$HCO_3(SO_4)$ water type). Beside their major and isotopic composition, these deep groundwater types differ also in their trace constituents including contaminants load, which is discussed in the following chapter.

Samples from Mailuu-Say River have a typical meteoric signal with its low solutes and a composition of Ca-Mg-HCO_3-type. On the other hand, the Kulmin-Say river water has a Na-Mg-SO_4 dominated composition, clearly demonstrating a strong impact of other sources than precipitation only. Please note, that other tributaries as well as Mailuu-Say samples from the south in Figure 10 are located on a mixing line marked by the northernmost Mailuu-Say water on one end and the (contaminated) Kulmin-Say on the other. This clearly demonstrates the strong and southward increasing impact of contaminated tributaries to the water quality of the Mailuu-Say River, resulting in an increasing sulphate and sodium fraction to the originally Ca-Mg-HCO_3 water type.

The sampled wells tapping the quaternary ("shallow") aquifer providing water bearing a remarkable resemblance to the Mailuu-Say water with respect to their major composition (Ca-Mg-HCO_3). Further southward, also the shallow aquifer receives inputs of sodium and potassium dominated fluids, so that the associated water composition is arranged on the same mixing line than discussed above ("GW-qH" in Figure 10). This dependency indicates a hydraulic interconnection between the shallow aquifer and the Mailuu-Say river, combined with an exchange of solutes (see also Fig. 7). The shallow aquifer seems to be subject to locally varying influxes of deep groundwater with different composition (see above) and locally contaminated seepage water and tributaries of MailuuSay, additionally to a continuous exchange with Mailuu-Say River water.

Beside the natural water sources the water samples of "technogene" origin mark another group, strongly influenced by tailings, dumps and other contamination sources (Fig. 10). The water composition predominated by sodium, sulphate and bicarbonate may be explained by the specific nature of the tailing material comprising primary sulphides and carbonates as well as high fraction of gypsum precipitated during the leaching of limestone with sulphuric acid. Especially the seepage waters percolating through tailing bodies may show extra-

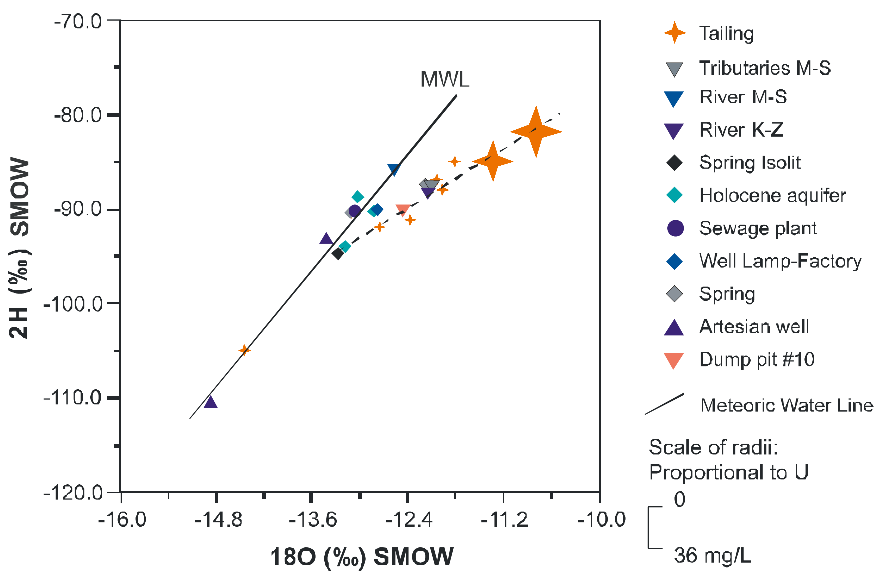

Figure 11: Plot of the fraction of the stable water isotopes δ^2H and δ^{18}O in selected water samples. Lowest values mark artesian water from Sarabiya (station 17). From the local meteoric water line (MWL) diverging dashed line marks a prevalent evaporative effect in selected "technogene" waters.

ordinary high content in dissolved solids (station 14: TDS_{calc} up to 10000 mg/L!), comprising also a high load of various contaminants. One reason is the fine-grained tailing material providing a large reactive surface area as well as a high residence time for seepage waters. Another reason is implied by the stable hydrogen and oxygen isotope ratios of selected water samples (Fig. 11). While the majority of natural waters plot along the local meteoric water line, technogene waters mostly are characterized by an increased $\delta^{18}O$. This indicates to the role of evaporation effects, leading to an accumulation of heavy oxygen isotopes as well as the non-evaporating solutes ($r_{(\delta18O-TDScalc)}$ = 0.62). Therefore, evaporation may explain the extremely high content of dissolved solids of some seepage waters, including contaminants.

2.4 Contamination of water resources

Uranium is the most important contaminant in the valley of Mailuu-Suu, but locally also other inorganic chemicals giving rise for health concern. Even when contamination sources and transport path is still not clear in detail, the relevance of flooded mining excavations should not be underestimated in comparison to the contaminant load contributed by superficial mining residues like dumps or tailings. Please note, that preceding water quality studies are explicitly not considered here due to quality assurance reasons.

The analyses of the water samples revealed that almost all water resources are at least locally affected by increased uranium contents. Figure 12 provides an overview about the samples failing the international WHO guideline for drinking water with respect to selected contaminants. Uranium is by far the most problematic parameter with more than 50% of the sampled water failing the recommended threshold value of 15 µg U/L. Also other solutes are locally failing their threshold values and therefore lead to adverse health effects in case of consumption. Further details about all the analysis data are given in ANNEX 2.

The contaminants load of a water body varies seasonally mainly depending on precipitation and inflow of other sources such as seepage water, groundwater or tributaries. The variability can be roughly estimated to be 0 - 30%. While being low in the case of deep groundwater (as shown by artesian wells), the variability is rising towards the surface with maximum deviation from preceding measurements in surface waters (rivers, seepage water). Subsequently, the different water types are discussed with respect to their dissolved uranium content (compare Figures 10 & 13):

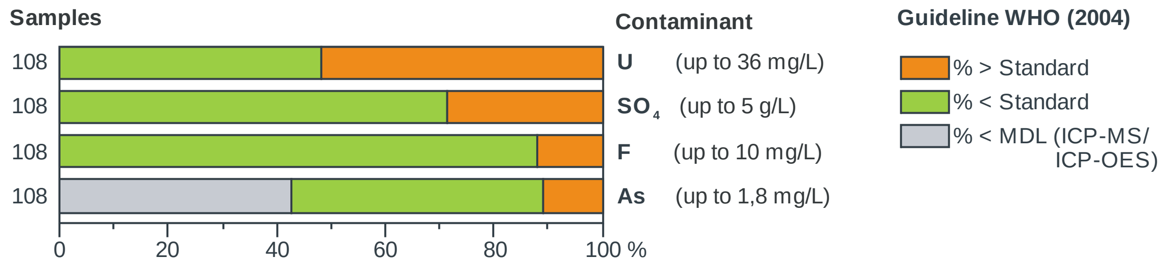

Figure 12: Fraction of taken water samples (total n = 108) failing the WHO DW-guideline ("standards") for selected contaminants (U: 15 µg/L, SO_4: 500 mg/L, F: 1.5 mg/L, As: 10 µg/L). MDL represents the method detection limit (U, As: ICP-MS, SO_4, F: ICP-OES). Modified after Wagner et. al. 2007.

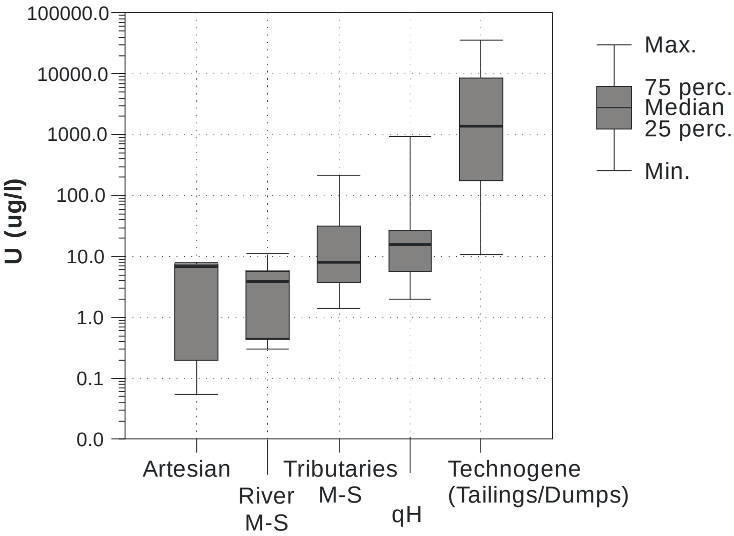

Figure 13: Box & Whisker plot showing distribution of uranium in five sample groups: “artesian” wells, “Mailuu-Say river”, its “tributaries” incl. Kulmin-Say, quaternary aquifer (“qH”) and “technogene” affected water e.g., seepage water from dumps and tailings.

- Seepage water percolating through tailing bodies: due to its radioactive inventory, the associated seepage water show extremely high uranium contents up to 36 mg/L. Probably, the fine grain size of the tailing material (and thus their high specific surface area) combined with high residence lead to the high solutes concentrations in the fluids (up to 12000 µS/cm).
- Surface water (rivers, creeks): the main river Mailuu-Say obviously receives influx from groundwater, seepage water and tributary surface water, which are partially affected by significant contamination (e.g., Kulmin-Say 170-220 µg/L U). Though its contaminant load during its north to south directed course is increasing. Nevertheless, the river water of the Mailuu-Say remains below the WHO guideline for drinking water quality (11 µg/L in the area of Kok-Tash) up to now.
- “Shallow” groundwater of quaternary alluvial sediments (sand, gravel) in river valleys: the groundwater of these strata is contaminated with uranium in the city area of Mailuu-Suu (up to 30 µg/L) yet above the WHO guideline value. Even the area of Kok-Tash south of Mailuu-Suu is already significantly affected.
- “Deep” groundwater of tertiary, cretaceous and (possibly) jurassic aquifers: the groundwater has high uranium contents (up to 140 µg/L), demonstrating the uranium ore minerals distributed in the associated aquifer host rock. Whether flooded mining excavations have increased the dissolved uranium content cannot be proven with the available data. Furthermore, two other deep groundwater sources have been identified: The artesian wells in the very northern area (Sarabiya) are an exception, because the associated deep aquifer is not affected by high or even moderate uranium content. Another group of artesian wells provide deep groundwater with ~ 7 µg/L uranium. Unfortunately, the depths of deep wells are not documented.

2.4.1 Radiological assessment of the water samples

In frame of this project, the Center for Radiation Protection and Radioecology (ZSR, Leibniz-University Hannover) has received 33 water samples from the investigated region of Mailuu-Suu in order to assess the toxicity of water samples from a radiologic point of view using radioanalytic methods. Due to partially very low concentrations of relevant radiologic isotopes, a modified approach have been applied combining sensitive radioanalytic methods with equilibrium calculations from known contents of the parent radioisotopes. The radiologic risk emanating from the observed water samples is briefly discussed subsequently. A characterisation of dominating speciation of dissolved uranium is summarized in p. 30. Further details about the radiologic assessment by ZSR are documented in ZSR (2007, 2008) and in Annex 7 and 8, respectively.

The radiological assessment of the water path has been carried out based on an estimation of the effective annual doses to human resulting from water consumption from specific water sources. Dose contributions resulting from the use of waters for feeding animals and for watering purposes could not be taken into account due to the lack of relevant data. The radiation exposure by drinking contaminated water was evaluated assuming an average volume of 750L (630L) drinking water consumed by adults (children) in Mailuu-Suu every year, according to TACIS (2003).

Similarly to results of the anorganic-chemical analysis discussed before, about 50% of the water samples are not eligible for drinking water purposes from a radiological point of view; they exceed the limit value of 0.1 mSv/a according to EU drinking water guideline (EU 1998). Additionally, few other water sample stations (e.g., 10, 19) fail the radiation limit value. Even when this effect may be partly founded in overestimations due to a conservative approach (compare Annex 7), children should not be fed with water in case of any doubt of its quality (ZSR 2007, 2008).

2.5 Description of selected sampling stations

The extended excavations of the previous uranium ore mining together with the associated dumps and tailings on the surface result in the mobilisation of uranium and other pollutants and the contamination the water resources in the Mailuu-Suu valley.

As basis for an assessment of extend of pollution and its sources, BGR identified and monitored the water composition at 50 sampling stations (Fig. 14). The various stations allow sampling of seepage water from tailings impoundments, surface water (rivers, creeks) and groundwater (deep and shallow aquifers) comprising springs, dug wells, artesian wells and recently drilled groundwater-monitoring-wells. The water quality of the local drinking water supply was one focus of the sampling campaigns, therefore the central water supply plant (stations 1, 2) as well as several decentralized public water supply wells have been investigated (Fig. 14). The composition of the surface water from the central water supply, far north' of any mining activities, was taken as natural background reference unaffected by any anthropogenic influence.

Other sampling stations have been chosen according to their estimated significance for the characterization of the different water resources in Mailuu-Suu valley. Furthermore, presumed sources of contamination were monitored by seepage water of tailings impoundments as well as springs, which may fed by underground mining structures. Where necessary, the sampling network was intensified by the construction of additional groundwater monitoring wells in the shallow aquifer.

Subsequently, the respective sampling stations are briefly described, including a summary of the major findings. Complete analytical results are documented in Annex 2, Table 2 at the end of this chapter provides an evaluation of the water sources in terms of drinking water purpose.

Station 1; central water supply plant (surface water): The central water supply plant, which was built far north of the mining activities and thus is not influenced by them, is taken as reference for clean water. No parameter fails the WHO drinking water guideline.

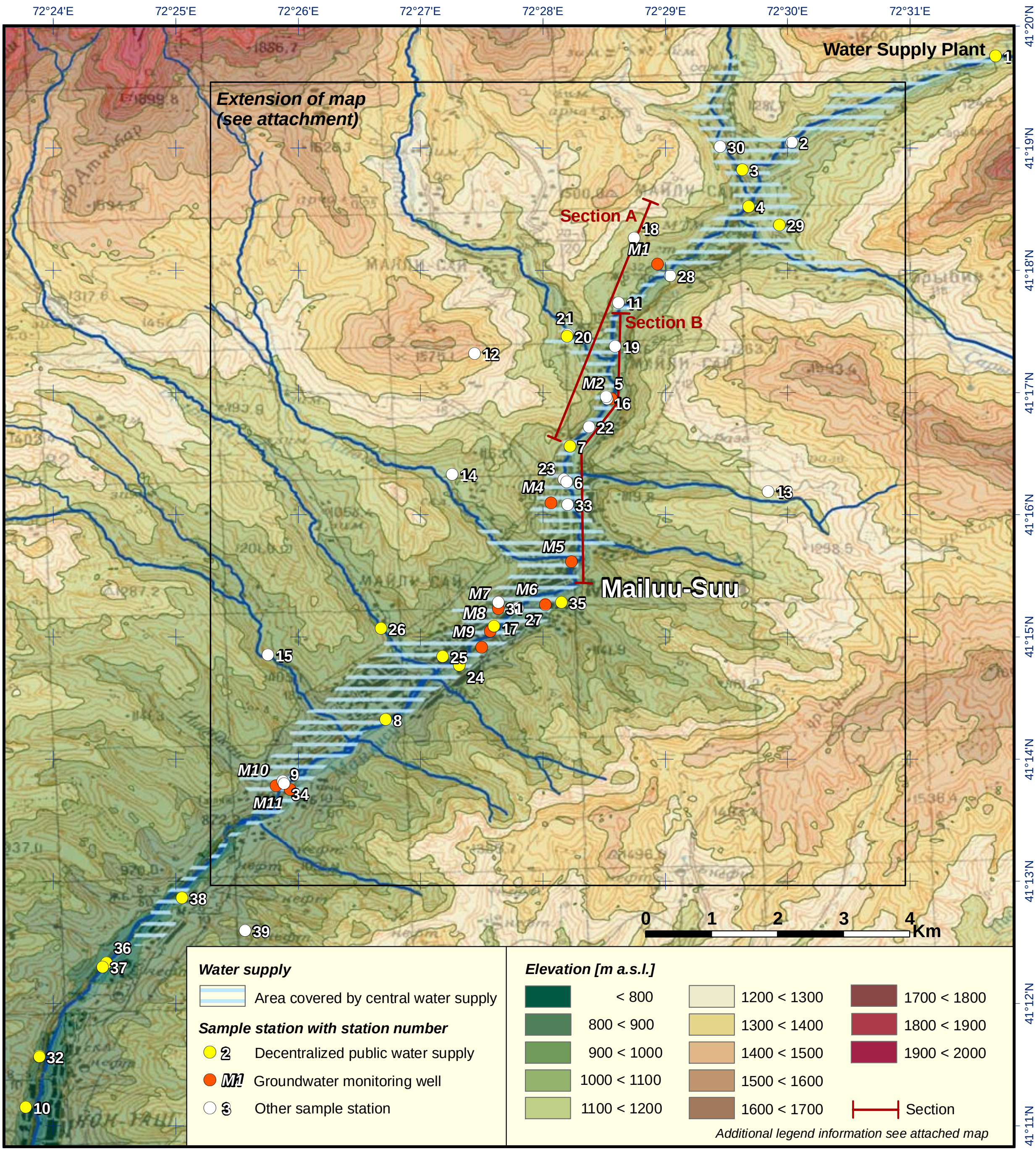

Figure 14: Mailuu-Suu valley with locations of sampling stations, and coverage of public water supply. Note also the locations of sections A and B (see Figures 2 and 9) as well as the extension of detailed map (see Attachment).

Station 2; leakage in water supply pipe (surface water): This water source is one of the various locations, where the central water supply pipe is damaged and looses water. If water loss would be minimized by appropriate maintenance and the inhabitants of Mailuu-Suu educated to reduce drinking water consumption, even the village Kok-Tash further southwards may be supplied by this plant.

Station 3; Artesian well Ul. Pioneerskaya (deep aquifer): The artesian well in the Ul. Pioneerskaya in the village Sarabiya is not influenced by the uranium mining activities further southward. But in the water, which comes from the deep underground (shown by a weak H_2S-smell), several other parameters fail international drinking water guidelines (arsenic, fluorine, strontium), possibly due to geogenic reasons. Therefore, BGR recommends not using this water for drinking water purposes.

Station 4; spring south of Sarabiya, Ul. no. 4 (quaternary aquifer): In July 2006 the nitrite-content was determined as too high, which makes this water source ineligible for drinking water purposes, although the uranium-content is not exceeded.

Station 5; seepage water of tailings impoundment 3 + 18 (technogenic, Fig. 15): This seepage water exceeds the WHO threshold value for uranium by more than 100 times (1700 µg/L U), also the sulphate content is too high. However, the environmental impact is limited by the low rate of water flow (0.1-0.5 L/min).

Station 6; Kulmin-Say before flowing into Mailuu-Say (surface water). Depending on the season, the water of this Mailuu-Say tributary contains 170-220 µg/L uranium. Therefore, the river Kulmin-Say with its high water discharge of 50-100 L/min is the second largest contamination source for the Mailuu-Say River. In contrast to other tributaries the Kulmin-Say is water-bearing all seasons (perennial). Therefore, the Kulmin-Say is not only fed by snowmelt from the surrounding mountains, but is also the receiving river for artesian (deep) groundwater. Whether the high uranium content mainly originates from contaminated groundwater or by the erosion of waste rock dumps 1 and 2, which are reaching down into the river, is still not clear. It is important to convince people not to use this water for drinking purposes or livestock feeding, which has been a common practice.

Station 7; H_2S-spring below road to ISOLIT (cretaceous aquifer): Station 7 (see Fig. 8) corresponds to a spring directly flowing into the river Mailuu-Say. The impact of crude oil and uranium ore layers distributed within the associated aquifer to the water chemistry is obvious. The uranium content exceeds several times the recommendable threshold for drinking-water. Nevertheless, it is hard to estimate to what extent the flooded mining excavations have increased the uranium content of the spring water. The considerable high dissolved sulphate content could be even higher (x20), but most of the sulphur is present in reduced form (e.g., sulphide). This has led to the still common usage for

Figure 15: Outflow of seepage water (Station 5) of tailing no. 3 on the eastern river bank of the Mailuu-Say, opposite to the plant ISOLIT.

health treatment purposes, which is not advisable due to its high trace metal content.

Station 8; collection tank of the lamp bulb factory (quaternary aquifer): The tank of the lamp bulb factory collects a water-mixture, officially consisting of bank filtrate of the Mailuu-Say, groundwater of the quaternary aquifer and centrally supplied water, which is added. The uranium-content of 29 µg/L makes this water ineligible for drinking. Obviously, a third component within this water mix is expected, because both Mailuu-Say (bank filtrate) water as well as centrally supplied water have uranium contents not exceeding 15 µg/L. This water is supposed to be used for industrial purposes, only.

Station 9; sewage treatment plant (surface water): The sewage treatment plant is supposed to clean sewage water from the central water system. High Al-content indicates the application of alumina compounds in frame of the water treatment process.

Station 10; dug well in Kok-Tash (quaternary aquifer): The uranium-content is significantly increased, but is still below the WHO-guideline value. Other parameters, such as strontium, also show elevated values and which are close to international threshold values. Therefore, this water needs special attention to assure its drinking-water quality.

Station 11; seepage water of tailings impoundment no. 5 (technogenic): A well close to the foot of the drainage dam tailing 5, where confined water is flowing continuously from the tailing body, probably representing groundwater mixed with seepage water (Fig. 16). Likely contamination sources comprise the radiologic tailing material, possibly supplemented by uranium containing groundwater (cretaceous), resulting in an uranium content of more than 8 mg/L. Combined with the remarkable flow rate of 3-10 L/min, the seepage water of tailings no. 5 is one major contamination source for the Mailuu-Say River (up to 122 g per day). Its impact to the underlying quaternary aquifer is still unknown.

Station 12; seepage water of tailings impoundment no. 3 (technogenic): Sampling of seepage water from tailing 3 was possible at the existing drilling 2 (of 4) from TACIS (2003). In July 2006, the water depth was 3.4 m below ground level. The dissolved uranium content reaches almost 3 mg/L. Similarly to Tailing 5, a groundwater inflow of possibly uranium-containing cretaceous groundwater is expected in tailing 3 (TACIS, 2003).

Station 13; creek dewatering shaft no. 10 (surface water): The area north of the Kulmin-Say was intensively mined for uranium. Locally, creeks rinse throughout dumps material and discharge into Kulmin-Say River. Station 13 represents one creek rinsing dump material originating from old shaft

Figure 16: Continuous discharge of seepage water (Station 11) of tailings impoundment no. 5.

no. 10, resulting in a considerable amount of contaminants (e.g., 150 µg/L, October 2006).

Station 14; seepage water of tailings impoundment no. 16 (technogenic): The seepage water of tailing no. 16 (Fig. 17) represents the most contaminated water with respect to its uranium content (up to 36 mg/L !), found in the Mailuu-Suu valley. Domestic animals graze in this area and even drink the contaminated water of the draining Aschwas-Say. Therefore, a contaminants transfer to the local citizen via the food chain cannot be excluded. By contrast, the contaminants contribution of this source to the total contamination of the Mailuu-Say via the Aschwas-Say is low due to a water flow rate of only 0.01-0.1 L/min.

Figure 17: Outflow of seepage water (Station 14) at the bottom of tailing no. 16.

Station 15; seepage water of tailing no. 13 (technogenic): The tailing is located near the banks of the Ailampa-Say and normally shows no superficial discharge of seepage water. Thus it was an extraordinary situation in July 2006, when a wet area below tailing 13 in the dry riverbed of the Ailampa-Say has been observed. Containing more than 300 µg/L uranium, it can be assumed that tailing 13 generally leaks directly into the underlying quaternary aquifer.

Station 16; spring on the area of ISOLIT (cretaceous aquifer): Like Station 7, this spring has its origin in cretaceous strata. Similarly, the discharged groundwater has an increased uranium content (82 µg/L) and other heavy metals..

Station 17; artesian well near mosque (deep aquifer): In contrary to the artesian wells in Sarabiya, the groundwater of this artesian well near the central mosque in the Mailuu-Suu city area shows a significantly higher uranium content (7.5 µg/L), which is still below the WHO threshold value of 15 µg/L. Nevertheless, high sulphate- and strontium-contents leads to the recommendation not to use this water for drinking purpose. The depth of the already existing artesian wells is not documented. Gas bubbles (CH_4) and cords of oil indicate that the artesian well near the central mosque is tapping a deep aquifer of the cretaceous or even the jurassic strata.

Station 18 creek behind tailing no. 6 (surface water, Fig. 18): Northwest of tailing no. 6 mining is supposed to be carried out, because a small contaminated creek is rinsing through

Figure 18: Creek behind the drainage channel of tailings impoundment no. 6 (Station 18).

uranium-containing dump material. Unfortunately, the allocation of the associated mining activities is difficult, because no dumps and/or shafts are documented northwest of tailings impoundment no. 6.

Stations 19, 23, 27, 32, 33, 34; sampling of the Mailuu-Say River (surface water): The Mailuu-Say streams southward through the Mailuu-Suu valley, heading to Uzbekistan, 20 km further south and the Fergana-Valley. The selected sampling stations along the N-S directed Mailuu-Say riverbed generally confirm a continual increase of the uranium content in the river water up to a maximum value of 12 µg/L in the area of Kok-Tash (October 2006). In the northernmost part, the Mailuu-Say river water is quite low in uranium (<0.5 µg/L), which represents a geogene background value for local surface waters. Already after passing the tailings no. 5-7, uranium content of Mailuu-Say increases up to 5 µg/L. Further southward, the Mailuu-Say passes several tailings (incl. No. 3, 8, 9), receives the rivers Kara-Agach and Kulmin-Say as well as spring water (Station 7 and 16), resulting in a uranium content up to 7 µg/L. Generally, the solutes content of the Mailuu-Say River is supposed to response directly to changing inputs as well as seasonal dilution effects.

Station 20; spring in Kara-Agach (tertiary aquifer): Results show that the area of Kara-Agach is heavily contaminated (uranium 144 µg/L). Also other parameters such as nitrate, sulphate and strontium are exceeding international threshold values for drinking water. This spring is one of the few locations, where a water source in tertiary strata could be sampled.

Station 21; river Kara-Agach (surface water): As a consequence of the extensive mining activities in the area, also the river water of the Kara-Agach fails the WHO threshold values (uranium 38 µg/l). Due to the remarkable water volume of 100-500 L/min (depending on the season) the Kara-Agach represents an important contamination source to the Mailuu-Say River.

Station 22; pumpstation (deep aquifer): The artesian well is used to supply the town of Koshkor-Ata with drinking water and shows, similar to the other artesian wells in the area of Sarabiya, no impact by former mining activities.

Station 24; dug well, Ul. Tuleberdieva (quaternary aquifer); This dug well represents one of the few opportunities to obtain information of the groundwater quality of the shallow aquifer east of the Mailuu-Say. With more than 15 µg/l uranium the water of this dug well is not recommended to be used for drinking water purposes.

Station 25; artesian well Ul. Artesianskaya (deep aquifer): Similar to the artesian well near the central mosque in the city Mailuu-Suu, the water of the artesian well in the Ul. Artesianskaya is contaminated by means of uranium (7 µg/L), but so far below the WHO-guideline value of 15 µg/L. Also other parameters here are not yet exceeded, thus the water could be used for drinking. Nonetheless, BGR recommends a continuous monitoring of this artesian well.

Station 26; Bedre-Say east of the city border (surface water): The contamination of the Bedre-Say (29 µg/L uranium) shows that even west of the city area contamination sources exist, where no adits and superficial mining left-overs are officially documented.

Station 28; creek opposite tailings impoundment no. 7 (surface water): During heavy rainfalls, numerous temporary creeks are forming. Herewith, the sampled creek had its origin in the mountains east of the Mailuu-Say and north of the Kulmin-Say and drains away after a few days. Even this ephemeral creek revealed a high uranium load of 125 µg/L. Normally dry mining residues were probably flooded during extreme precipitation events, which results in an increased contaminant load of the local waters bodies.

Station 29; artesian well Ul. Vostochnaya (deep aquifer): Similar to other artesian wells in the village Sarabiya, this station is not influenced by any mining activities, which were carried out further southward. Nevertheless, the deep groundwater with a weak H_2S-smell shows naturally increased trace constituents, such as arsenic.

Station 30; tributary Sarabee/Akbalyk (surface water): Before flowing into the Mailuu-Say, the tributary Sarabee/Akbalyk shows a low uranium load (1.9 µg/L). The information sources about mining-activities in this area are inconsistent. The uranium might as well be originated in its origin geogene background.

Station 31; central water supply in flat Ul. Sabetschuka 6 in Mailuu-Suu: This station has been selected to trace adverse modifications within the pipe work of central water supply. At least the tap in the observed flat receives water in good drinking water quality.

Station 35; artesian well, eastern city of Mailuu-Suu (deep aquifer): This artesian well, drilled at the riverside of a creek bed, is contaminated and not recommended for drinking water purposes. Even in case of the breakdown of the central water supply, citizen must find other opportunities than using this water. The only documented contamination source east of the city is the tailing no. 15.

Station 36, 37; springs in Kok-Tash (quaternary aquifer): The springs in Kok-Tash, which are located at the banks of the Mailuu-Say in unconsolidated sediments, are significantly polluted (uranium ~20 µg/L) and demonstrate increasing contamination of the shallow (quaternary) aquifer directed downstream (N → S).

Station 38; artesian well in Kok-Tash (deep aquifer): Since the inhabitants in Kok-Tash, south of Mailuu-Suu barely have a chance to get access to the central water supply, this artesian well in the north of Kok-Tash is of great value. So far the water quality passes the recommendations of the WHO guideline, but future monitoring is necessary to confirm this result.

Station 39; mountainous spring east of Njefteprom (tertiary): To overcome the supply shortage of Kok-Tash, a spring in the mountains (tertiary strata) east of Njefteprom (south of Mailuu-Suu) was checked about its eligibility for drinking water purposes. Unfortunately, also this spring is contaminated and should not be used as drinking water.

Groundwater-monitoring-wells M1 – M11: Generally, the quaternary (shallow) aquifer, which is monitored by these wells, is significantly contaminated by uranium, concerning the concentration of 0.4 µg/L in the water of central water supply plant (Station 1; river water of the Mailuu-Say) and even 0.05 µg/L in the water of the artesian well in the Ul. Artesianskaya in the village Sarabiya (Station 3) – both not affected by the uranium ore mining – as background for surface/shallow water and deep groundwater, respectively.

- M1 – seepage water of tailing no. 6: Seepage water is strongly contaminated in terms of uranium (>900 µg/L).
- M4 – shallow groundwater is contaminated, but yet not above the WHO thresholds.
- M5 – shallow groundwater is contaminated above the WHO limit value (26 µg/L).
- M6 – shallow groundwater is contaminated above the WHO limit value (15 µg/L).
- M7 – shallow groundwater is contaminated above the WHO limit value (28 µg/L).
- M8 – shallow groundwater is contaminated above the WHO limit value (20 µg/L).
- M9 – shallow groundwater is contaminated above the WHO limit value (53 µg/L).
- M10 – shallow groundwater is contaminated above the WHO limit value (90 µg/L).
- M11 – shallow groundwater is contaminated above the WHO limit value (137 µg/L).

Table 2: Evaluation of water quality based on observed water samples. Their suitability for drinking purposes has been assessed only in terms of anorganic and radiological studies (U = uranium, Al = alumina, As = arsenic, F = fluorine, Mo = molybdenum, NO_2 = nitrite, NO_3 = nitrate, Rad. = radiation > 0.1 mSv/a, SO_4 = sulphate, Sr = strontium). Please note, that microbial issues are not considered.

Station	Location	Type/origin	Suitable Drinking	Contaminants
1	Central Water supply plant	Surface water	yes	
3	Artesian well, Street of Pioneers	Deep aquifer	no	As, F, Sr
4	Spring south of Sarabiya; street No. 4	Quaternary	no	NO_2, Rad.
5	Seepage water, tailing No. 3 + 18	Technogenic	no	U, SO_4, Rad.
6	Kulmin-Say close to Mailuu-Say	Surface water	no	U, SO_4, Sr, Rad.
7	H_2S-spring below road to ISOLIT	Cretaceous	no	U, Sr, Rad.
8	Well from lamp factory	Quaternary	no	U, Sr, Rad.
9	Sewage treatment plant	Surface water	no	Al
10	Dug well in Kok-Tash	Quaternary	no	Rad.
11	Seepage water of Tailing No. 5	Technogenic	no	U, Al, As, F, Mo, NO_2, NO_3, SO_4,Rad.
13	Creek dewatering shaft No. 10	Surface water	no	U, As, F, SO4, Sr, Rad
14	Seepage water of Tailing No. 16	Technogenic	no	U, As, F, Mo, SO_4, Rad.
15	Seepage water of Tailing No. 13	Technogenic	no	U, Mo, SO_4, Sr, Rad.
16	Spring on the area of ISOLIT	Cretaceous	no	U, Al, Rad.
17	Artesian well near mosque	Deep aquifer	no	SO_4, Sr, Rad.
18	Creek behind ailing No. 6	Surface water	no	U, SO_4, Sr, Rad.
19	Mailuusay down Tailings No. 5,6,7	Surface water	no	Rad.
20	Spring in Kara-Agach	Tertiary	no	U, NO_3, SO_4, Sr, Rad.
21	Kara-Agach-river end of village	Surface water	no	U, Rad.
22	Artesian well ('pumpstation')	Deep aquifer	yes	
23	Mailuu-Say down Tailing No. 3	Surface water	yes	
24	Dug well (Ul. Tuleberdieva)	Quaternary	no	U, Rad
25	Artesian well Ul. Artesianskaya	Deep aquifer	yes	
26	Bedre-Say at city border	Surface water	no	U, SO_4, Sr, Rad
27	Mailuu-Say in the city	Surface water	yes	
28	Creek opposite Tailing No. 7	Surface water	no	U, F, SO_4, Sr, Rad
29	Artesian well Ul. Vostochnaya	Deep aquifer	no	As
30	Down of Sarabee + Akbalyk	Surface water	yes	
31	Water pipe in BGR-flat	Surface water	yes	
32	Mailuusay near Kok-Tash	Surface water	yes	
33	Mailuusay down of Kulminsay	Surface water	yes	
34	Mailuu-Say down of the sewage treatment plant	Surface water	yes	

35	Artesian well, east' city	Deep aquifer	**no**	U
36	Spring in Kok-Tash	Quaternary	**no**	U
37	Spring in Kok-Tash	Quaternary	**no**	U
38	Artesian well in Kok-Tash	Deep aquifer	**yes**	
39	Spring east of Njeftеprom	Tertiary	**no**	U
M1	GW-monitoring-well	Quaternary	**no**	U
M4	GW-monitoring-well	Quaternary	**yes**	
M5	GW-monitoring-well	Quaternary	**no**	U
M6	GW-monitoring-well	Quaternary	**no**	U
M7	GW-monitoring-well	Quaternary	**no**	U
M8	GW-monitoring-well	Quaternary	**no**	U
M9	GW-monitoring-well	Quaternary	**no**	U
M10	GW-monitoring-well	Quaternary	**no**	U
M11	GW-monitoring-well	Quaternary	**no**	U

Tributaries like the Ailampa-Say are seasonally dry (by contrast to the Kulmin-Say River, see above). Just during snow melt and heavy rainfalls, surface water is using their river beds. It can be assumed that seepage water of tailing located close to the banks of the Ailampa-Say (tailing no. 1, 2, 4, 13, 14), generally penetrates into the underground.

2.6 Relevance of selected water solutes in Mailuu-Suu

Arsenic: Especially in deep groundwater tapped by artesian wells the northern part of the valley the arsenic content is increasing the WHO threshold value of 10 µg/L. This might be caused by a naturally elevated arsenic content of the rocks of lower cretaceous – jurassic age in the underground. Reducing redox-conditions favour an enrichment of dissolved arsenic in groundwater.

Manganese: In the frame of the World Bank Disaster Hazard Mitigation Project Kyrgyz authorities intend to identify water samples with high uranium content indirectly by determining manganese using a spectrophotometer. This unusual idea is based on the fact that potassium permanganate ($KMnO_4$) is extensively used throughout the uranium ore processing, indicating an apparent correlation of manganese and uranium. Even when this is possibly the case in solid tailing material, the dissolved manganese content is neither significant, nor correlated to uranium. Obviously, manganese cannot act as indicator for a high uranium contents, because (1.) elevated dissolved uranium content is not only caused by tailings material (=processing residues), but also by waste rock dumps and contaminated deep groundwater. Furthermore (2.), while uranium(VI) is mobile under oxidized conditions, high dissolved manganese contents occur only under a reduced environment so that the mobile Mn-species(II) predominate. Consequently, manganese has a low solubility under oxidizing conditions and precipitating while uranium is transported, and vice versa under reducing conditions.

Sulphate: The locally high sulphate content in the water samples could generally originate by two ways: (1.) by sulphide (XS_2) oxidation (e.g., pyrite) or (2.) by gypsum ($CaSO_4$) dissolution. In the deep underground pyrite and other sulphides seems to play a significant role as indicated by reducing conditions, H_2S (e.g., Station 7) and residual rock material. Sulphide oxidation would result in an acidification of the surrounding aquifer. In contrast, all water samples have shown a to circum-neutral pH, probably because of the high neutralization capacity of carbonate host rocks. By contrast, the origin of high dissolved sulphate by dissolution of gypsum is likely for seepage water percolating through tailing material. Large amounts of gypsum were formed during uranium ore processing using sulphuric acid (H_2SO_4) and subsequent neutralization with lime (CaO) and limestone ($CaCO_3$). The WHO suggests a guideline threshold of 500 mg/L sulphate in drinking water.

Thorium: Thorium is a decay product of the uranium decay and a common constituent in radiologic material. However, in all water samples only very low thorium contents could have been determined (<1 µg/L), which probably is due to the different mobilisation conditions of uranium and thorium.

Uranium: Generally, dissolved uranium is mobile and accumulates in water, if oxidizing redox-conditions are present. The majority of water samples from Mailuu-Suu are characterized by a neutral or weakly basic pH and an oxidizing Eh. Under such conditions the aquatic U(VI) speciation is dominated primarily by neutral dicalcium-uranyl-tricarbonate complexes ($Ca_2UO_2(CO_3)_{3(aq)}$) but also by the negatively charged uranyl-carbonate complexes $UO_2(CO_3)_2^{2-}$, $UO_2(CO_3)_3^{4-}$ and $(UO_2)_2CO_3(OH_3)_3^-$ (ZSR/BGR 2006, ZSR 2008). Since most mineral surfaces are also negatively charged in this pH range, except iron- and alumina(hydr)oxide minerals, which are predominantly positively charged, we face a high mobility of different uranyl-complexes. Whereas the latter are able to sorb negatively charged uranyl-carbonate complexes to the extent limited by their sorption capacity, no surfaces show an affinity for neutral dicalcium-uranyl-tricarbonate complexes (ZSR/BGR 2006). The migration of uranium is additionally favored due to the fact that precipitation of U (VI) is effectively hindered by the formation of these stable complexes even at weakly reducing conditions (ZSR/BGR 2006, ZSR 2008). Also fluorine and nitrite (which are elevated in some samples) are supposed to have a complexion potential for uranium (BURNS & FINCH, 1999). Generally, uranium migration may also be facilitated as a result of colloidal transport, but according to our results, colloidal transport can be neglected in the investigated surface water and groundwater (ZSR 2008). A few springs and wells in the Mailuu-Suu valley (e.g., Station 7) provide uranium-bearing groundwater at reducing conditions. Therefore, the oxidation state of uranium is expected to be four-valent. The stability of inorganic colloids can be enhanced by a coating with dissolved organic matter. In such case, also colloidal transport of uranium in rivers cannot be excluded. The WHO suggests a guideline value of maximum 15 µg/L uranium in drinking water.

Vanadine: Referring to the original mineral phases, local uranium ores were mainly consisting of uranium-vanadates. Therefore, vanadium is supposed to be related to uranium. In fact, the content of vanadium in groundwater samples is quite low because its favourable retention under oxidizing conditions.

2.7 Assessment of contamination sources

Mining residues such as dumps and tailings impoundments are the most obvious contamination sources, but the contamination situation of the water bodies seems to be more complex. Generally, it is characterized by an interaction of punctual sources, such as seepage discharge of numerous dumps and tailings impoundments as well as more diffuse contaminant sources of geogene origin in deep aquifers (uranium mineralisation, metal sulphides, crude oil), possibly intensified by the drainage of flooded mining structures. The confined deep groundwater swells into shallow groundwater and surface water bodies transferring their solutes to the primarily Ca-Mg-HCO_3 waters of meteoric origin and good water quality. Due to the - seasonally depending - high water flow rate of the Mailuu-Say, the contamination influx is diluted so that maximum uranium content of the river water south of Mailuu-Suu valley (Kok-Tash, station 32, up to 11 µg/L U) was determined after the dry season in October 2006.

The main contaminant sources for the river Mailuu-Say are various discharging dumps and tailing bodies as well as contaminated tributaries. VANDENHOVE et al. (2002) identified Tailing no. 3 as the major environmental hazard, estimating the radioation of this tailing body with 650 TBq as high as 60% of the total radiation of all tailings impoundments. This serious evaluation of the direct radiologic hazard is limited to the location itself and does not consider contaminants transport into the environment. Based on the existing data Table 3 shows that focusing on remediation of tailings impoundment no. 3 - as also proposed by IAEA (2003) - will not significantly decrease the contaminants influx due to the comparatively low daily uranium discharge into the river Mailuu-Say. Also the contribution of the uranium-bearing spring water of station 7 to the Mailuu-Say is low due to the low flow rate of 0.5-1 L/min (not displayed in Table 3). Overall, seepage water of tailings impoundment no. 5 (possibly supplemented by spring water at the base of the tailing body) seems to be the major contaminant for the river Mailuu-Say with up to 122 g uranium per day.

Table 3: Approximate uranium release of the main contamination sources for the Mailuu-Say River, calculated from the uranium content as determined in 10/2006.

contamination source	U [µg/L]	discharge [L/min]	max. U release [g/d]
seepage water of tailings impoundment no. 3	1760	up to 0.5	1
seepage water of tailings impoundment no. 5	8500	up to 10	122
seepage water of tailings impoundment no. 16	36000	up to 0.1	5
water of the river Kara-Agach	39	up to 500	28
water of the river Kulmin-Say	171	up to 100	25

Similarly to the Mailuu-Say River, contaminants load of the shallow aquifer is lowered by dilution, since the shallow aquifer is directly recharged by precipitation events, snow melt and river bank filtration. Based on the existing data, the relevance of the specific various contamination sources remains unclear.

3. Mitigation Measures

Based on the evaluation of local water resources one main goal of the BGR project was to provide stakeholders and authorities with opportunities to encounter the contamination situation. To achieve this, several measures have been carried out:

- Training and qualification course: Authorities in Mailuu-Suu as well as citizens were informed about the situation and how to prevent associated risks.

- Designing and improving of the monitoring network: groundwater-monitoring-wells were drilled, by which the opportunity was achieved to take water samples not just out of natural sampling locations like springs.
- An evaluation of local laboratories demonstrated the need for improvement of the analytical opportunities in Kyrgyzstan.
- CEC in Mailuu-Suu was enabled to achieve a first estimation about the drinkability of water by simple in-situ analytical equipment. This was combined with a russian manual, explaining how to handle the equipment.
- Finally, a public information campaign giving recommendations to the citizens of Mailuu-Suu and to provide information on the project in a nationwide scale.

Futhermore, the efforts of CEC were accompanied and the World Bank activities in frame of the Disaster Hazard Mitigation Project BGR supported with expertise.

3.1 Training and qualification measures

3.1.1 Seminar on groundwater monitoring

From November, 27th until December, 1st 2006 BGR conducted a seminar on groundwater monitoring in Mailuu-Suu (JUNG, 2006). Following a capacity building approach, the target group of the seminar included delegates of local authorities and selected citizen of Mailuu-Suu. The presence of representatives of the MoE and PIU improved the involvement of Bishkek authorities into mitigation activities in frame of the Mailuu-Suu hazard.

To reinforce the lessons learned, practical training about groundwater monitoring techniques was offered to the local participants in spring 2007. Furthermore, laboratory technicians of the local CEC have been trained in analysis techniques. Besides the attention paid to the situation in Mailuu-Suu, the achieved abilities of the participants also cover comparable situations in whole Kyrgyzstan.

Motivation for the seminar: During the seminar the participants had to acquire the necessary background for groundwater monitoring. They were taught to be aware of potential hazards like the uptake of toxic elements due to low quality water. The participants learned to monitor the water resources by themselves with professional supervision of the CEC. Further awareness was be given to the matter, why to continue groundwater monitoring after the BGR project has ceased.

Lecturer: Dr. Hagen Gunther Jung (BGR Germany) with support of his interpreter, Mrs. Bermet Moltaeva, conducted the lectures.

Participants: Main target group of the proposed seminar were representatives of local authorities in Mailuu-Suu. Additionally, committed representatives of the Mailuu-Suu citizens strengthened the local expertise. The involvement of the MoE/PIU was highly desirable to ensure sustainability of the transferred knowledge and to support further cooperation between the governmental structures in Bishkek and the local authorities in Mailuu-Suu. The local authorities were kindly asked to support the selection and delegation process, resulting in the following list of participants:

1. *Aman Sarnogoev - representative of the MoE, Bishkek*

2. *Alexander Meleshko - representative of the MoE, Bishkek*
3. *Asylbek Keshikbaev - representative of PIU*
4. *Ashir Abdulaev - head of Emergency Department of the MoE in Mailuu-Suu*
5. *Rasul Mamataliev – Junior Monitoring specialist of MoE in Mailuu-Suu*
6. *Gulbara Taabaldieva – Laboratory technician of Sanitary-Epidemic station in Mailuu-Suu*
7. *Saipilla Mairykov – representative of Ecology Department of Mailuu-Suu*
8. *Nemat Mambetov –Chief Doctor of the Sanitary-Epidemiological Station (CEC) of Mailuu-Suu*
9. *Kanybek Tashkenbaev – Head of the Local Self-Government body (Aiyl Okmoty) of Sarybie village*
10. *Bakyt Akhmatov - Head of the Local Self-Government body (Aiyl Okmoty) of*
11. *Kok-Tash village*
12. *Akhmet Karakagan –representative of the central water supply (Gorvodokanal)*
13. *Tair Asanov – Chief Engineer of the central water supply (Gorvodokanal)*
14. *Zarkanbek Unusaliev – citizen of Mailuu-Suu*
15. *Radik Temirbaev – citizen of Mailuu-Suu*
16. *Ainura Jorobaeva - citizen of Mailuu-Suu*
17. *Muratbek Kalykov – representative of Chuj ecological laboratory*

Time needed: Overall 5 whole-day-sessions were offered. Four lessons (each having 45 minutes) in the morning and two lessons in the afternoon were connected by lunch.

Language: The seminar lessons were held in English and simultaneously translated into Russian.

Facilities needed: The seminar has been carried out in the presentation room of the MoE/PIU in Mailuu-Suu. BGR provided a multimedia projector and stationeries for the participants.

Contents:

Session 1	*Session 2*	*Session 3*	*Session 4*	*Session 5*
- Presentation of the BGR project - Introduction and expectations of the participants - Goal of the seminar	- General hydrogeology - Hydrogeology in Mailuu-Suu	- General water chemistry - Analytical parameters - Water quality in Mailuu-Suu	- Technical equipment - Sampling procedure - Practical training in the field	- Drilling of water wells - GW-monitoring for Mailuu-Suu - Discussion about continuation of monitoring

Deliverances:

- Russian manual of groundwater monitoring in Mailuu-Suu
- Participants of the seminar were invited for coffee-breaks and lunch
- Participants received a certificate of attendance to testify knowledge and abilities to raise interests of potential employers in the future
- 150, - KGS daily allowance for local participants.

<u>Outcomes</u>: Selected persons in Mailuu-Suu are enabled to monitor the groundwater by taking water samples and measuring basic analytical parameters. They were trained how to avoid the use of water which potentially is giving cause for sanitary concern. In order to achieve sustainability for the BGR project the seminar ceased with a discussion between the local participants, the MoE/PIU, and the city administration of Mailuu-Suu regarding the continuation of the groundwater monitoring activities initiated by BGR. The parties agreed that the local CEC will be in charge for performing the monitoring of the groundwater quality according to the Kyrgyz legislation. Furthermore, the parties agreed that the existence of an eligible water laboratory in Kirgizstan is essential.

3.1.2 Continued training and qualification measures

Qualification measures and on-the-job training of local experts in Mailuu-Suu were continued during the whole duration of the BGR project, with focus on practical training in the field. The participants were recruited from a quality monitoring group, the local CEC suggested to BGR:

- Chief doctor *Nemad Mambetov*
- Epidemologist *Talant Orosaliev*
- Laboratory technician *Gulbara Taabaldieva*

3.2 Drilling of groundwater-monitoring-wells

To obtain a better insight into the quality of the groundwater of the quaternary aquifer in the river valley, the Osh branch of KyrgyzGIIZ conducted 11 drillings with a total length of 142.5 m (M1 – M11). Within these drillings groundwater monitoring wells have been installed (Fig. 19).

Figure 19: Groundwater-monitoring-well downstream of tailings impoundment No. 6.

The holes were drilled with a diameter of 120 mm using dry drilling-technique. The drillings were completed with PVC-pipes with a PVC-filter at the lower part. The space between pipe and borehole wall was filled with gravel, sand and finally sealed with clay. An appropriate cap protects the completed well. The geological and technical data are documented in ANNEX 5.

3.3 Evaluation of Kyrgyz laboratory capabilities

3.3.1 Central Scientific Research Laboratory / Chuj Ecological Laboratory

In order to identify an analytical laboratory in Kyrgyzstan, which is able to determine the uranium content in water, a comparison was performed between BGR and the Central Scientific Research Laboratory (CSRL, Kara Balta), represented by Chuj Ecological Laboratory. The results show that CSRL is able to determine relative precisely uranium in fluids with more than 200 µg U/L (ANNEX 4). Due to the WHO recommendation of a threshold of 15 µg U/L, CSRL needs to improve its analytical opportunities to be able to determine uranium according to international standards. At the present time, no analytical laboratory in Kyrgyzstan is able to determine uranium directly in an appropriate way.

3.3.2 Sanitary-Epidemic Station in Mailuu-Suu (CEC)

The laboratory of CEC in Mailuu-Suu is already able to determine in-situ parameter, such as temperature, dissolved oxygen, redox potential, specific electric conductivity, as well as the sulphate concentration in water. Additionally, the laboratory was trained by BGR to determine alkalinity in the field. In order to strengthen the capabilities, CEC received appropriate mobile equipment (see below).

3.4 Manual about water-monitoring in Mailuu-Suu

Based on the content of the seminar (see 3.1.1), supplemented by the operation instruction of the necessary equipment, a manual on water monitoring in Mailuu-Suu in Russian language was handed out to the participants of the seminar as well as to CEC in Mailuu-Suu and MoE in Bishkek (JUNG, 2007). Following this manual, local experts in Mailuu-Suu are enabled to continue the activities of the BGR project. During the final project phase, BGR was available as scientific-technical advisor in CEC to reinforce the training measures.

3.5 Provision of field analysis equipment

Within its project BGR has provided the CEC in Mailuu-Suu with necessary equipment to monitor the water quality of groundwater and surface water, whereas MoE/PIU is the owner of the equipment. BGR recommends that the operator of this equipment is the local CEC, since according to Kyrgyz law the health authorities are responsible for evaluating the quality of drinking water.

- 2 sets of mobile measuring units for in-situ determination of temperature, pH, electric conductivity, redox-potential and dissolved oxygen
- 1 flow-through-chamber to enable the determination of the redox-potential
- 2 water pumps “Comet” for sampling (+ accumulator + recharge facility)
- 2 groundwater-level meters
- 3 titration apparatus for determination of alkalinity
- Laboratory material.

3.6 Public information campaign

To overcome lack of information among citizens a public information event was offered in Mailuu-Suu. In collaboration with MoE (here implemented by Wisutec) and the local CEC the event took place in the city hall (dom cultura). BGR informed about its project and the major results. Recommendations were given to prevent citizens from further uptake of uranium and about the water resources presently appropriate for drinking purposes. Reinforcement of the recommendations was aimed by providing an informational brochure (see ANNEX 6) in Russian language (2000 copies). In frame of a press conference held in Bishkek, a summary about the activities and achievements of the BGR project were propagated nationwide.

3.7 Support of the World Bank project in Mailuu-Suu

The equipment provided by the World Bank project is thought to specialize on the additional analytical needs during its geotechnical measures. As described earlier, this equipment, especially the spectrophotometer, is not able to determine uranium in water. Helpful are the two automatic measuring stations, which are intended to install in the river Mailuu-Say above and below the tailings impoundments. Nonetheless, a regular monitoring is indeed necessary.

To overcome insufficient opportunities for uranium determination in Mailuu-Suu as well as in whole Kyrgyzstan BGR offered to the World Bank a training measure of Kyrgyz experts in its analytical laboratory in Germany. BGR offered its support to PIU regarding the tasks of monitoring and analyzing the water quality as well as requests for advice in technical questions like the construction of further groundwater-monitoring-wells.

4. Recommendations

Direct radiation is only a local hazard, especially in close vicinity to tailings impoundments, because radiation decreases rapidly with distance. Contamination of water with radionuclides is considered to be the main hazard for the citizens of Mailuu-Suu. As stated above, just the central water supply satisfy WHO drinking water standard and is recommendable for consumption. Therefore, it is of high importance for the inhabitants of Mailuu-Suu that the central water supply is rehabilitated and maintained continuously to assure its functionality.

Currently, the World Bank intends to shift several tailings and waste rock dumps to the stable tailing no. 6. This will achieve geotechnical safety against landslide hazards and erosion processes. To avoid further mobilization of contaminants from their new place of deposition into ground- and surface water, further covering and sealing measures should be taken into consideration.

Nonetheless, the intended geotechnical measures are not able to improve the recent contamination situation in Mailuu-Suu. By contrast, exposing the tailing material during transport might even enhance the mobilization of contaminants (by water and wind). Therefore, BGR supported the World Bank project with designing a hydrogeological monitoring concept to observe the current contamination situation. The following measures are recommended to be taken into consideration.

4.1 Regular monitoring of the water quality

The contamination situation in Mailuu-Suu changes over the years due to ongoing migration processes. Water sources, which are now of good quality, might turn toxic in the future. Therefore, continued monitoring of the water quality is necessary. Monitoring activities in the future should include the sampling locations selected by BGR, because they represent all water sources available in Mailuu-Suu and provide a first data basis.

To assure a regular monitoring in Mailuu-Suu, local authorities, selected citizens and a newly formed monitoring group inside CEC has been trained and appropriate equipment was provided (see 3.1 and 3.5).

4.2 Additional monitoring needs due to World Bank activities

Additionally to the regular water monitoring in Mailuu-Suu performed by CEC, the geotechnical measures of DHMP cause extra monitoring needs. BGR has identified 49 sampling locations in the Mailuu-Suu valley, including ten newly installed groundwater-monitoring-wells, which should be sampled in a periodic scheme by the water monitoring consultant employed by DHMP. Water sampling of the selected stations including field analysis takes two weeks working time for two experienced persons. It is desirable that the net of sampling stations will be extended by new drilled monitoring wells, especially focussing deeper aquifers and potential contamination sources and the area outside of Mailuu-Suu city.

The variability in contaminant load of water of the various sampling points over the year is not remarkably high. Therefore, under normal conditions beside geotechnical activities of the DHMP, it is sufficient to take water samples two times per year – e.g. once in early spring and once in late autumn.

At present time equilibrium between the environment and the mining residues can be presumed: 40 and more years after depositing tailings and waste rocks the release of contaminants is considered to be stable and continuous. This might change significantly, if mining residues are transferred to the geotechnical stable tailing 6. Consequently, during shifting and approximately one month afterwards sampling points downstream of the former deposition places (seepage water and creek/river water; for each location ~3 sampling points), which might be affected, should be monitored weekly. This should be continued, if high contaminants load is still observed. After this period, it is sufficient to take water samples monthly, maximum for one year or even less in case of a significant decrease in contaminant load.

The water quality of the area along and downstream of the newly constructed shifting road should be monitored by ~3 sampling points (during the works and one month afterwards on a weekly base, then monthly for one year). Special attention should be paid to wastewater and residues, which are caused by cleaning trucks and other heavy equipment.

When tailings and waste rocks have reached their new place of deposition, sampling points downstream of tailings impoundment no. 6 (including the groundwater-monitoring-well M1) should be monitored monthly in order to observe changes in seepage water and river water quality (~5 sampling points). This monthly activity should be continued for one year; in case of increasing contamination it should last even longer. Afterwards, monitoring activities regarding tailing no. 6 can be reduced to sampling every 3rd month.

The local water monitoring consultant of DHMP should hold contact to local authorities, in order to inform the public quickly in case of increasing contamination. Especially in Kok-Tash, water of the Mailuu-Say is used for drinking purposes, a water resource which is a very vulnerable against contamination. In total, it is not unlikely that 2 years after all shifting works have ceased increased monitoring intervals can be reduced again to 2 times in a year as scheduled in the frame of regular monitoring. Overall, flexibility concerning the sampling intervals should be applied responding to the local situation, which might be caused by the geotechnical works.

DHMP proposes to make use of “standard methods using also the opportunities of a specialized laboratory” (MoE & DHMP, 2008). The question arises, if analytical techniques are available in Kyrgyzstan to determine contaminants according to the WHO drinking water guideline. In frame of a laboratory assessment, Chuj Ecological Laboratory (acting in behalf of CSRL, Kara Balta) was able to determine uranium in water just above a detection limit of 200 µg/L (exceeding 13x the international threshold). The Ministry of Health stated they know no other laboratory in Kyrgyzstan, who could determine uranium.

The equipment intended to be purchased by the DHMP project for the CEC in Mailuu-Suu is not satisfying, because it does not determine uranium, as stated earlier. Costs of appreciable equipment (e. g., ICP-MS) certainly exceed 500.000 US$, additionally to high cost for materials supply and continuous maintenance as well as training to gain high experienced technical personal.

To temporarily overcome the lack of analytical opportunities the author has developed an approach, which supports decisions based water quality assumptions (see below). Please note, that this approach is based on the present data and it can not be guaranteed, if it can cope with a future contaminant load, such as might be mobilized during geotechnical measures.

As a costly alternative, water samples could be sent to proven analytical laboratories outside of Kyrgyzstan, a quite expensive alternative requiring logistic efforts. The water monitoring consultant of DHMP must urgently provide solutions for the present lack of analytical opportunities.

4.3 Identifying and avoiding contaminated water

BGR recommends to the citizens of Mailuu-Suu to consume only water provided by the central water supply. Natural water resources (surface water and shallow groundwater) seem to have good quality only upstream (north) and away from any mining activities. Nonetheless, especially the area of the village Kok-Tash south of Mailuu-Suu is not supplied by central water. Citizen of Kok-Tash overcome this problem by using several decentralized water wells, of which just water of the sampling stations 10 and 38 provide water with drinking water quality (compare chapter 2.5). Additionally, the inhabitants also use river water of the Mailuu-Say. Recently, the river water has satisfying quality even in the south of the valley. But this is hardly to ensure, because future contamination events will directly affect Mailuu-Say River and thus the consumer’s health. Furthermore, diseases due to microbial pollution cannot be excluded, so that river water should be boiled prior to consumption.

In case of heavily contaminated water sources it is advisable to close these and to alert the affected citizen. Other water sources may continue to be used with the following restrictions (Table 4), even when they are contaminated to a lesser extent. All water sources, principally fulfilling drinking water quality, are considered to be not eligible when they are surface water in urban areas, private or already affected by contaminants, but still below the WHO recommendations. By contrast, the central water supply plant, which was constructed north of the mining works and any industrial activity, probably won't be influenced by any contamination.

Table 4: Recommended usage of water sources in the valley of Mailuu-Suu.

Water source	drinking	animal feeding	irrigation
Central water	yes	yes	yes
Deep artesian wells	no *	yes	yes
Shallow dug wells	no	no	no
Mailuu-Say	no	no	yes
Other rivers	no	no	no

* Note that the artesian well in the Ul. Artesianskaya has drinking water quality, but continuous monitoring is needed to assure this in the future.

Lacking the ability to determine uranium in Kyrgyzstan, CEC in Mailuu-Suu was enabled to achieve a first estimation about the water quality. When usage of the central water supply is not possible, each new water source assigned for consumption must be tested with the field and laboratory equipment provided by BGR. These instruments yield physico-chemical in-situ parameters, which allow a first hydrochemical evaluation of the water resources.

Trend analyses show an **apparent correlation** of uranium with the total solutes. The latter may be traced in field by specific electrical conductivity as well as the associated parameters alkalinity and. Please note, that this approach does not allow any genetic conclusion and cannot substitute advanced water analysis. Nevertheless, it may serve as a simplified decision support system, quickly identifying water sources very likely failing drinking water requirements.

If the three parameters alkalinity, sulphate and specific electrical conductivity are below their recommended limits (Table 5), calculated based on existing hydrochemical data, the concentration of uranium and other contaminants is presumably fulfilling the WHO recommendations for drinking water. It is necessary to consider all three parameters and only one failed parameter indicates suspicion about the drinkability. However, even if all parameters are below their safety limit, no ultimate assurance can be provided by this approach.

Table 5: Recommended limit values for alkalinity, sulphate and specific electrical conductivity.

Alkalinity[1]:	max. 350 mg/L
Sulphate:	max. 180 mg/L
Spec. electrical conductivity:	max. 1000 µS/cm.

[1] the safety limit for alkalinity is applicable just for samples directly analyzed after sampling, otherwise the alkalinity values are not reliable.

This simplified empiric approach as well as the safety limits have been appointed based on the existing hydrochemical data and therefore only reflect the local hydrochemical and hydrogeological setting. Neither any simple transfer to comparable locations, nor any reverse conclusions should be conducted.

4.4 Treating contaminated water from tailing and dump sites

Additionally to prevention strategies, there is the opportunity to treat contaminated water in order to reduce its contaminant load. For instance, passive treatment systems like Permeable Reactive Barriers (PRB) or Constructed Wetlands recently achieved valuable results and are reasonable for remote areas due to their low maintenance needs.

In Mailuu-Suu, remediation measures of selected contaminant sources like discharge of tailings bodies or affected tributary rivers would have beneficial outcomes as well as treating the groundwater by existing artesian wells, which are currently used by the public.

Long term in-situ cleaning activities of the affected aquifers are supposed to be less effective, because the distribution of contamination sources is diffuse. The construction of cut-off-barriers to stop further influx of contaminated groundwater would achieve just local benefits, because it is hardly possible to catch all the locations, where contaminants migrate into other strata.

4.5 Additional groundwater-monitoring-wells

Sampling of already existing water sources may lead to a decrease of the monitoring activities during dry seasons, when many water sources are dried out. To overcome this problem, further monitoring wells need to be installed to allow a continual insight into quality and quantity of the groundwater.

The 11 groundwater-monitoring-wells installed by BGR provide insight into the quaternary (shallow) aquifer, predominantly within the city area of Mailuu-Suu. They provide examples for further drillings and well constructions, which are necessary to effectively monitor the groundwater.

At the following drilling locations it is advisable to construct further groundwater monitoring wells, preferably arranged in galleries (Fig. 20):

Inside the city area (zone I): In zone I the monitoring wells drilled by BGR provide sufficient information about the water quality within the shallow quaternary aquifer. The already existing artesian wells provide information about the deeper groundwater, but identification of the associated aquifer is difficult due to lacking data about the well depth. Consequently, further deep groundwater monitoring wells need to be drilled inside the city area of Mailuu-Suu in order to achieve get insight into the nature of the deeper aquifers.

Around the city borders (zone II): Because of rare sampling possibilities in this area, additional well drillings are recommended in order to observe the shallow quaternary aquifer as well as deep aquifers. In deep aquifers well drillings might have to be up to several hundred meters deep, but just further hydrogeological studies and the drilling-works itself can clarify this matter.

Generally, groundwater monitoring wells aiming contaminant sources such as seepage water from tailing bodies will improve the existing monitoring-network. It is advisable to install a monitoring well between a tailings body and the next draining river to catch contaminated seepage water. The necessary filter depth of monitoring wells should be sufficient to reach groundwater even in dry seasons, when the groundwater level is low.

Also attention has to be paid to the drawdown funnel, which is developing during water pumping. The wells should be drilled with a diameter of at least 120 mm using dry drilling-technique. According to Figure 21 the drillings are to complete with PVC-pipes with at least 1 m filter length. The space between pipe and borehole wall has to be filled with small gravel, sand and to be sealed with clay. An appropriate cap protects the well. In comparison to steel pipes, PVC does not alter the water chemistry due to sorption and

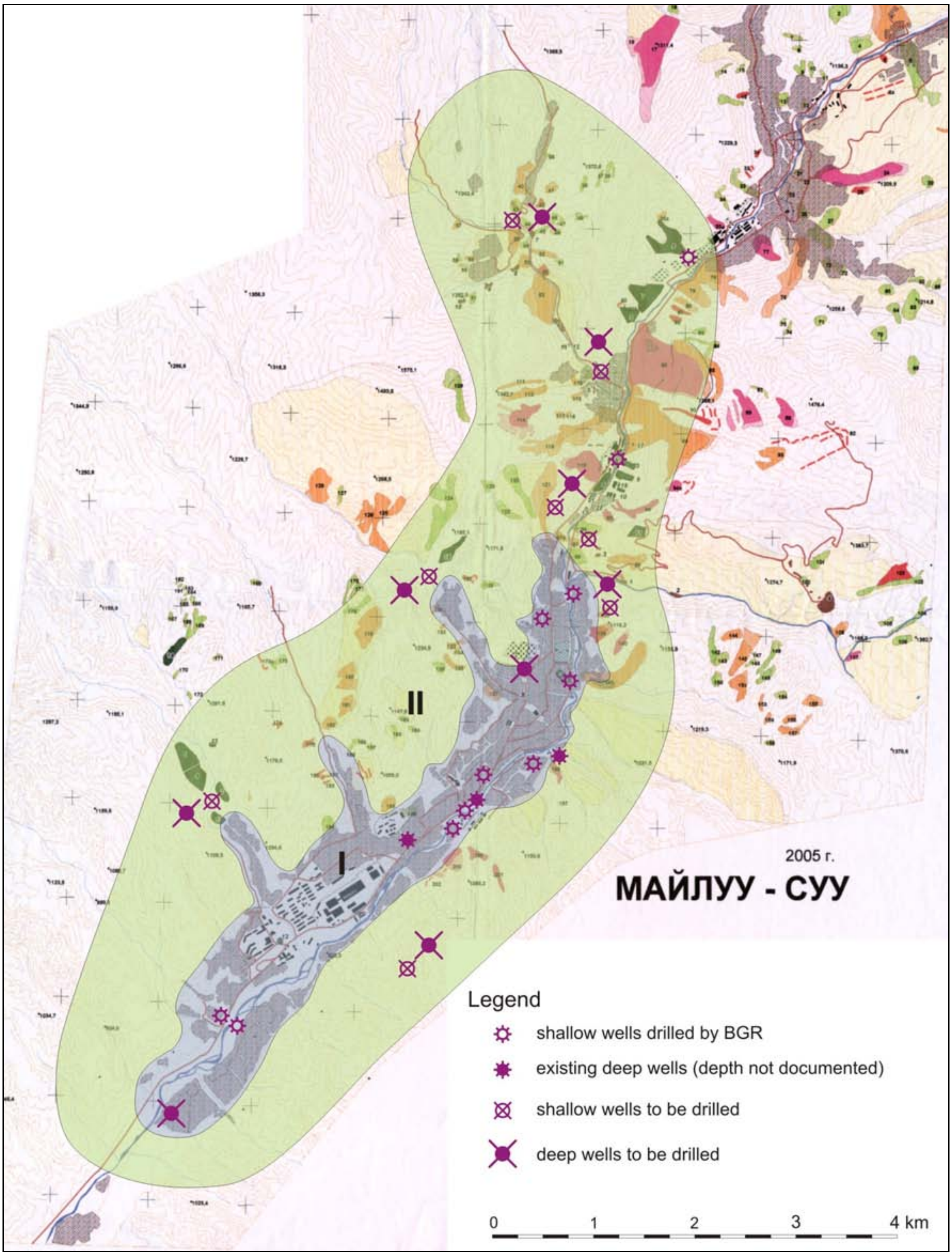

Figure 20: Sketch map with recommended locations of further monitoring wells inside (zone I) and around the city area of Mailuu-Suu (zone II), including wells already constructed by BGR (base map modified after MoE, 2005).

desorption processes.

In the absence of local drilling data, the exact depth of well drillings can be determined just in the field, while drilling works are carried out. If the groundwater level is reached, drilling should be continued for a few meters, in order to catch any seasonal variation of the groundwater level and to enable a sufficient filter length. It is not recommendable to construct multi-level groundwater-monitoring-wells to catch more than one aquifer by one drilling due to the high demand of sealing measures (PRINZ, 1991). Contrarily, every well should catch just one aquifer.

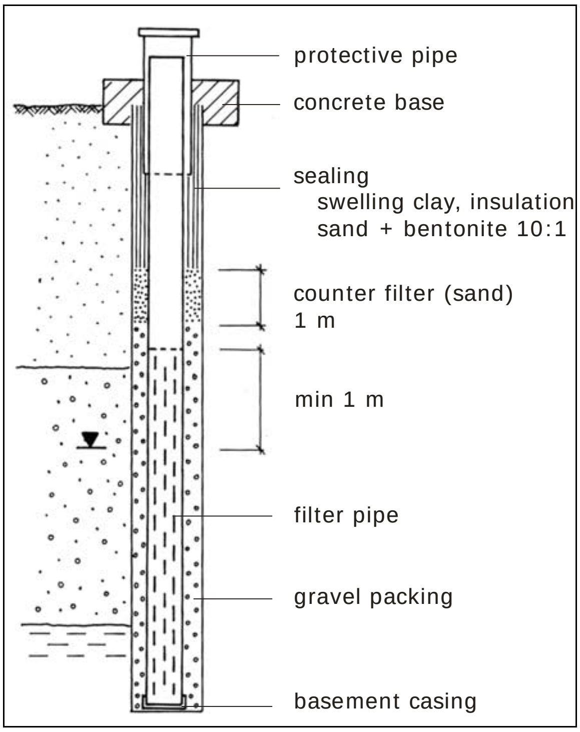

Figure 21: Recommended technical design of a groundwater monitoring well.

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ANNEX

ANNEX 1: Location and description of water sample stations (see Fig. 6)

ANNEX 2: Analytical data of water samples, January 2006 – April 2008

ANNEX 3: WHO-guideline values for drinking water (after WHO 2006)

ANNEX 4: Results [mg/L] of the Central Scientific Research Laboratory represented by Chuj Ecological Laboratory (comp. BGR-results ANNEX 2)

ANNEX 6: Information brochure given to citizens in Mailuu-Suu, translated into Russian

ANNEX 7: Interim Report of Centre for Radiation and Radioecology (ZSR), Leibnitz-University Hannover

ANNEX 8: “Radiological Evaluation of Waters from Mailuu-Suu, Kyrgyzstan”, ZSR-Presentation held during Public Information workshop, 18.9.2007, Mailuu-Suu

ANNEX 1: Location and description of water sample stations (see Fig. 6)

Stat. no.	Location	Type	Latitude north	Longitude east
1	Central water supply plant Mailuu-Suu: catchment basin, pre-filter system, 4-5 km N' Mailuu-Suu	surface water	41.329233°	72.528300°
2	Outflow, leakage in water supply pipe, ~1 km S' of water supply plant	surface water	41.31738	72.50054
3	Artesian well, Street of Pioneers (ул. Пионерская), apron of rusty steel pipe; used as drinking water; weak smell of H_2S	deep aquifer	41.313733°	72.493833°
4	Spring in urban area, outflow close to Mailuu-Say River S' of bus station; street No. 4, E' riverbank. Used as drinking water	quaternary	41.308783°	72.494633°
5	Seepage water, tailing No. 3 (+ 18): E' river-bank, opposite to ISOLIT; outflow close to the base of tailing 3 onto tailing 18	technogenic	41.282500°	72.475383°
6	Kulmin-Say river, tributary of Mailuu-Say: sampling close to inflow (west bank), high stream velocity	surface water	41.271150°	72.469883°
7	Spring below an adit, S' of road to ISOLIT; level of Mailuu-Say river, nearby leakage of oil; water foams due to degassing of H_2S	cretaceous	41.276050°	72.470333°
8	Well from lamp factory: sampling from collecting tank, well system on E' river bank producing bank filtrate of the Mailuu-Say	quaternary	41.238783°	72.445233°
9	Sampling of the outflow of the sewage treat-ment plant Mailuu-Suu, E' river bank; S' city center	surface water	41.230333°	72.431217°
10	Private dug well in village Kok-Tash: E' river bank, 7 km S' of Mailuu-Suu center; water used for irrigation and for drinking	quaternary	41.185833°	72.396233°
11	Seepage water at the base of tailing No. 5; collected by a well towards the Mailuu-Say-river (mixed with artesian groundwater)	technogenic	41.295600°	72.476933°
12	Porewater tailings impoundment no. 3 out of well 2 of 4 (the closest to Mailuu-Say); porewater level 3.40m (30.06.06)	technogenic	41.28232°	72.4762°
13	Small creek dewatering the southern area of shaft no. 10; runs into Kulmin-Say	surface water	41.269883°	72.497333°
14	Seepage water of tailings impoundment no. 16; collected by horizontal well at the southwestern end towards the Aschwas-Say; foams weakly	technogenic	41.272217°	72.454300°
15	Seepage water of tailings impoundment no. 13 into the river bed of Ailampa-Say;	technogenic	41.247533°	72.429217°
16	Spring in the vicinity of ISOLIT, running eastwards to the Mailuu-Say-river	cretaceous	41.282817°	72.475233°
17	Artesian water well near mosque; cords of oil and CH_4 gas bubbles (deep aquifer); no smell of H_2S	deep aquifer	41.251500°	72.459967°
18	creek behind tailings impoundment no. 6	surface water	41.304450°	72.479050°
19	Mailuu-Say downstream of tailings impoundments no. 5, 7, 6	surface water	41.289690°	72.476490°
20	private spring in Kara-Agach, not used as	tertiary	41.291000°	72.469980°

	drinking water			
21	Kara-Agach-river at the end of the village	surface water	41.291320°	72.470030°
22	Artesian well ('pumpstation'); water is transported north' of tailings impoundment no. 6 to this location via pipe	deep aquifer	41.278680°	72.472930°
23	Mailuu-Say downstream of tailings impoundments No. 3 ff	surface water	41.271500°	72.469470°
24	dug well east' city of Mailuu-Suu (Ul. Tuleberdieva)	quaternary	41.246150°	72.455280°
25	Artesian well Ul. Artesianskaya (in Mailuu-Suu); no smell of H_2S	deep aquifer	41.247380°	72.453000°
26	Bedre-Sai at Mailuu-Suu city border	surface water	41.251170°	72.444590°
27	Mailuu-Say downstream of Aschwasay	surface water	41.253970°	72.463190°
28	creek opposite tailings impoundment No. 7	surface water	41.299280°	72.483980°
29	Artesian spring Ul. Vostochnaya (Sarabiya); H_2S-smell	deep aquifer	41.306250°	72.498890°
30	downstream of Sarabee + Akbalyk rivers in Kogoi (Sarabiya)	surface water	41.31693	72.49076
31	Water from central water supply pipe, flat in Mailuu-Suu (Ul. Sabetschuka 6, Kw. 3)	surface water	41.25471	72.46055
32	Mailuu-Say north' of Kok-Tash (opposite to station 10)	surface water	41.19267	72.39813
33	Mailuu-Say down of Kulmin-Say	surface water	41.26813	72.47022
34	Mailuu-Say near sewage treatment plant	surface water	41.22982	72.4313
35	Artesian water well east' city	deep aquifer	41.25481	72.46926
36	spring in Kok-Tash	quaternary	41.20558	72.40712
37	spring in Kok-Tash	quaternary	41.20505	72.40662
38	Artesian well in Kok-Tash	deep aquifer	41.21446	72.41747
39	mountaineous spring east' of Njefteprom	tertiary	41.21004	72.42603
M1	Groundwater-monitoring-well downstream of T6	quaternary	41.30142	72.48172
M2	Groundwater-monitoring-well downstream of T3 (near Station 5)	quaternary	41.28242	72.4755
M4	Groundwater-monitoring-well north of city (western riverbank)	quaternary	41.26822	72.46786
M5	Groundwater-monitoring-well near gastinitza intourist (western river bank)	quaternary	41.26025	72.4705
M6	Groundwater-monitoring-well on eastern riverbank	quaternary	41.25453	72.46706
M7	Groundwater-monitoring-well in the mid of the city (western riverbank)	quaternary	41.25389	72.46061
M8	Groundwater-monitoring-well downstream of central mosque (western riverbank)	quaternary	41.25036	72.45947
M9	Groundwater-monitoring-well near location 24 (eastern riverbank)	quaternary	41.2487	72.45825
M10	Groundwater-monitoring-well near sewage water plant (western riverbank)	quaternary	41.22978	72.43027
M11	Groundwater-monitoring-well near sewage water plant (eastern riverbank)	quaternary	41.22903	72.43214

ANNEX 2: Analytical data of water samples, January 2006 – April 2008

Station ID	Sample ID	Sampling Date	Temp.	Eh	pH	ELC	DO	TIC	TOC	NPOC	Al	As	Ba	BO2	Br	Ca	Cl	HCO3 +CO3	Cr	Cs	Cu	F	Fe	K	Li	Mg	Mn	Mo
			°C	mV		µS/cm	mg/l	mg/l	mg/l	mg/l	µg/l	µg/l	µg/l	mg/l	mg/l	mg/l	mg/l	mg/l	µg/l	µg/l	µg/l	mg/l	mg/l	mg/l	µg/l	mg/l	µg/l	µg/l
1	1_1	Jan-06	0.3	243	7.43	240	10.15				2.4	<0.3	62	0.18	<0.01	36.6	2.3	133	12.6	0.00	1.1	0.08	0.053	3.1	1.3	6.7	1.7	1
1	1_2	Jul-06	11.6	393	6.2	193	10.67	22.5	0	1.2	21.3	<6	60	0.09	0.01	31.7	<0.1	118	0.8	<0.02	<0.8	0.05	0.006	0.5	8.3	4.5	1.0	0
1	1_3	Oct-06	9.5	176	8.4	221					3.0	0.3	68	0.15	<0.01	36.7	0.8	128	1.0	0.00	0.6	0.07	0.002	0.8	1.6	6.4	0.6	1
1	1_4	Mar-07			8.4	212					<3	0.3	59	0.21	0.00	38.7	0.8	139	0.9	0.00	0.3	0.09	<0.003	0.5	1.8	7.1	<0.5	1
10	10_1	Jan-06	9.6	79	6.79	1575	7.1				1.4	0.6	0	0.77	0.18	114.0	139.0	228	7.7	0.01	0.6	0.32	0.021	5.2	10.3	50.0	1.2	10
10	10_2	Jul-06	18.5	332	6.5	896	5.87	49.6	3.6	1.7	31.6	<6	30	0.50	0.06	69.9	51.3	234	2.0	<0.02	2.2	0.21	0.043	2.8	12.1	29.9	4.0	17
10	10_3	Oct-06	18.6	198	7.7	1072					4.0	1.1	54	0.57	0.09	106.0	71.3	275	1.8	0.01	0.7	0.19	0.005	4.0	9.3	33.5	0.6	15
10	10_4	Mar-07			7.5	1369					<3	0.6	63	0.67	0.12	108.0	140.0	232	2.9	0.01	1.0	0.22	<0.003	3.9	12.7	45.8	1.8	14
11	11_1	Jul-06	14	375	6.8	1693	1.45	110	27.8	2.9	271.3	1109.0	41	0.68	0.09	98.2	36.4	418	<5	<0.5	7.0	3.43	0.003	4.1	177.6	30.3	296.2	187
11	11_2	Oct-06	15.8		7.2	2120					10.0	1832.3	25	0.88	0.08	86.3	48.4	379	<0.5	0.28	<2	10.40	0.006	5.3	26.8	29.4	0.4	269
11	11_3	Mar-07			7.4	1902					4.0	1693.1	30	0.78		114.0	29.3	396	<1		3.0	9.53	<0.003	5.6	36.0	36.2	407.0	
12	12_1	Jul-06	27	261	6.6	1063	4.04	69.4	3.7	2.7	227.7	120.0	37	0.33	0.03	46.8	16.8	334	<5	<0.5	<20	2.55	0.01	5.4	18.0	13.9	79.0	66
13	13_1	Jul-06	17.1	221	7.7		8	90.8	0.1	7.7	10.8	<6	18	8.54	0.90	386.0	339.0	461	5.6	0.02	1.3	1.66	0.005	6.1	192.2	375.0	12.7	9
13	13_2	Nov-06	22.4		8	9900					16.0	18.8	16	18.16	1.15	405.0	449.0	510	1.6	0.03	2.7	2.36	0.089	19.3	282.0	641.0	0.1	18
13	13_3	Mar-07			8.1	6690					4.0	<3	15	7.74	1.19	308.0	408.0	360	4.4	0.01	1.6	1.37	<0.003	6.2	173.0	355.0	<5	10
14	14_1	Jul-06	23.3	329	8.7	9460	6.9	582	21.3	10.2	448.2	60.0	58	1.24	0.16	21.3	46.6	2850	32.7	<1	34.0	3.47	0.021	7.8	322.1	32.7	5.0	1443
14	14_2	Oct-06	18.8		8.8	12430					7.0	94.5	23	1.43	0.21	17.9	70.9	3598	3.5	0.13	17.3	4.18	0.015	11.7	52.0	47.8	<50	1946
14	14_3	Mar-07			8.6	10990					5.0	<60	25	1.31	0.24	23.2	77.4	3548	<2	<0.2	27.0	5.12	0.012	10.2	53.0	43.8	<100	
15	15_1	Jul-06	20.7	374	7.6	2100	7.5	114	6.8	3.8	19.4	<6	41	1.92	0.21	112.0	73.7	545	0.9	<0.02	2.0	0.49	0.011	14.1	46.5	75.5	58.5	324
15	15_2	Oct-06	16.9	220	7.5	2150					4.0	<0.6	37	2.17	0.20	126.0	92.9	522	0.6	0.01	4.2	0.68	0.004	14.5	42.5	83.6	1.7	366
16	16_1	Jul-06	13.1	308	6.9	1154	1.94	54	4.4	1.8	764.8	<6	54		0.12	88.0	37.5	252	1.6	0.11	0.9	0.38		3.2	36.2	39.4	23.2	12
16	16_2	Nov-06	15.6	175	7.5	971					3.0	0.3	40	0.62	0.09	84.4	31.2	253	0.5	0.01	0.5	0.46	0.003	3.3	22.8	36.4	1.1	12
16	16_3	Mar-07			7.7	822					23.0	<1.5	36	0.54	0.11	78.5	29.4	275	0.7	0.01	1.0	0.47	0.013	2.8	22.6	34.2	<2.5	12
17	17_1	Jul-06	18.5	279	6.7	2350	4.93	31.1	0.6	0.7	14.6	<6	14		0.57	54.5	299.0	155	7.0	<0.02	<0.8	0.20		3.5	35.2	26.6	<10	5
17	17_2	Oct-06	15.8	125	8.4	2360					2.0	1.1	13	0.48	0.50	58.5	313.0	155	8.0	0.01	0.4	0.41	0.008	3.7	32.9	28.5	1.1	5
17	17_3	Mar-07			8.6	2120					<3	0.9	12	0.45	0.69	54.8	317.0	162	5.7	0.01	0.2	0.23	0.004	3.7	31.0	27.0	<1	5
17	17_4	Apr-08			7.9	2360					4.0	1.1	12	0.38	0.60	55.2	312.0	155	7.3	0.02	0.4	0.09	0.009	3.5		26.9	1.5	5
18	18_1	Oct-06	19.4		8.2	1933					5.0	1.6	57	0.84	0.26	173.0	98.1	290	1.8	0.01	0.8	1.03	0.003	5.0	54.9	63.6	5.4	7
18	18_2	Mar-07			8.3	2020					77.0	<1.5	46	0.82	0.44	178.0	128.0	280	1.9	0.02	0.8	1.18	0.048	4.4	52.0	72.8	5.8	6
19	19_1	Oct-06	14.1		8.5	269					6.0	0.7	65	0.23	<0.01	40.1	3.7	142	0.7	0.00	0.4	0.10	0.005	1.0	2.5	8.2	1.5	2
19	19_2	Mar-07			8.5	274					47.0	0.8	39	0.27	0.01	41.5	3.5	161	1.2	0.01	1.4	0.18	0.045	1.1	4.4	10.2	2.8	2
2	2_1	Jan-06	0.9	93	6.85	234	9.63				3.1	0.3	51	0.18	0.01	37.3	3.0	134	5.1	0.00	2.5	0.08	0.021	2.8	1.3	6.6	1.7	1
20	20_1	Oct-06	18.4		7.7	3070					7.0	<1.5	17	1.77	0.10	336.0	42.4	493	<0.05	0.01	1.1	1.03	0.004	29.5	152.0	210.0	<2.5	31
20	20_2	Mar-07			7.8	2320					2.0	<3	11	1.49		265.0	35.2	469	<0.1	0.02	1.8	0.90	<0.003	28.2	118.0	153.0	<5	33
21	21_1	Oct-06	17.2		8.7	869					9.0	0.6	59	0.92	0.04	56.7	15.7	266	2.5	0.01	0.9	0.44	0.01	4.2	31.1	49.3	1.9	6
21	21_2	Mar-07			8.7	371						0.5	73		0.01	48.8	2.7	198	0.9	0.00	0.5	0.26		1.5	8.0	15.8	<0.5	3
22	22_1	Nov-06	30.1		7.9	402					2.0	10.2	80	0.20	0.02	44.1	4.9	195	0.0	0.15	0.2	0.56	0.054	1.5	6.9	21.6	3.4	8
23	23_1	Nov-06	13	0	8.7	303					4.0	0.4	64	0.24	0.01	41.9	4.4	148	0.8	0.00	0.4	0.12	0.005	0.9	3.7	9.7	2.0	2
23	23_2	Mar-07			8.5	303					143.0	0.7	39	0.28	0.01	44.6	3.9	168	1.4	0.02	1.2	0.20	0.124	1.2	4.5	11.7	9.4	2
24	24_1	Oct-06	14.4	171	7.2	1023					4.0	<0.3	66	0.50	0.07	110.0	43.1	365	1.8	0.01	0.7	0.25	0.005	3.9	11.5	37.0	0.5	8
24	24_2	Mar-07			7.4	889					<3	<0.6	56	0.38	0.10	95.9	42.2	314	1.6	0.01	0.6	0.34	0.011	3.7	14.5	34.0	1.5	11
25	25_1	Oct-06	17.3	170	8.2	1440					3.0	1.5	16	0.51	0.26	27.0	160.0	209	21.5	0.01	0.4	0.27	0.011	2.6	17.8	13.1	1.1	10
25	25_2	Mar-07			8.4	1291					<3	1.2	15	0.49	0.33	25.6	161.0	216	22.0	0.01	0.3	0.37	0.004	2.6	21.9	12.5	1.3	11
25	25_3	Apr-08			7.9	1408					2.0	2.1	15	0.39	0.28	26.0	157.0	209	23.0	0.02	0.4	0.64	0.017	2.4	29.4	12.5	1.6	10
26	26_1	Oct-06	16.5		8.7	2540					7.0	<1.5	49	2.26	0.23	161.0	116.0	345	4.5	0.01	1.4	0.69	0.008	7.0	44.5	119.0	4.6	5
26	26_2	Mar-07			8.7	587					16.0	0.6	30	0.50	0.03	56.5	14.8	220	2.4	0.00	1.4	0.32	0.016	1.5	12.5	25.5	5.4	2
27	27_1	Oct-06	11.5		8.5	330					11.0	0.4	57	0.28	<0.01	42.0	6.0	143	1.0	0.00	0.6	0.12	0.011	1.1	4.1	10.9	3.8	2
27	27_2	Mar-07			9.4	335					33.0	0.5	40	0.30	0.01	49.5	5.3	176	1.3	0.01	0.9	0.18	0.034	1.1	6.0	13.0	7.6	2
28	28_1	Oct-06	15.6		8.7	2440					14.0	2.1	33	1.81	0.25	116.0	93.2	317	2.8	<0.005	1.3	1.76	0.013	6.5	71.0	122.0	22.0	17
29	29_1	Oct-06	20.8		7.7	484					3.0	12.4	76	0.29	0.04	45.4	10.6	218	0.0	0.07	0.2	0.47	0.385	1.9	9.0	25.6	4.7	9
29	29_2	Mar-07			7.8	456					<3	14.9	76	0.28	0.05	45.3	12.6	228	0.0	0.07	0.3	0.57	0.42	1.8	11.7	25.6	6.1	10
3	3_1	Jan-06	24.1	<70	7.23	449	2.57				3.1	8.3	108	0.29	0.04	41.3	12.0	189	1.5	0.19	0.2	1.53	0.316	1.7	10.0	21.5	3.5	7
3	3_2	Oct-06	25.7		7.2	433					3.0	12.3	92	0.30	0.04	42.4	11.6	188	0.1	0.22	0.1	1.48	0.322	1.8	12.1	21.5	4.4	9
3	3_4	Mar-07			7.7	605					<3	10.1	311	0.30	0.36	53.9	87.1	194	0.0	0.20	0.1	1.78	0.419	1.8	12.0	23.6	25.3	9

To be continued →

Station ID	Sample ID	Na	NH4	Ni	NO2	NO3	Pb	PO4	Rb	Sb	SiO2	Tin	SO4	Sr	Th	U	V	Zn	calc TDS	18-O	2-H	3-H	Sum Anions	Sum Cations	E.N.
		mg/l	mg/l	µg/l	mg/l	mg/l	µg/l	mg/l	µg/l	µg/l	mg/l	µg/l	mg/l	mg/l	µg/l	µg/l	µg/l	µg/l	mg/l	‰	‰	TU	meq/l	meq/l	meq. %
1	1_1	2.9	0.02	7.7	0.01	2.8	0.1	0.16	0.3	0.1	5.1	0.024	13.7	0.148	0.000	0.4	0.5	1.7	207				2.59	2.59	0.03
1	1_2	2.1	0.02	3.53	0.01	1.3	<1		<2	0.1	3.9	<0.4	8.5	0.132	0.004	0.5	0.6	<3.6	171				2.14	2.07	-1.71
1	1_3	4	<0.01	0.33		1.8	0.5	0	0.3	0.9	4.7	0.06	15.6	0.169	0.000	0.3	0.5	1.4	199				2.48	2.56	1.60
1	1_4	3.1	<0.01	0.43		2.5	0.1	<0.03	0.2	1.1	5.6	<0.02	14.3	0.182	0.000	0.4	0.5	1.4	212				2.64	2.67	0.48
10	10_1	149	0.01	2.36	<0.05	44.0	<0.05	0.13	0.7	0.2	15.8	<0.02	422	1.438	0.000	6.0	2.8	24.5	1170				17.20	16.45	-2.21
10	10_2	66.2	0.01	2.75	0.01	25.3	<1		<2	0.4	14.4	<0.4	168	1.001	0.010	5.0	4.7	5.1	664	-13.19	-93.9	8.6	9.20	8.93	-1.50
10	10_3	77.1	<0.01	0.24		22.2	0.2	0.12	0.7	0.8	14.4	0.03	228	1.15	0.006	7.0	3.7	2.1	834				11.64	11.53	-0.47
10	10_4	138	<0.01	0.57		45.1	0.4	0.08	0.8	0.8	15.9	0.05	336	1.45	0.000	6.9	2.8	4.7	1067				15.49	15.30	-0.64
11	11_1	219	0.01	74.95	28.3	16.0	20.0		<50	1.1	15.2	<10	414	0.673	0.112	8639.0	17.4	<5	1298	-12.04	-86.8	10.2	16.94	17.16	0.64
11	11_2	341	<0.01	5.79		89.1	<2.5	1.02	7.9	1.6	17.5	<1	586	0.657	0.087	8511.0	22.9	<9	1606	-11.96	-87.9	10.9	21.80	21.79	-0.03
11	11_3	302	<0.01	<5		83.9	<5	0.88			16	<2	571	0.814		11274.3	22.0	<3	1580				21.10	22.06	2.23
12	12_1	154	<0.01	57.41	0.01	21.8	<20		<50	<1	5.9	<10	208	0.365	0.325	2873.0	<5	<5	816	-14.45	-105.1		10.77	10.36	-1.90
13	13_1	905	0.03	4.51	<0.01	6.5	<1		<2	0.2	12.6	<0.4	3381	8.389	0.009	131.0	1.9	<3.6	5892	-12.46	-90.1	11.6	87.76	89.87	1.19
13	13_2	1531	0.17	3.59		1.6	<1	0.21	3.2	4.3	11.6	<0.4	5436	9.07	0.080	151.0	2.8	5.3	9036				134.44	140.31	2.13
13	13_3	990	0.01	1.55		5.8	<0.5	<0.03	1.3	1.6	6.3	<0.2	3376	6.96	0.003	117.1	1.6	9.7	5833				87.92	87.99	0.04
14	14_1	2160	0.01	102.37	0.13	7.0	40.0		<100	<2	9.8	<20	2348	1.082	0.118	28772.0	45.8	<5	7526	-11.34	-85	54.9	100.29	98.05	-1.13
14	14_2	3423	<0.01	<2		6.4	<5	1.07	<10	2.9	9.7	2.16	4173	0.887	0.106	36079.0	63.3	31.2	11406	-10.82	-81.9	78.2	152.13	154.06	0.63
14	14_3	3160	<0.01	<5		7.4	<10	0.92	<20		9.8	<4	4088	1.02	<0.02	27507.3	41.0	<3	11005				146.22	142.52	-1.28
15	15_1	225	0.02	5.74	<0.01	22.9	<1		<2	0.4	13.8	<0.4	552	1.991	0.015	330.0	2.6	36.3	1640	-12.75	-91.9	8.7	22.91	22.01	-2.00
15	15_2	256	<0.01	4.35		19.0	0.3	0.01	1.3	2.0	14.6	0.05	608	2.1	0.011	318.0	2.5	9.7	1743	-13.12	-90.5		24.70	24.73	0.07
16	16_1	88.4	0.01	2.58	0.02	2.3	<1		<2	0.2		<0.4	324	1.22	0.080	112.0	3.5	4.5	838	-13.12	-90.5	12.9	12.00	11.68	-1.33
16	16_2	76.3	<0.01	0.45		1.7	<0.05	0.01	0.7	0.6	10.9	0.03	277	1.13	0.003	82.0	2.4	0.5	777				10.85	10.64	-0.97
16	16_3	72.2	<0.01	0.44		2.8	<0.25	<0.03	0.6	1.9	9.8	<0.1	222	1.04	0.003	73.3	1.9	<3	729				10.03	9.98	-0.29
17	17_1	402	<0.01	2.47	<0.01	12.1	<1		2.3	<0.04		<0.4	538	2.241	0.011	7.0	4.5	<3.6	1494	-14.86	-110.4	<0.9	22.40	22.54	0.33
17	17_2	393	<0.01	0.15		12.1	<0.1	0	2.3	0.5	10.5	0.06	540	2.28	0.030	7.0	5.0	<0.4	1518				22.84	22.51	-0.73
17	17_3	400	<0.01	0.13		12.6	<0.1	<0.03	1.9	1.1	10.4	<0.04	489	2.21	<0.0002	5.6	4.0	1.5	1480				22.01	22.51	1.12
17	17_4	398	0.03	0.2	<0.01	12.5	0.3	<0.02	2.0	0.8	10.1	0.03	560	2.19	0.001	6.7	5.3	0.9	1537				23.22	22.42	-1.75
18	18_1	187	<0.01	0.47		15.9	0.3	0	2.4	1.2	17.1	0.05	690	3.05	0.025	44.0	10.0	1.3	1545	-12.37	-91.2	9.7	22.21	22.21	0.00
18	18_2	231	<0.01	0.78		18.3	0.4	<0.03	2.4	0.1	15.9	<0.1	795	3.28	0.024	39.7	7.4	4.0	1729				25.13	25.13	0.00
19	19_1	6.2	<0.01	0.39		2.4	0.1	<0.01	0.3	0.6	5.6	0.03	21.1	0.267	0.002	5.0	0.5	0.6	231	-12.56	-85.8	14.4	2.92	2.98	1.10
19	19_2	9.8	<0.01	0.65		4.6	0.2	<0.03	0.5	6.3	7.2	0.03	28.6	0.357	0.022	3.2	1.1	1.4	269				3.42	3.38	-0.55
2	2_1	3.4	0.55	2.85	0.01	2.9	<0.03	0.1	0.5	0.1	5	0.043	13.8	0.137	0.000	0.3	0.4	6.5	210				2.63	2.66	0.65
20	20_1	154	<0.01	1.6		76.9	<0.25	0.02	4.6	1.1	16.3	<0.1	1524	4.73	0.017	144.0	3.8	4.9	2890	-12.18	-87.4	12.6	42.32	41.64	-0.82
20	20_2	111	0.05	2.65		54.3	<0.5	<0.03	3.9	2.2	15	<0.2	1110	3.61	0.003	103.2	5.4	73.0	2247				32.73	31.47	-1.96
21	21_1	65.1	<0.01	0.65		7.2	0.2	0.01	1.0	1.4	11.5	0.04	228	1.24	0.004	39.0	2.0	0.8	706	-12.09	-87.5	12.5	9.69	9.86	0.87
21	21_2	13.5	<0.01	0.18		4.3	0.1		0.5	0.2		0.03	54.1	0.5646	0.002	6.8	2.2	4.4	340				4.53	4.38	-1.74
22	22_1	9.8	<0.01	0.12		0.1	<0.05	0.02	1.9	2.7	10	<0.02	49.3	1.13	0.002	0.3	<0.01	0.5	338				4.39	4.47	0.89
23	23_1	9.1	<0.01	0.34		2.3	0.1	0	0.4	1.1	5.7	0.07	31.7	0.305	0.001	7.0	0.5	0.3	254				3.25	3.32	0.98
23	23_2	10.8	<0.01	0.87		4.8	0.2	<0.03	0.6	9.5	7.9	0.02	37.7	0.41	0.050	5.0	1.3	1.4	292				3.74	3.72	-0.28
24	24_1	69	<0.01	0.48		21.9	0.3	0.01	0.8	0.7	12.7	0.03	195	1.26	0.014	15.0	0.7	1.8	860	-12.83	-90.3	12.2	11.63	11.67	0.17
24	24_2	60.6	<0.01	0.6		15.9	0.2	<0.03	0.9	1.1	11.3	<0.04	189	1.12	0.001	16.3	0.9	3.9	769				10.55	10.34	-0.99
25	25_1	252	<0.01	0.02		6.1	0.2	0	1.3	0.6	11.8	0.04	277	1.12	0.010	7.0	7.0	0.5	961				13.82	13.48	-1.25
25	25_2	257	<0.01	0.18		5.6	0.2	<0.03	1.4	1.2	11.6	<0.04	262	1.06	0.000	7.0	7.6	3.6	956				13.65	13.58	-0.27
25	25_3	261	0.02	0.2	<0.01	6.8	0.4	<0.02	1.4	0.9	11.2	0.02	288	1.06	0.001	6.9	8.0	1.7	976				14.00	13.77	-0.82
26	26_1	269	0.05	0.31		23.9	<0.25	0.02	0.5	1.2	14.5	<0.1	973	3.58	0.017	29.0	1.6	1.2	2035				30.13	29.80	-0.55
26	26_2	43.5	<0.01	0.35		4.9	0.1	<0.03	0.3	1.9	10.3	<0.02	144	0.629	0.003	5.7	1.6	0.5	523				7.12	6.87	-1.81
27	27_1	12.9	<0.01	0.74		3.6	0.2	0	0.4	1.1	6.1	0.07	45.2	0.338	0.002	6.0	0.6	0.3	272				3.52	3.59	1.05
27	27_2	13.5	<0.01	0.56		5.1	0.2	<0.03	0.4	5.0	8	0.03	46.6	0.427	0.010	5.9	1.0	0.8	319				4.10	4.17	0.89
28	28_1	277	0.07	0.86		9.0	<0.25	0.01	2.9	1.9	11.8	<0.1	1001	3.49	0.022	125.0	13.0	<0.9	1961				28.92	28.14	-1.36
29	29_1	22.4	0.02	0.07		0.1	0.1	0.01	2.2	1.9	10.6	0.02	68.8	1.3	0.005	0.1	0.0	0.9	406				5.33	5.43	0.91
29	29_2	25.6	0.05	0.24		0.0	0.1	<0.03	2.6	2.4	10.5	<0.02	70.2	1.25	0.000	0.1	0.0	1.3	422				5.59	5.56	-0.22
3	3_1	17.9	0.07	0.98	<0.01	0.1	<0.05	0.04	2.2	0.9	12.1	0.078	53.6	1.514	0.002	0.0	0.0	0.2	353				4.64	4.69	0.56
3	3_2	17.4	0.02	0.24		0.0	<0.05	<0.03	2.6	1.7	12.4	0.03	55.6	1.88	0.001	0.0	<0.01	0.2	355	-13.41	-93.1	14.4	4.65	4.74	0.96
3	3_4	49	0.04	0.11		0.0	<0.05	<0.03	2.5	1.7	12.7	<0.02	53.3	2.41	0.000	0.1	0.0	0.5	481				6.85	6.87	0.20

← To be continued →

Station ID	Sample ID	Sampling Date	Temp.	Eh	pH	ELC	DO	TIC	TOC	NPOC	Al	As	Ba	BO2	Br	Ca	Cl	HCO3 +CO3	Cr	Cs	Cu	F	Fe	K	Li	Mg	Mn	Mo
			°C	mV		µS/cm	mg/l	mg/l	mg/l	mg/l	µg/l	µg/l	µg/l	mg/l	mg/l	mg/l	mg/l	mg/l	µg/l	µg/l	µg/l	mg/l	mg/l	mg/l	µg/l	mg/l	µg/l	µg/l
30	30_1	Oct-06	14.5		8.5	414					10.0	0.4	40	0.76	0.00	56.3	2.7	213	1.4	0.00	1.3	0.19	0.011	1.5	5.2	16.0	1.9	1
30	30_2	Mar-07			8.7	312					41.0	0.4	27	0.45	<0.01	51.6	1.6	188	1.7	0.01	0.9	0.19	0.042	0.9	3.9	11.7	1.4	1
31	31_1	Oct-06			6.6	251					5.0	0.4	64	0.16	0.00	37.3	0.7	127	0.7	0.00	1.3	0.07	0.003	0.5	1.4	6.2	<0.5	1
32	32_1	Oct-06			6.8	451					5.0	0.6	0	0.33	0.03	50.1	11.5	167	1.0	0.00	1.0	0.14	0.009	1.3	5.6	15.4	3.7	11
32	32_2	Mar-07			8.3	256						0.3	103		0.01	39.5	4.1	145	1.0	0.00	0.8	0.14		1.5	3.3	8.7	<0.5	4
32	32_3	Apr-08			7.3	322					27.0	0.5	49	0.14	0.01	42.3	4.8	137	1.0	0.01	1.0	0.12	0.024	0.9	18.9	8.9	3.4	4
33	33_1	Mar-07			8.7	317					111.0	0.6	39	0.29	0.01	48.7	4.4	174	1.4	0.02	1.2	0.17	0.108	1.1	5.7	11.9	9.5	2
33	33_2	Apr-08			7.6	268					56.0	0.5	39	0.13	<0.01	37.6	3.0	134	1.2	0.01	1.0	0.11	0.082	0.8	2.8	7.6	6.4	1
34	34_1	Mar-07			8.3	235					17.0	0.3	45	0.16	0.01	37.1	3.9	136	1.1	0.01	1.5	0.11	0.019	1.0	2.4	7.5	3.4	1
35	35_1	Mar-07			7.4	2300					113.0	<1.5	17	0.70	0.38	141.0	197.0	350	1.6	0.03	1.3	0.48	0.113	2.7	40.5	112.0	6.2	10
36	36_1	Mar-07			7.2	1149					<3	<0.6	63	0.75	0.10	128.0	52.6	439	0.4	0.01	3.5	0.14	<0.003	3.7	14.8	46.1	1.4	6
37	37_1	Mar-07			7.2	971					<3	<0.6	39	0.67	0.09	106.0	38.8	378	1.2	0.01	1.7	0.17	<0.003	3.2	13.4	39.0	<1	21
38	38_1	Mar-07			8.1	1081					<3	1.7	33	0.87	0.22	14.5	113.0	336	0.0	0.01	1.4	1.12	0.682	2.8	23.5	6.4	21.6	36
38	38_2	Apr-08			7.9	1176					4.0	1.7	32	0.76	0.19	13.4	107.0	324	0.1	0.01	0.3	0.98	0.551	2.3	2.3	6.2	18.8	34
39	39_1	Mar-07			8.3	1072					26.0	0.9	67	0.54	0.16	84.7	53.9	279	1.9	0.05	1.3	0.73	0.34	2.0	21.5	48.0	19.0	14
4	4_1	Jan-06	5	104	7.05	373	8.82				1.2	<0.3	23	0.14	0.01	54.5	4.3	204	5.9	0.00	0.9	0.38	0.033	2.8	5.0	13.1	0.7	3
4	4_2	Jul-06	15.6	354	6.5	577	8.7	64.1	5.1	1.5	10.3	<6	53	0.35	0.02	79.9	6.7	300	0.8	<0.02	1.1	0.35	0.001	2.7	11.1	18.6	1.0	3
4	4_3	Oct-06	15.6		7.8	360					2.0	<0.3	32	0.24	<0.01	51.9	2.4	211	0.7	0.00	0.6	0.42	0.002	3.4	5.9	11.9	<0.5	4
4	4_4	Mar-07			8	282					<3	<0.3	23	0.14	<0.01	47.0	1.8	182	0.6	0.00	0.6	0.42	<0.003	1.5	4.9	10.9	<0.5	4
5	5_1	Jan-06									20.5	2.7	35	0.47	0.02	51.2	23.5	512	1.2	0.01	1.6	0.34	0.023	4.2	14.7	26.2	16.4	25
5	5_2	Jul-06	24.7	317	7.1	2390		148	6.2	7	71.2	<30	71	0.99	0.05	51.8	35.9	721	3.0	<0.1	<4	0.63	0.118	6.7	52.8	34.2	351.3	52
5	5_3	Nov-06	17.3	220	8.2	2430					65.0	4.3	30	0.78	0.02	51.7	39.5	675	0.2	0.02	1.5	0.93	0.058	6.2	37.6	38.2	34.0	52
5	5_4	Mar-07			8.5	784					43.0	3.1	6	0.36	0.01	56.5	11.9	311	0.5	0.01	5.2	0.56	0.025	4.2	13.0	17.2	<5	25
6	6_1	Jan-06	1.2		7.6	4910	12				5.7	<3.3	17	3.22	0.67	228.0	233.0	397	14.8	0.01	2.4	1.13	0.023	8.6	109.9	236.0	89.7	15
6	6_2	Jul-06	22.4	298	6.6	4640	7.88	52.8	0	5.5	21.6	<6	36	3.49	0.60	209.0	203.0	269	8.7	0.03	1.4	1.27	0.008	9.7	121.1	216.0	70.6	26
6	6_3	Nov-06	15.7	190	8.6	5110					13.0	<3	19	3.65	0.65	234.0	256.0	307	11.4	0.03	1.1	1.05	0.01	9.3	113.0	247.0	32.8	18
6	6_4	Mar-07			8.7	3690						<3	31		0.62	240.0	190.0	267	7.2	0.02	1.7	1.25		7.5	94.6	181.0	<5	28
7	7_1	Jan-06	19	<340	7.34	2490	0.8				33.4	<15	314	1.68	0.44	107.0	151.0	1247	4.9	0.07	4.1	1.52	0.023	8.6	98.5	91.3	13.0	3
7	7_2	Jul-06	22	<117	7.9	2550	1.53	204	19.9	7.4	26.8	<6	173		0.06	93.4	136.0	936	0.3	0.06	<0.8	1.35		8.1	97.5	94.1	10.7	3
7	7_3	Nov-06	22.3	-352	7.2	2500					4.0	0.9	226	1.77	0.41	116.0	167.0	1010	0.1	0.05	<0.08	1.34	0.005	9.1	84.0	99.9	9.3	3
7	7_4	Mar-07			7.2	2310						8.0	198		0.03	88.0	194.0	881	0.1	0.04	<0.08	1.07		8.8	90.0	98.0	<1	8
8	8_1	Jan-06	14.7	<119	6.88	1163	4.72				1.3	<0.6	57	0.77	0.07	114.0	38.7	368	4.2	0.01	0.7	0.33	0.018	4.1	16.4	46.2	1.0	8
8	8_2	Jul-06	16.1	326	6.9	1160	9.55	81	7.2	1.8	11.9	<6	59		0.07	105.0	34.0	375	1.8	<0.02	1.5	0.23		2.6	20.6	43.3	<10	7
8	8_3	Oct-06	18.5		7.2	1241					4.0	<0.3	62	0.90	0.10	121.0	41.4	377	1.4	0.01	0.7	0.27	0.004	3.4	18.7	51.8	<0.5	7
8	8_4	Mar-07			7.3	1150					5.0	<0.6	56	0.78	0.10	112.0	39.4	371	1.5	0.01	0.7	0.30	0.005	3.1	20.4	49.3	<1	8
9	9_1	Jan-06									6.5	<0.6	50	0.21	0.01	36.6	9.3	159	7.3	0.01	3.0	0.08	0.16	3.8	1.5	6.8	23.8	10
9	9_2	Jul-06	20.7	450	6.2	309	8.05	37.8	11.1	3.5	434.4	<6	78		<0.01	33.9	7.9	136	3.6	0.05	5.9	0.06		2.9	5.2	5.0	54.3	7
9	9_3	Oct-06	16.6	220	7.7	327					10.0	0.4	68	0.23	<0.01	39.2	10.9	103	0.4	0.01	1.6	0.07	0.144	2.7	2.0	6.6	16.7	16
9	9_4	Mar-07			7.6	281					18.0	0.4	52	0.20	0.00	35.2	11.4	96.8	0.4	0.02	1.7	0.09	0.092	2.4	2.0	5.7	51.0	39
M10	M10-1	Mar-07			7.5	2400						<1.5	20		0.36	131.0	93.7	282	1.9	0.03	0.9	0.91		7.5	40.6	98.5	<2.5	274
M10	M10-2	Apr-08			7.5	2420					7.0	<1	17	1.82	0.10	154.0	97.5	403	3.0	0.04	1.3	0.48	0.012	5.1	10.9	109.0	2.3	126
M1	M1-1	Mar-07			7.3	710					471.0	<3		0.54	0.02	59.8	5.7	417	3.9	0.05	2.2	0.99	0.457	6.6	24.2	25.5	42.1	8
M11	M11-1	Mar-07			7.4	940						<0.6	60		0.10	75.6	38.2	312	0.7	0.02	1.2	0.38		5.3	17.2	36.0	<1	154
M2	M2-1	Mar-07			7.4	367																						
M4	M4-1	Mar-07			7.4	830						0.4	50		0.04	86.4	21.7	356	0.9	0.02	0.5	0.40		5.3	23.5	43.6	<0.5	28
M5	M5-1	Mar-07			7.3	1774					13.0	<1.5	65	0.99	0.30	120.0	75.9	389	0.2	0.02	1.6	0.29	0.022	5.5	27.0	67.3	10.0	3
M5	M5-2	Apr-08			7.5	1930					3.0	0.4	16	0.88	0.21	119.0	74.1	376	0.1	0.01	1.6	0.14	0.007	3.6	7.0	66.7	0.7	2
M6	M6-1	Mar-07			7.4	1715						<1.5	38		0.28	153.0	148.0	274	1.0	0.02	1.0	0.07		5.6	18.8	68.5	<2.5	29
M7	M7-1	Mar-07			7.6	933						<0.6	37		0.11	86.9	39.0	371	5.3	0.02	0.9	0.75		7.2	29.9	48.3	<1	37
M7	M7-2	Apr-08			7.2	1600					3.0	0.9	188	0.57	0.06	125.0	26.8	398	0.3	0.02	5.5	0.35	0.001	8.1	23.3	28.7	2.1	15
M8	M8-1	Mar-07			7.6	624					17.0	0.6	142	0.40	0.05	84.4	17.5	264	1.1	0.01	1.4	0.24	0.013	4.2	6.4	17.4	35.9	11
M8	M8-2	Apr-08			7.6	768					59.0	0.4	55	0.55	0.08	54.4	29.1	265	0.6	0.01	2.5	0.56	0.093	4.1	16.1	19.0	23.8	29
M9	M9-1	Mar-07			7.3	723					58.0	<0.3	79	0.37	0.06	76.7	27.1	290	1.3	0.01	1.1	0.28	0.032	2.9	8.8	28.6	7.7	9
M9	M9-2	Apr-08									95.0	<0.5	67	0.29	0.06	74.1	31.0		1.7	0.03	2.0	0.36	0.118	3.5	8.0	25.3	7.8	10

← To be continued →

Station ID	Sample ID	Na	NH4	Ni	NO2	NO3	Pb	PO4	Rb	Sb	SiO2	Tin	SO4	Sr	Th	U	V	Zn	calc TDS	18-O	2-H	3-H	Sum Anions	Sum Cations	E.N.
		mg/l	mg/l	µg/l	mg/l	mg/l	µg/l	mg/l	µg/l	µg/l	mg/l	µg/l	mg/l	mg/l	µg/l	µg/l	µg/l	µg/l	mg/l	‰	‰	TU	meq/l	meq/l	meq. %
30	30_1	12	<0.01	0.53		4.9	0.1	<0.03	0.3	1.2	11.4	0.02	41.6	0.448	0.002	1.9	1.5	0.7	361				4.52	4.70	1.92
30	30_2	10.5	<0.01	0.68		5.3	0.2	<0.03	0.3	4.7	9.6	0.02	33.1	0.363	0.008	1.4	1.4	4.5	313				3.91	4.03	1.52
31	31_1	2.5	<0.01	0.4		2.2	0.1	<0.01	0.2	0.7	4.8	<0.02	12.9	0.172	0.001	0.3	0.5	2.6	195				2.41	2.50	1.83
32	32_1	22.8	<0.01	2.2		5.2	0.1	0.04	0.4	1.2	6.5	0.36	77.4	0.458	0.001	12.0	0.6	23.6	358				4.77	4.81	0.41
32	32_2	8.3	<0.01	0.27		3.7	<0.05		0.5	0.5		<0.02	30.7	0.302	0.001	3.9	1.5	0.6	242				3.20	3.10	-1.64
32	32_3	9.6	0.01	1.2	<0.01	19.7	0.1	<0.02	0.4	2.2	6.6	0.01	33.1	0.298	0.003	3.4	0.8	0.7	264				3.40	3.30	-1.45
33	33_1	11	0.01	0.71		5.0	0.2	<0.03	0.6	4.3	8.3	<0.02	41.7	0.395	0.033	5.6	1.4	0.9	307				3.93	3.94	0.07
33	33_2	6.2	0.01	1	<0.01	4.7	0.3	0.03	0.3	3.4	6.2	0.01	23.6	0.272	0.006	2.3	0.8	0.6	225				2.86	2.81	-0.87
34	34_1	6.4	<0.01	1.02		3.8	0.2	<0.03	0.4	1.7	6	0.02	21.5	0.23	0.003	2.4	0.7	1.8	224				2.85	2.78	-1.29
35	35_1	266	0.01	0.78		23.2	0.3	<0.03	1.0	0.1	14.6	<0.1	744	3.07	0.027	34.5	2.5	2.4	1856				27.20	27.98	1.42
36	36_1	89.9	0.01	2.21		27.0	0.5	<0.03	0.8	1.1	13.2	<0.04	247	1.24	0.000	21.3	1.3	4.5	1049				14.27	14.22	-0.18
37	37_1	77.5	<0.01	1.08		22.6	1.2	<0.03	0.8	0.2	12.9	0.06	205	1.01	0.001	19.4	1.5	4.6	885				11.94	11.98	0.18
38	38_1	247	<0.01	0.45		0.0	0.7	<0.03	1.9	0.2	14.5	0.04	160	0.52	0.001	11.3	2.9	<3	898				12.09	12.08	-0.03
38	38_2	233	<0.01	0.3	<0.01	0.0	0.2	0.02	1.5	0.8	13.6	0.01	162	0.523	0.001	10.7	2.6	0.7	865				11.76	11.39	-1.60
39	39_1	84.7	<0.01	1.3		8.5	0.4	<0.03	0.8	0.2	22.3	<0.04	268	1.56	0.044	19.7	5.8	3.3	855				11.85	11.96	0.43
4	4_1	7.5	<0.01	4.28	<0.01	6.3	<0.05	0.05	0.2	0.1	7.3	0.027	26	0.338	0.000	2.0	0.3	0.6	327				4.13	4.21	0.88
4	4_2	14.5	<0.01	3.55	0.18	13.7	<1		<2	0.3	11.5	<0.4	48.7	0.642	<0.002	4.0	0.5	<3.6	498	-13.04	-88.7	12.7	6.36	6.24	-0.97
4	4_3	8.9	<0.01	0.66		2.7	0.1	0.02	0.4	1.0	10.1	0.03	18.5	0.42	0.000	2.0	0.5	0.6	322				3.98	4.06	0.97
4	4_4	5.1	<0.01	0.62		4.9	0.1	<0.03	0.2	1.3	6.9	0.03	17.4	0.344	0.000	2.1	0.2	1.4	279				3.50	3.51	0.20
5	5_1	317	0.43	2.17	0.02	2.1	0.2	0.1	0.9	0.7	9.2	0.112	437	0.598	0.006	1696.0	3.2	0.8	1386				18.22	18.65	1.16
5	5_2	480	0.01	8.59	<0.01	1.2	<5		<10	0.4	14.6	<2	623	0.941	0.025	1096.0	3.9	5.0	1973	-11.81	-84.9		25.86	26.50	1.23
5	5_3	526	<0.01	4.18		0.9	<0.5	0.07	2.3	6.6	14.4	0.26	719	0.952	0.012	1763.0	6.7	<1.8	2076				27.73	28.80	1.89
5	5_4	112	<0.01	1.19		0.1	0.6	<0.03	<1	4.0	8.4	0.21	188	0.566	0.007	925.5	2.7	<3	712				9.38	9.24	-0.79
6	6_1	669	0.01	5.06	<0.1	17.5	<0.55	0.06	<1.1	0.1	11.3	<0.22	2230	4.972	0.007	173.0	1.4	<2	4042				59.97	60.25	0.24
6	6_2	617	0.02	6.6	<0.01	17.3	<1		2.1	0.3	11.4	<0.4	2121	5.35	0.032	222.0	3.0	<3	3685	-12.14	-88.1	10.8	54.68	55.44	0.69
6	6_3	755	<0.01	0.26		16.4	<0.5	0.01	1.6	1.6	11.1	0.25	2456	5.2	0.005	171.0	2.2	<1.8	4303				63.75	65.22	1.14
6	6_4	507	<0.01	1.18		13.4	0.6		1.2	0.4		<0.2	1850	4.2633	<0.001	135.3	2.0		3262				48.57	49.23	0.68
7	7_1	308	1.3	7.8	0.3	1.4	<2.5	0.27	<5	<0.1	15.4	<1	147	2.96	0.016	114.0	4.3	9.5	2087				27.92	26.64	-2.36
7	7_2	276	0.65	2.49	<0.01	0.2	<1		6.0	0.1		<0.4	250	3.419	0.008	180.0	3.2	<3.6	1800	-13.28	-94.7	11	24.46	24.75	0.60
7	7_3	314	<0.01	0.1		0.3	<0.1	0.09	6.2	0.1	17	0.04	305	3.47	0.001	137.0	3.3	<0.4	2046				28.72	28.00	-1.27
7	7_4	331	0.08	0.1		<0.03	<0.1		5.7	0.3		<0.04	357	2.9355	0.001	100.5	1.7	0.6	1962				27.41	27.17	-0.44
8	8_1	73.4	0.01	3.29	0.04	20.5	<0.1	0.09	0.9	0.2	12.8	0.045	277	1.356	0.000	29.0	1.1	0.6	958				13.26	12.82	-1.68
8	8_2	72.4	<0.01	3.61	<0.01	21.3	<1		<2	0.2		<0.4	246	1.327	0.005	29.0	1.1	4.5	902	-12.79	-90	11.3	12.59	12.06	-2.15
8	8_3	83.2	<0.01	0.93		26.1	0.1	0.01	1.0	0.7	14	0.05	272	1.6	0.001	30.0	1.2	1.1	993				13.45	14.05	2.18
8	8_4	86.4	<0.01	0.87		21.1	0.1	<0.03	0.9	1.2	13.3	<0.04	303	1.51	0.001	29.4	1.0	2.4	1001				13.86	13.52	-1.24
9	9_1	9.6	6.9	3.67	2.7	1.5	0.2	2.1	1.1	0.5	5.3	0.045	17.8	0.153	0.001	1.0	0.3	4.2	262				3.34	3.29	-0.73
9	9_2	8.7	5.4	6.37	0.01		1.7		<2	1.2		<0.4	13.3	0.153	0.038	1.0	1.4	29.2	214	-13.07	-90.2	12.6	2.73	2.91	3.20
9	9_3	8.9	<0.01	3.8		34.1	0.3	2.25	1.5	4.4	5.1	0.05	16	0.187	0.010	1.0	0.4	75.0	230				2.95	2.97	0.19
9	9_4	13.9	<0.01	17.23		35.2	0.4	2.42	1.4	7.8	6.1	0.03	15.6	0.178	0.004	0.6	0.7	42.8	226				2.88	2.90	0.36
M10	M10-1	253	0.03	2.68		51.1	<0.25		2.3	0.3		<0.1	901	2.685	<0.0005	90.0	2.5		1822				26.91	25.91	-1.90
M10	M10-2	249	0.03	1.7	<0.01	62.0	0.3	0.04	1.3	6.5	14.6	0.06	857	2.85	0.006	232.6	2.1	4.0	1957				28.24	27.69	-0.99
M1	M1-1	69.4	<0.01	7.22		15.5	1.3	0.03	1.5	6.1	17.6	<0.2	67.2	0.723	0.151	942.7	3.9		689				8.70	8.35	-2.07
M11	M11-1	96	<0.01	1.31		19.6	0.1		1.0	0.4		<0.04	218	1.0112	<0.0002	136.7	1.8	2.6	803				11.07	11.07	0.02
M2	M2-1																						0.00	0.00	0.00
M4	M4-1	41.6	<0.01	7.28		33.1	0.1		2.5	0.3		<0.02	144	1.3136	0.001	10.7	1.9	2.4	734				10.00	9.88	-0.61
M5	M5-1	217	<0.01	3.88		16.1	21.7	<0.03	1.7	1.7	16.8	<0.1	597	3.232	0.003	26.3	1.6	3.0	1510				21.23	21.19	-0.11
M5	M5-2	221	<0.01	1.6	<0.01	15.7	2.8	<0.02	2.1	0.8	16	0.03	642	3.29	0.001	31.1	2.8	5.4	1539				21.89	21.21	-1.58
M6	M6-1	165	<0.01	6.03		26.6	0.3		1.6	0.3		<0.1	513	2.2298	<0.0005	15.4	1.6		1356				19.79	20.65	2.12
M7	M7-1	94.9	<0.01	1.23		0.2	<0.1		1.6	0.7		<0.04	265	1.2737	0.001	28.4	2.2	0.6	915				12.75	12.66	-0.34
M7	M7-2	56.1	<0.01	23.1	<0.01	20.6	0.1	0.09	1.9	2.1	14.2	0.01	183	0.901	0.001	26.2	1.9	0.5	863				11.45	11.28	-0.75
M8	M8-1	37.4	<0.01	2.35		7.6	0.1	0.03	0.7	5.0	10.7	<0.02	127	0.657	0.004	19.8	1.2	0.4	572				7.60	7.40	-1.36
M8	M8-2	84	<0.01	2.7	<0.01	1.0	2.4	0.04	1.0	4.2	9.6	0.02	147	0.75	0.011	17.6	1.4	3.0	616				8.27	8.07	-1.27
M9	M9-1	47	<0.01	0.93		18.0	7.3	<0.03	0.7	4.3	11	0.02	127	0.849	0.013	12.4	1.1	1.1	630				8.47	8.33	-0.84
M9	M9-2	45.6	0.02	4	<0.01	13.9	0.5	0.04	1.2	6.3	10.1	0.03	149	0.905	0.025	52.6	1.9	1.9	355				4.22	7.89	30.25

← To be continued

ANNEX 3: WHO-guideline values for drinking water (after WHO 2006)

For drinking water quality water has to have a chemical content lower than:

Alumina (Al)	0.2 mg/L
Arsenic (As)	10 µg/L
Barium (Ba)	700 µg/L
Calcium (Ca)	no limit value established
Chlorine (Cl)	5000 µg/L
Chromium (Cr)	50 µg/L
Fluorine (F)	1.5 mg/L
Iron (Fe)	no limit value established
Kalium (K)	no limit value established
Magnesia (Mg)	no limit value established
Manganese (Mn)	400 µg/L
Molybdenum (Mo)	70µg/L
Sodium (Na)	no limit value established
Nickel (Ni)	20 µg/L
Nitrite (NO_2)	0.2 mg/L
Nitrate (NO_3)	50 mg/L
Sulphide	no limit value established
Sulphate (SO_4)	WHO: not of health concern at levels found in drinking-water TrinwV: 240 mg/L
Strontium (Sr)	1500 µg/L *
Thorium (Th)	no chemical limit value established
Uranium (U)	15 µg/L (chemical limit value)

* according to german drinking water limit (TrinkwV 2001)

ANNEX 4: Results [mg/L] of the Central Scientific Research Laboratory represented by Chuj Ecological Laboratory (compare with BGR-results ANNEX 2)

27.02.2007 **Cert. of analysis / Ref. # 11-09/137** 1 of 1

Чуйская экологическая лаборатория

На Ваш исх. № 517 от 28. 11.2006 г.								
		Вода	**С консервацией**					
BGR-sample no. (Oct/Nov 2006)			**4_3**	**8_3**	**6_3**	**11_2**	**14_2**	**blank**
#	**Element**	**Ед измер.**	-------	-------	-------	-------	-------	-------
1	**U**	мг/л	<0,2	<0,2	<0,2	11,04	32,33	<0,2
2	**Ag**	мг/л	<0,02	<0,02	<0,02	<0,02	<0,02	<0,02
3	**Al**	мг/л	<0,04	<0,04	0,070	0,067	0,127	<0,04
4	**As**	мг/л	<0,03	<0,03	<0,03	2,203	0,051	<0,03
5	**Ba**	мг/л	0,023	0,056	0,008	0,015	0,010	<0,001
6	**Be**	мг/л	<0,0002	<0,0002	<0,0002	<0,0002	<0,0002	<0,0002
7	**Bi**	мг/л	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05
8	**Ca**	мг/л	62,1	142,9	264,8	100,3	20,2	<0,02
9	**Cd**	мг/л	<0,001	<0,001	<0,001	0,022	<0,001	<0,001
10	**Co**	мг/л	<0,008	<0,008	<0,008	<0,008	<0,008	<0,008
11	**Cr**	мг/л	<0,007	<0,007	<0,007	<0,007	<0,007	<0,007
12	**Cu**	мг/л	<0,005	<0,005	<0,005	0,014	0,060	<0,005
13	**Fe**	мг/л	0,017	0,059	<0,006	<0,006	<0,006	0,082
14	**K**	мг/л	3,8	3,7	9,7	5,4	11,3	<0,2
15	**La**	мг/л	<0,004	<0,004	<0,004	<0,004	<0,004	<0,004
16	**Mg**	мг/л	20,0	86,5	408,4	48,5	79,0	<0,03
17	**Mn**	мг/л	<0,003	<0,003	0,030	0,478	<0,003	<0,003
18	**Mo**	мг/л	<0,007	<0,007	<0,007	0,233	1,434	<0,007
19	**Na**	мг/л	9,4	86,7	556,6	316,3	1399	0,433
20	**Ni**	мг/л	<0,007	<0,007	0,031	<0,007	0,008	0,043
21	**P**	мг/л	<0,05	<0,05	<0,05	0,296	0,298	<0,05
22	**Pb**	мг/л	<0,04	<0,04	<0,04	<0,04	<0,04	<0,04
23	**Sb**	мг/л	<0,06	<0,06	<0,06	0,010	<0,06	<0,06
24	**Sc**	мг/л	<0,004	<0,004	<0,004	<0,004	<0,004	<0,004
25	**Se**	мг/л	<0,2	<0,2	<0,2	<0,2	1,079	<0,2
26	**Sn**	мг/л	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05
27	**Sr**	мг/л	0,464	1,765	5,565	0,719	0,880	<0,001
28	**Te**	мг/л	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05
29	**Ti**	мг/л	<0,005	<0,005	<0,005	<0,005	<0,005	<0,005
30	**V**	мг/л	<0,006	<0,006	<0,006	0,025	0,051	<0,006
31	**W**	мг/л	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
32	**Y**	мг/л	<0,004	<0,004	<0,004	<0,004	<0,004	<0,004
33	**Zn**	мг/л	<0,003	<0,003	<0,003	<0,003	<0,003	<0,003
34	**Zr**	мг/л	<0,005	<0,005	0,015	<0,005	0,067	<0,005
			Без консервации					
35	**Сульфаты (SO_4^{2-})**	мг/л	24,7	276	2444	518,5	4609	
36	**Хлориды (Cl^-)**	мг/л	4	45	265	52	76	
37	**Нитриты (NO_2^-)**	мг/л	<0,003	<0,003	<0,003	0,052	<0,003	
38	**Нитраты (NO_3)**	мг/л	13,9	22,9	13,9	63,5	12,9	
39	**Фторид (F^-)**	мг/л	<0,19	<0,19	<0,19	0,4	<0,19	
40	**Щелочность**	ммоль/л	3,5	6,0	5,3	6,4	64,4	

КОНЕЦ ДОКУМЕНТА
END OF DOCUMENT

Authorised signatories:

Head of CSRL — **Dr. L. Evteeva**
Quality Manager — **Dr. I. Olekhnovitch**
The Head of the Department of Analytical Testing — **L. Eroshenko**

ANNEX 5: Original technical documentation of the groundwater-monitoring-wells

2007 г	КЫРГЫЗГИИЗ	Ошский филиал

Способ проходки: *колонковое бурение* *Скв. № 1 (хвостохранилище №6 развалина фабрики,правый берег)*

Масштаб 1:100 Отметка устья ________

№ слоя	Геологический индекс	Глубина залегания м, от	Глубина залегания м, до	Мощность слоя	Литологический разрез	Описание пород	Уровень подземных вод, м: Появ. дата	Уровень подземных вод, м: Уст. дата	Группа ручной разр.СНиП IV-5-82
1	tQ_4	0,0	1,0	1,0		Бетон толщиной 0,4 м. Насыпной грунт: гравий, галька,суглинок.			III
2		1,0	3,2	2,2		Суглинок, красновато-коричневый,низкопористый, твердый, с содержанием песка до 10%,с включением гравия до 5%.			II
3		3,2	5,5	2,3		Песок гравелистый краснокоричневый, плотный,с включением щебня и гальки до 5% и единичными глыбами.			II
4		5,5	9,8	4,3		Дресвяный грунт, краснокоричневый, маловлажный с суглинистым заполнителем, с включением щебня до10% и единичными глыбами. Обломочный материал представлен осадочными породами.			III
5	$^{p}Q_{3-4}$	9,8	15,4	5,6		Пески гравелистые, дресвяные грунты и суглинки переслаивающиеся. Грунт маловлажный, краснокоричневый, средней плотности.			III
6		15,4	18,0	2,6		Галечниковый грунт с песчаным заполнителем до 30%,маловлажный, с содержанием валунов до 10-15 %. Обломочный материал невыветрелый, средней окатанности, представлен в основном осадочными породами.	18.0 / 29.03.07	17.7 / 31.03.07	IV
7	$^{a}Q_{3-4}$	18,0	18,4	0,4		Глина краснокоричневого цвета, плотная, с включением песка и гравия до 10-15%.			IV
8		18,4	22,0	3,6		Галечниковый грунт с песчаным заполнителем до 30%, с содержанием валунов до 15-20%; обломочный материал невыветрелый, средней окатанности, представлен в основном осадочными породами.		18.95 / 04.04.07	IV

Документировал: ____________________ Т.Аширбаев.

Лист № 1

2007 г	КЫРГЫЗГИИЗ	Ошский филиал

Способ проходки: *колонковое бурение*

Скв. № 4
(хвостохранилище.№3.
левый берег реки Майлису)

Масштаб 1:100

№ слоя	Геологический индекс	Глубина залегания м, от	до	Мощность слоя	Литологический разрез	Описание пород	Уровень подземных вод, м: Появ. дата	Уст. дата	Группа ручной разр.СНиП IV-5-82
1	tQ4	0,0	0,8	0,8		Насыпной грунт: гравий, галька,суглинок.			III
2		0,8	2,2	1,4		Галечниковый грунт с песчаным заполнителем до 30%, с содержанием валунов до 10%;(насыпной).			III
3		2,2	6,0	3,8		Пульпа серого цвета, влажная, (песок мелкозернистый,заиленный).		5,7 / 16.04.07	II
4	a Q3-4	6,0	8,8	2,5		Галечниковый грунт с песчаным заполнителем до 30%, с содержанием валунов до 20%; обломочный материал невыветрелый средней окатанности.	6,30 / 02.04.07		IV

Скв. №7
(устье Кульмен- сая) Отметка устья ________

№ слоя	Геологический индекс	от	до	Мощность слоя	Литологический разрез	Описание пород	Появ. дата	Уст. дата	Группа
1	tQ4	0,0	1,2	1,2		Насыпной грунт: гравий, галька, суглинок.			III
2	ap Q3-4	1,2	2,5	1,3		Суглинок светло-коричневый, макропористый, полутвердой консистенции.			II
3		2,5	10,0	7,5		Галечниковый грунт с песчаным заполнителем до 30%, маловлажный, с содержанием валунов до 20%; обломочный материал невыветрелый, хорошей окатанности.	7,65 / 03.04.07	8,60 / 04.04.07; 9,15 / 16.04.07	IV

Документировал: ____________________ Т.Аширбаев.

Лист № 2

2007 г	КЫРГЫЗГИИЗ	Ошский филиал

Способ проходки: *колонковое бурение* *Скв. № 8* *(Почта.Правый Берег)*

Масштаб 1:100

№ слоя	Геологический индекс	Глубина залегания м от	Глубина залегания м до	Мощность слоя	Литологический разрез	Описание пород	Уровень подземных вод, м Появ. дата	Уровень подземных вод, м Уст. дата	Группа ручной разр. СНиП IV-5-82
1		0,0	4,0	4,0		Супесь коричневая, твердая, с включением гравия и гальки до 15-20%.			II
2	ap Q_{3-4}	4,0	14,0	10,0		Галечниковый грунт влажный, с песчаным заполнителем до 40%, с содержанием валунов от 20 до 25%.	14,0 14.04.07	12,60 14.04.07 16.04.07	IV
3	P_3-N_1	14,0	18,0	4,0		Алевролит светло-коричневого цвета, плотный.			V

Документировал: ______________________ Т.Аширбаев.

Лист № 3

2007 г	КЫРГЫЗГИИЗ	Ошский филиал

Способ проходки: *колонковое бурение* *Скв. № 9*
(Дом Хагена.Правый Берег)

Масштаб 1:100

№ слоя	Геологический индекс	Глубина залегания м от	Глубина залегания м до	Мощность слоя	Литологический разрез	Описание пород	Уровень подземных вод, м Появ. дата	Уровень подземных вод, м Уст. дата	Группа ручной разр. СНиП IV-5-82
1	tQ_4	0,0	0,4	0,4		Насыпной грунт: гравий, галька, суглинок.			III
2		0,4	4,0	3,6		Суглинок светло-коричневый, сухой, твердой консистенции.			II
3	ap Q_{3-4}	4,0	15,0	11,0		Галечниковый грунт маловлажный, с песчаным заполнителем до 30%, с содержанием валунов от15 до 20%. Обломочный материал невыветрелый, хорошей окатанности, представлен осадочными породами.	10,0 13.04.07	9,8 14.04.07 16.04.07	IV

Документировал: ________________ Т.Аширбаев.

Лист № 4

2007 г	КЫРГЫЗГИИЗ	Ошский филиал

Способ проходки: *колонковое бурение* *Скв. № 10*
(Ниже гостиницы.Правый Берег)

Масштаб 1:100

№ слоя	Геологический индекс	Глубина залегания м		Мощность слоя	Литологический разрез	Описание пород	Уровень подземных вод,м		Группа ручной разр.СНиП IV-5-82
		от	до				Появ. дата	Уст. дата	
1	tQ_4	0,0	0,3	0,3		Насыпной грунт: (строительный мусор).			III
2	apQ_{3-4}	0,3	0,8	0,5		Суглинок светло-коричневый, полутвердой консистенции,в нижней части разреза с включением гравия .			II
3		0,8	7,3	6,5		Галечниковый грунт маловлажный,с супесчаным заполнителем до 35%, с содержанием валунов от 10 до 15%.		3,5 08.04.07 16.04.07	III
4		7,3	9,6	2,3		Песок светло-коричневого цвета, крупнозернистый.			II
5	P_3-N_1	9,6	13,0	3,4		Алевролит светло-коричневого цвета.	13,0 05.04.07	12,2 05.04.07	V
6		13,0	17,5	4,5		Песчаник светло-коричневого цвета трещиноватый, водонасыщенный			V
7		17,5	20,0	2,5		Гравелит светло-коричневого цвета,крепкий,плотный.			V

Документировал: ______________________ Т.Аширбаев.

Лист № 5

2007 г	КЫРГЫЗГИИЗ	Ошский филиал

Способ проходки: *колонковое бурение* *Скв. № 11*
(Школа №8,левый берег)

Масштаб 1:100

№ слоя	Геологический индекс	Глубина залегания м от	Глубина залегания м до	Мощность слоя	Литологический разрез	Описание пород	Уровень подземных вод,м Появ. дата	Уровень подземных вод,м Уст. дата	Группа ручной разр.СНиП IV-5-82
1	tQ_4	0,0	1,0	1,0		Насыпной грунт: гравий, галька,суглинок.			III
2	ap Q_{3-4}	1,0	4,0	3,0		Супесь светло-коричневая,с включением гравия и песка до 25%.			II
3		4,0	5,0	1,0		Галечниковый грунт влажный,с песчаным заполнителем до 30%, с содержанием валунов до 15%,обломочный материал невыветрелый,хорошей окатанности.	4,0 / 12.04.07	4,1 / 16.04.07; 5,3 / 12.04.07	IV
4	P_3-N_1	5,0	8,0	3,0		Глина светло-коричневого цвета, плотная, тугопластичной консистенции.			V

Скв. №12
(*Мечеть,правый берег*) Отметка устья ________

№ слоя	Геологический индекс	Глубина залегания м от	Глубина залегания м до	Мощность слоя	Литологический разрез	Описание пород	Уровень подземных вод,м Появ. дата	Уровень подземных вод,м Уст. дата	Группа ручной разр.СНиП IV-5-82
1	tQ_4	0,0	1,2	1,2		Насыпной грунт (строительный мусор).			III
2	a Q_{3-4}	1,2	10,0	8,8		Галечниковый грунт влажный, с песчаным заполнитлем до 30%, с содержанием валунов до 25%.	3,8 / 07.04.07	3,2 / 16.04.07; 3,6 / 08.04.07	IV

Документировал: ________________ Т.Аширбаев.

Лист № 6

2007 г	КЫРГЫЗГИИЗ	Ошский филиал

Способ проходки: *колонковое бурение* *Скв. № 13*

(Мечеть,левый берег)

Масштаб 1:100

№ слоя	Геологический индекс	Глубина залегания м		Мощность слоя	Литологический разрез	Описание пород	Уровень подземных вод, м		Группа ручной разр. СНиП IV-5-82
		от	до				Появ. дата	Уст. дата	
1	tQ_4	0,0	2,0	2,0		Насыпной грунт: гравий, галька,суглинок.			II
2	ap Q_{3-4}	2,0	4,5	2,5		Супесь светло-коричневая,твердая с включением гравия до 25%.			III
3		4,5	6,0	1,5		Суглинок светло-коричневый,макропористый,полутвердой консистенции.			II
4		6,0	12,0	6,0		Галечниковый грунт маловлажный,с песчаным заполнителем до 30%, с содержанием валунов до 15%,обломочный материал невыветрелый,хорошей окатанности.	9,5 / 11.04.07	8,4 / 16.04.07 8,9 / 11.04.07	IV

Документировал: ________________ Т.Аширбаев.

Лист № 7

2007 г	КЫРГЫЗГИИЗ	Ошский филиал

Способ проходки: *колонковое бурение* *Скв. № 14*

(ул.Заречная,правый берег)

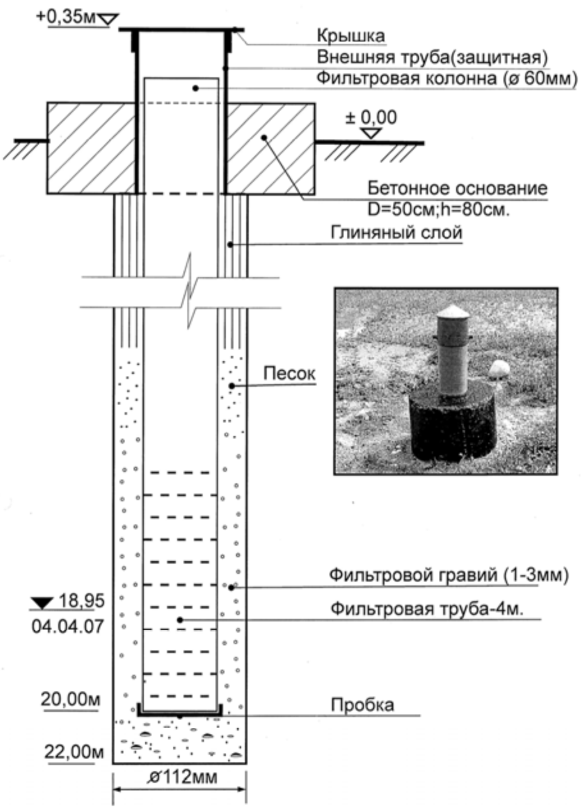
Масштаб 1:100

№ слоя	Геологический индекс	Глубина залегания м: от	до	Мощность слоя	Литологический разрез	Описание пород	Уровень подземных вод, м: Появ. дата	Уст. дата	Группа ручной разр.СНиП IV-5-82
1	tQ_4	0,0	1,2	1,2		Дорожная насыпь.			III
2		1,2	3,0	1,8		Суглинок светло-коричневый,макропористый,полутвердой консистенции с включением гравия до 20% и линз крупнозернистого песка.			IV
3	ар Q_{3-4}	3,0	7,5	4,5		Галечниковый грунт маловлажный,с песчаным заполнителем до 35%, с содержанием валунов до 20%,обломочный материал невыветрелый,хорошей окатанности.	7,5 / 10.04.07	5,5 / 10.04.07; 5,8 / 16.04.07	IV
4		7,5	8,0	0,5		Супесь светло-коричневая,с включением гравия и песка от 20-25%.			II
5		8,0	8,5	0,5		Песок светло-коричневого цвета, крупнозернистый.			II
6		8,5	12	3,5		Галечниковый грунт с песчаным заполнителем от 35 до 40%,с содержанием валунов до 20%.			IV
Скв. №15 *(ул.Заречная,левый берег.)* Отметка устья ________									
1		0,0	0,8	0,8		Галечниковый грунт маловлажный с песчаным заполнителем до 30%,с содержанием валунов от 20 до 25%.		0,9 / 16.04.07	IV
2	ар Q_{3-4}	0,8	7,0	6,2		Валунный грунт с песчаным заполнителем до 25% обломочный материал невыветрелый хорошей окатанности,представлен в основном осадочными породами.	2,4 / 11.04.07	1,8 / 11.04.07	V

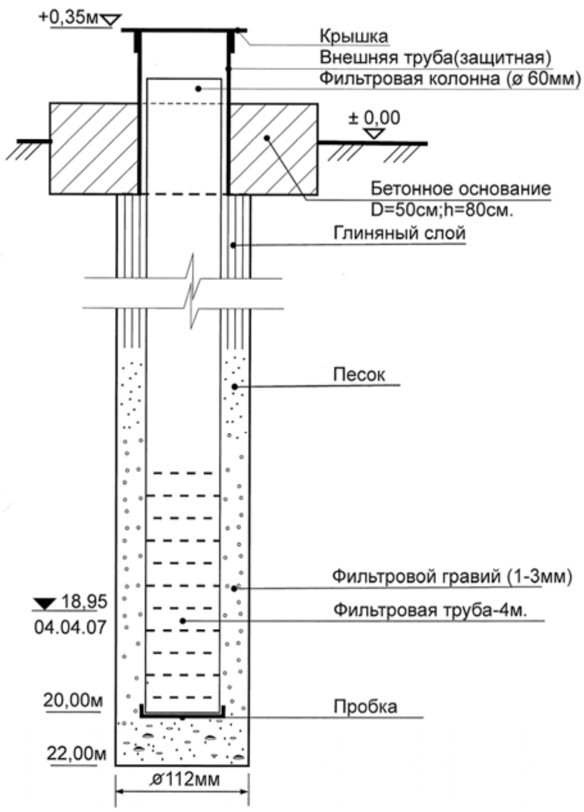
Документировал: ____________________ Т.Аширбаев.

Лист № 8

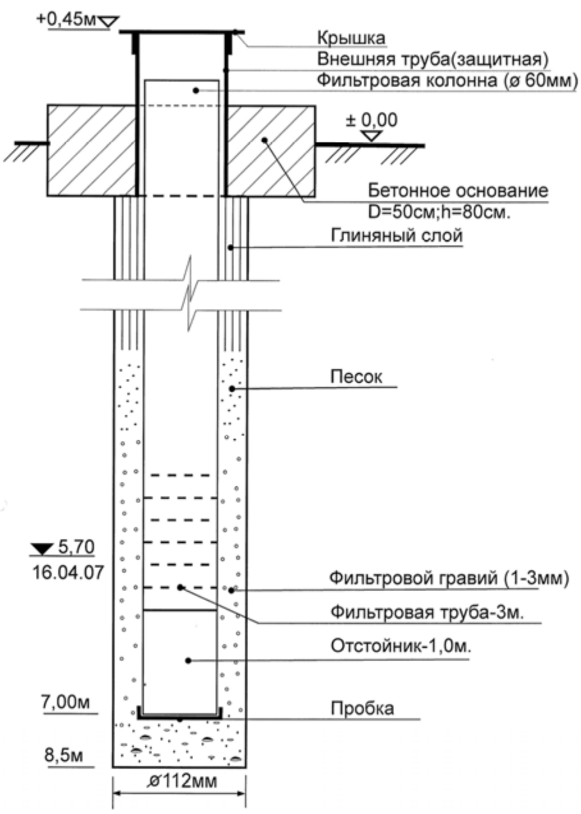
Скважина-пъезометр №1



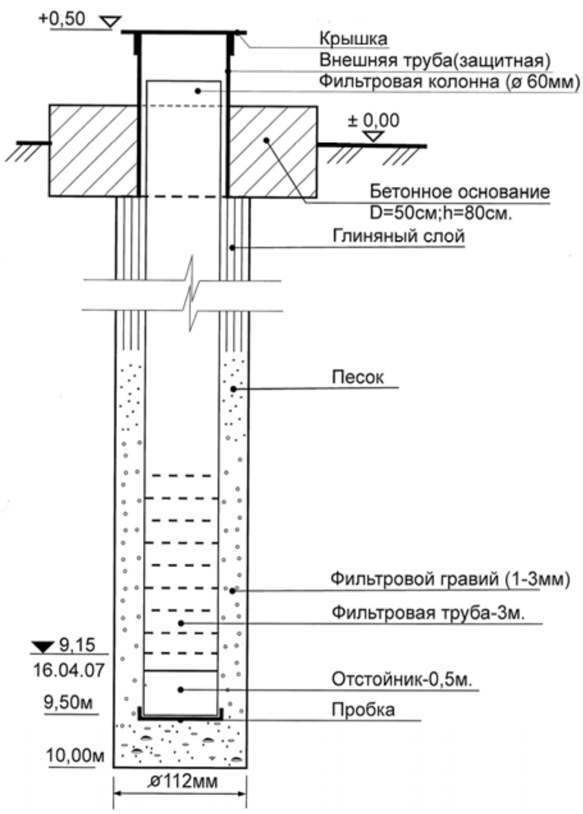
Скважина-пъезометр №1



Скважина-пъезометр №4



Скважина-пъезометр №7



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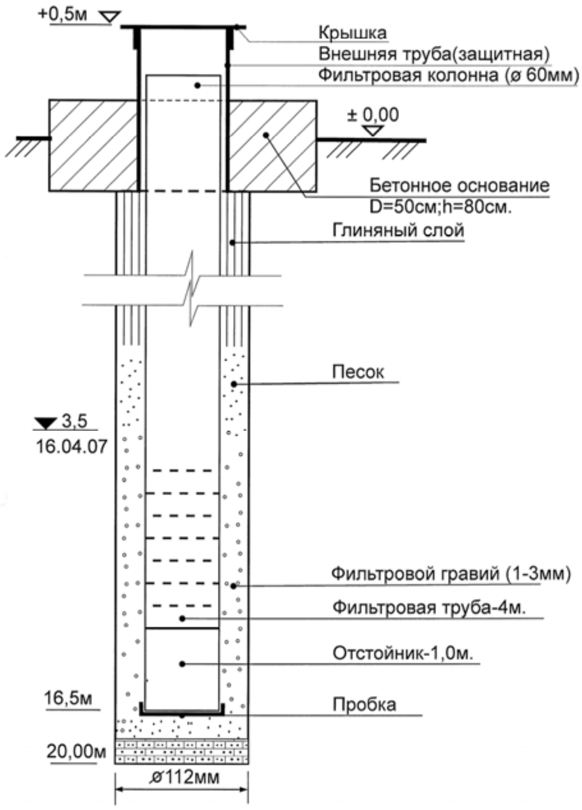

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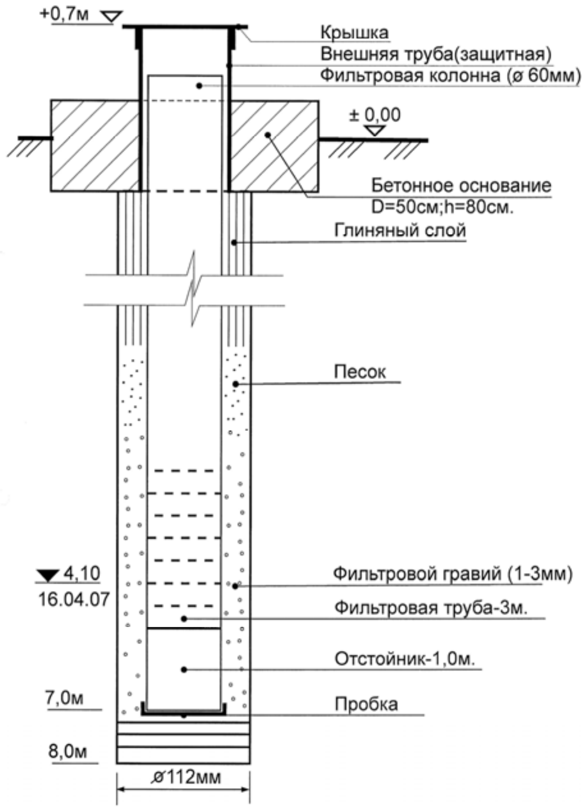

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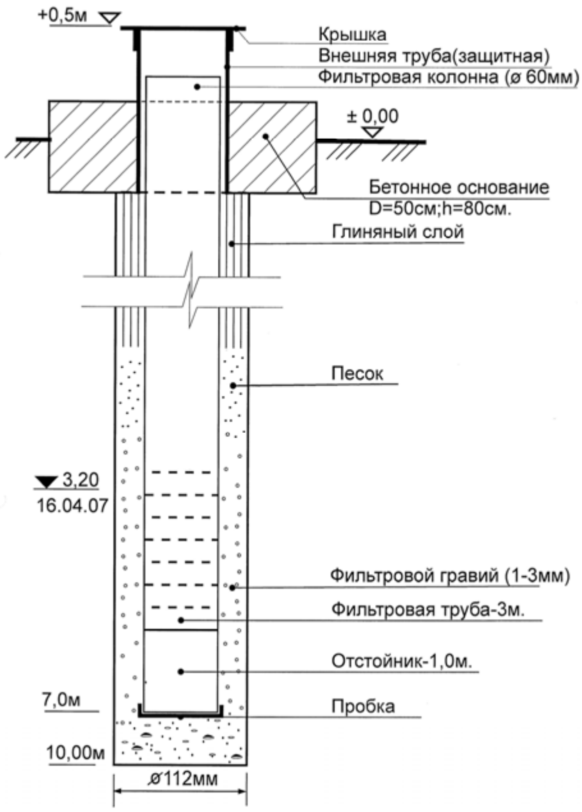

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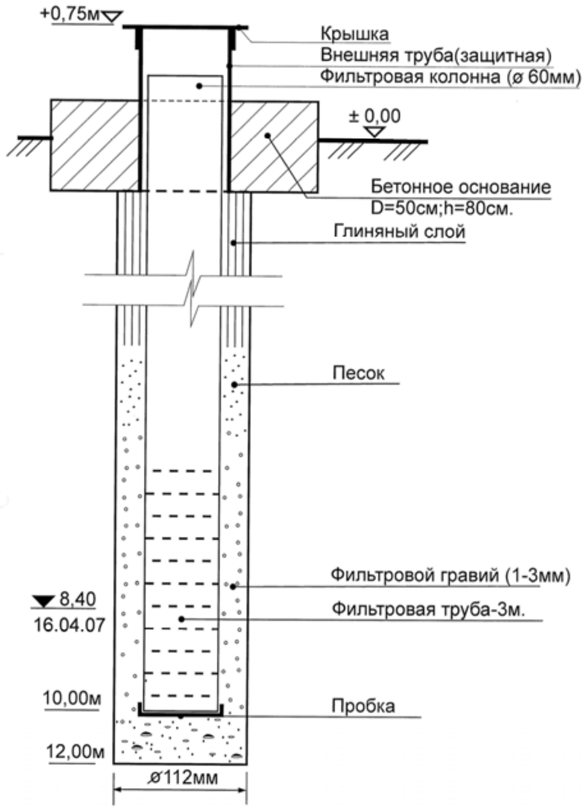

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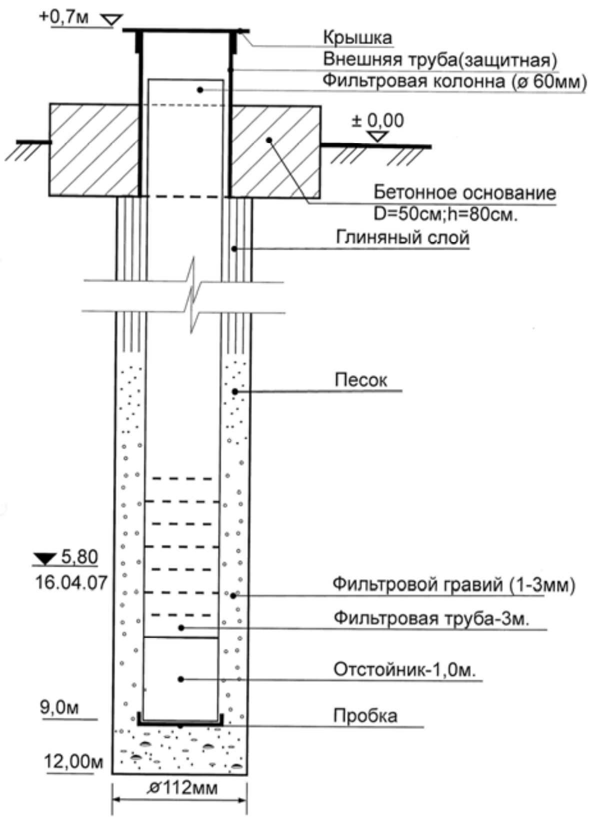

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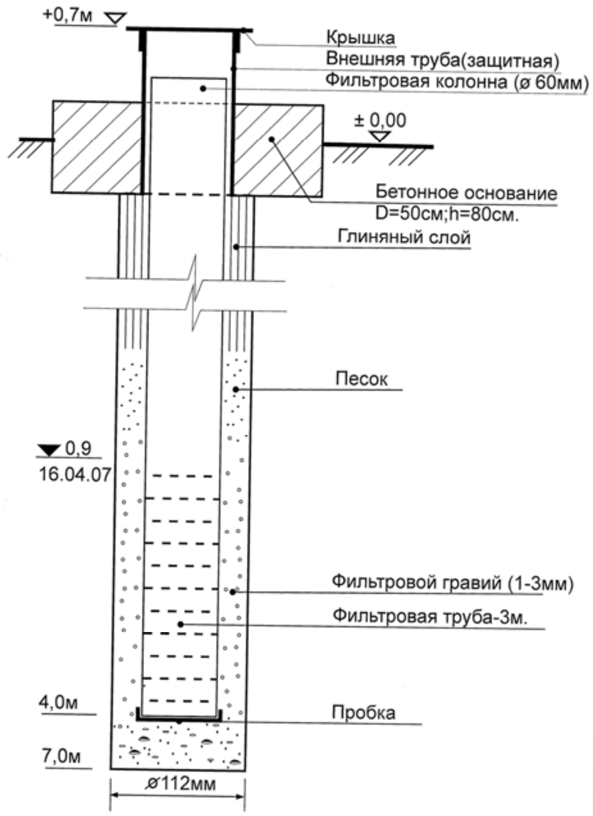

ANNEX 6: Information brochure given to citizens in Mailuu-Suu, translated into Russian

This brochure aims to improve the life quality of people in Mailuusuu. It shows how the use of drinking water of high quality can be assured there.

Content

The problem

Residues of former mining activities

In Kyrgyzstan are many places, where people have to cope with man-made impacts on the environment.

Former mining activities in Mailuusuu affected the water quality of rivers and groundwater.

Chemical and radiological examinations have shown that most of these water sources should not be used for drinking water purposes. Two third of all water sources known exceed chemical and radiological limit values.

To ensure that just drinking water of high quality is used the following recommendations should be taken into consideration:

The solution

Examination of rivers and groundwater

- just the centrally supplied water is recommendable to use as drinking water in Mailuusuu
- every other water source should be tested in advance of using by CEC
- prefer bottled water (mineral water) for the needs of children
- river water of the Mailuu-Say must be just used for drinking after being boiled, if better water is not available
- to boil drinking water in advance is generally safer
- assure long-term and periodical examination of water sources, because the water quality can change over the years
- customers should ask for the origin of meat to ensure that animals were fed with eligible water (see table)
- don´t crop fruits and vegetables on the tailings impoundments
- don´t use seepage water from mining residues for irrigation purposes

Water source	drinking	animal feeding	irrigation
Central water	*yes*	*yes*	*yes*
Deep artesian wells	no *	yes	yes
Shallow dug wells	no	no	no
Mailuu-Say	no **	no	yes
Other rivers	no	no	no

* at present time the artesian well north of Kok-Tash and in the Ul. Artesianskaya in Mailuusuu are drinkable, but continued examinations in the future should ensure this.
**just after being boiled

Radiation is just a local hazard (e.g., near to mining left-overs), because it rapidly decreases with distance.

No water cleaning measures in Mailuusuu are necessary, if the inhabitants comply with the given recommendations.

Towards a cleaner environment: the river Mailuu-Say

Any open Questions?

Please contact :

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BGR 2008

BGR Bundesanstalt für Geowissenschaften und Rohstoffe

Water quality in Mailuusuu

Recommendations for the usage of drinking water

in cooperation with

ANNEX 7: Interim Report of Centre for Radiation and Radioecology (ZSR), Leibnitz-University Hannover

Zentrum für Strahlenschutz und Radioökologie
Leibniz Universität Hannover
Herrenhäuser Str. 2 · D-30419 Hannover
Leiter: Prof. Dr. Rolf Michel
michel@zsr.uni-hannover.de

Contract Nr. 200-4500032442

between Federal Institute for Geosciences and Natural Resources (BGR) and Leibniz Universität Hannover.

Implementing institution: Center for Radiation Protection and Radioecology (ZSR)

Investigators: C. Bunnenberg, C. Wanke, A. Meleshyn, L. Johansson, T. Bisinger, R. Michel

Interim report of ZSR to TC-Project:

„Reduction of hazards posed by Uranium mining tailings in Mailuu-Suu, Kyrgyz Republic "

February 27, 2007

In the frame of the aforementioned contract, ZSR has obtained a total of 36 water samples and 1 sediment sample from the investigated region of Mailuu-Suu in Kyrgyz Republic till the end of 2006. Meanwhile, 33 samples were prepared and measured with respect to contents of selected natural isotopes of thorium, actinium and uranium/radium decay chains with help of different radioanalytical methods.

Due to partially very low concentrations of important isotopes, it has been decided to apply additional methods of sample preparation and measurement. This transfer to even more sensitive analytical methods is not yet accomplished, so that further improvements with respect to detection limits and measurement uncertainties are possible especially within a prolongation phase of the project.

So far, the vast majority of samples available for measurement were those of water. Therefore, the major attention of actual investigations is paid to a radiological assessment of water path through an estimation of effective annual doses to human resulting from water consumption from certain water sources. Dose contributions resulting from the use of waters for feeding animals and for watering purposes could not be taken into account due to the absence of the relevant data.

Working out of the second important aspect of the project, namely the identification of the contamination sources (tailings, mines) of sampled waters, is not possible based on the currently available material, since water samples can only provide a instantaneous imprint of the dissolved species. To conclude about sources, additional investigations of corresponding sediment samples are indispensable, which are enriched during a longer period of time with isotopes characterized by a particulate transport. Information about the contamination source can be then derived from radioactive disequilibrium analysis.

Results of analyses by BGR and ZSR

Data on chemical analyses of uranium and thorium, as provided by BGR, are summarized in Table 1. For a better comparison with the results of gamma-spectrometric measurements by ZSR as well as for an estimation of the radiation exposure, the mass concentrations (in µg/l) were recalculated to activity concentrations (in Bq/l). 1 µg uranium with natural isotope ratios corresponds to 12.45 Bq U-238 in equilibrium with 12.45 Bq U-234 and 0.58 Bq U-235. 1 µg thorium corresponds to 4.06 Bq Th-232.

Table 2 presents results of gamma-spectrometric measurements. Gamma-spectrometric method is often not sensitive enough to measure low activity concentrations in water samples of small volumes. Therefore, more time- and work-consuming analyses of dose relevant nuclides Pb-210 and Po-210 with help of liquid scintillation spectrometry (LSC) or alpha-spectrometry were carried out for such samples. The results are given in Table 3.

A comparison of activity concentrations for U-238 from chemical analyses as well as from gamma-spectrometry – for measured values above the decision limits – shows very good agreement between them, as shown in Figure 1. However, out of 21 measurements, only 6 measured values are above the detection limit and two values are between the decision and detection limits. Therefore, the values recalculated from analyses by BGR were used further to model the radiation exposure.

The gamma-spectrometric determination of Pb-210 is difficult as well, whereas that of Po-210 is not possible at all. The knowledge of activity concentrations of these two dose relevant nuclides is, however, indispensable for a realistic estimation of ingestion doses. Therefore, these nuclides were measured with help of LSC or alpha-spectrometry after additional chemical preparation. Table 3 shows that these methods allow a reliable determination of significantly lower radionuclide concentrations than those for gamma-spectrometry.

Determination of Ra-228 and Th-228, for which the measured values do not exceed the decision limits, represents a further difficulty. For Ra-226, only one measured value is above the decision limit, whereas two measured values are between decision and detection limits. For a more precise determination, an application of other measurement methods, based on a chemical preparation of samples, would be necessary.

It is clear from the presented results that there is no radioactive equilibrium for uranium-radium decay chain in studied water samples. The activities of uranium are clearly dominating, which points out to the transport of uranium in dissolved form with water.

There is no radioactive equilibrium between Pb-210 and its daughter nuclide Po-210 as well, as Table 3 shows. This is an important fact for the dose modelling, since an assumption of equilibrium would lead to a significant overestimation of calculated radiation exposure, especially as a result of application of detection limits for Pb-210 from gamma-spectrometry.

Modelling of radiation exposure

Radiological modelling of annual radiation exposure due to ingestion of contaminated water was carried out based on the above results with application of the dose factors defined in ICRP72 and in EURATOM standards. The age group of adults (>17 a) and, similarly to the approach used in TACIS report, the group of 7—12 years old children as representative for all age groups below 17 years were considered. Activity concentrations and annual consumption rates represent further input into the modelling approach. According to the survey of dietary habits of local population in TACIS report, annual water consumption equals 750 l for adults and 630 l for children.

The annual doses to adults resulting from uranium consumption with water and calculated based on uranium concentrations as measured by BGR are presented in Figure 2. The total dose due to U-238 in equilibrium with U-234 and Th-230 as well as U-235 in equilibrium with Pa-231 and Ac-227 is considered. The data show that based on these model assumptions the dose limit of 0.1 mSv/a according to EU Drinking Water Directive is exceeded in about half of all samples. This applies also for a comparison between uranium concentrations and the WHO guideline value of 15 µg/l as derived from the chemical toxicity of uranium.

A modelling of radiation exposure resulting from all dose relevant nuclides of natural decay chains was carried out for sampling station 10. According to BGR, this is the only station that can be considered as a drinking water source. It should be stressed that for a number of the relevant nuclides, activity measurements can only provide the corresponding detection limits. Therefore, activity concentrations for uranium and Th-232 isotopes were calculated from analyses by BGR. Furthermore, a radioactive equilibrium between uranium and its short lived decay products with is assumed. However, this assumption is not applicable for Ra-226, so that the corresponding detection limit had to be used in calculation. This leads to an overestimation of dose due to Ra-226, which is much likely characterized by a considerably lower value.

Figure 3 presents the modelling results for children. In Case 1, the detection limits are applied for Ra-228 and Th-228, which results in a conservative estimation. In Case 2, on the contrary, a radioactive equilibrium between Th-232 and its decay products is assumed. Since there are no indications for increased thorium content, this assumption appears to be a reasonable one, resulting in more realistic modelling results. A similar approach is used for adults, and the results are represented in Figure 4.

The conservative estimation (Case 1) shows an exceedance of 1 mSv a^{-1} for children. Even with a more realistic assumption (Case 2), which, however, is not backed enough, a dose limit of 0.1 mSv/a is exceeded. The results for adults are lower than for children, but they are above 0.1 mSv/a as well.

It can be expected, that with the proposed increase of water sample volume to 20 l and a subsequent reduction of the sample volume to 1 l through vaporization would allow more realistic estimations of doses. Based on these estimations as well as on investigations of sediment samples, reliable conclusions about contamination sources can be made.

Table 1: Activity concentrations of uranium and thorium calculated from chemical analyses by BGR (from: Analysendaten_nur Daten.xls, 21.12.06).

Station No.	Sample No.	Sampling date	Th	U	Th-232	U-238, U-234	U-235
			chem.	chem.	Activity	Activity	Activity
			µg/l	µg/l	Bq/l	Bq/l	Bq/l
1	1-1	Jan 06	0.0004	0.346	1.62E-06	4.31E-03	2.01E-04
		Jul 06	0.0042	0.4709	1.71E-05	5.86E-03	2.73E-04
		Sep 06	0.0002	0.3349	8.12E-07	4.17E-03	1.94E-04
2	2-1	Jan 06	0.0004	0.309	1.62E-06	3.85E-03	1.79E-04
3	3-1	Jan 06	0.0016	0.049	6.50E-06	6.10E-04	2.84E-05
	3-2	Sep 06	0.0014	0.0562	5.68E-06	7.00E-04	3.26E-05
4	4-1	Jan 06	0.0003	2.132	1.22E-06	2.65E-02	1.24E-03
	4-2	Jul 06	-0.002	4.0718	-8.12E-06	5.07E-02	2.36E-03
		Sep 06	0.0004	2.0763	1.62E-06	2.58E-02	1.20E-03
5	5-1	Jan 06	0.006	1696	2.44E-05	2.11E+01	9.84E-01
		Jul 06	0.0248	1096.354	1.01E-04	1.36E+01	6.36E-01
		Sep 06	0.0122	1763.3291	4.95E-05	2.20E+01	1.02E+00
6	6-1	Jan 06	0.0065	173	2.64E-05	2.15E+00	1.00E-01
	6-2	Jul 06	0.0317	221.9329	1.29E-04	2.76E+00	1.29E-01
		Sep 06	0.0054	171.1188	2.19E-05	2.13E+00	9.92E-02
7	7-1	Jan 06	0.0157	114	6.37E-05	1.42E+00	6.61E-02
	7-2	Jul 06	0.0075	179.6885	3.05E-05	2.24E+00	1.04E-01
		Sep 06	0.0014	136.8037	5.68E-06	1.70E+00	7.93E-02
8	8-1	Jan 06	0.0003	28.8	1.22E-06	3.59E-01	1.67E-02
	8-2	Jul 06	0.0045	29.0823	1.83E-05	3.62E-01	1.69E-02
		Sep 06	0.0008	29.7032	3.25E-06	3.70E-01	1.72E-02
9	9-1	Jan 06	0.001	0.488	4.06E-06	6.08E-03	2.83E-04
	9-2	Jul 06	0.0381	0.7496	1.55E-04	9.33E-03	4.35E-04
		Sep 06	0.0098	0.4844	3.98E-05	6.03E-03	2.81E-04
10	10-1	Jan 06	0.0002	6.37	8.12E-07	7.93E-02	3.69E-03
	10-2	Jul 06	0.0104	5.1313	4.22E-05	6.39E-02	2.98E-03
		Sep 06	0.0063	7.3837	2.56E-05	9.19E-02	4.28E-03
11	11-1	Jul 06	0.1123	8639.73	4.56E-04	1.08E+02	5.01E+00
	11-3	Sep 06	0.0866	8511.06	3.52E-04	1.06E+02	4.94E+00
12		Jul 06	0.3248	2872.649	1.32E-03	3.58E+01	1.67E+00
13	13-1	Jul 06	0.009	130.528	3.65E-05	1.63E+00	7.57E-02
		Sep 06	0.0803	150.8396	3.26E-04	1.88E+00	8.75E-02
14	14-1	Jul 06	0.1178	28771.96	4.78E-04	3.58E+02	1.67E+01
	14-2	Sep 06	0.1063	36079.015	4.32E-04	4.49E+02	2.09E+01

Station No.	Sample No.	Sampling date	Th	U	Th-232	U-238, U-234	U-235
			chem.	chem.	Activity	Activity	Activity
			µg/l	µg/l	Bq/l	Bq/l	Bq/l
15	15-1	Jul 06	0.0148	329.6358	6.01E-05	4.10E+00	1.91E-01
	15-3	Sep 06	0.0113	317.6521	4.59E-05	3.95E+00	1.84E-01
16	16-1	Jul 06	0.08	112.1948	3.25E-04	1.40E+00	6.51E-02
		Sep 06	0.0034	82.3233	1.38E-05	1.02E+00	4.77E-02
17	17-1	Jul 06	0.011	7.1504	4.47E-05	8.90E-02	4.15E-03
		Sep 06	0.0299	7.5591	1.21E-04	9.41E-02	4.38E-03
18	18-1	Sep 06	0.025	43.6196	1.02E-04	5.43E-01	2.53E-02
19	19-1	Sep 06	0.0015	4.8519	6.09E-06	6.04E-02	2.81E-03
20	20-1	Sep 06	0.0169	144.0914	6.86E-05	1.79E+00	8.36E-02
21	21-1	Sep 06	0.0039	38.5414	1.58E-05	4.80E-01	2.24E-02
22		Sep 06	0.0015	0.2826	6.09E-06	3.52E-03	1.64E-04
23		Sep 06	0.0009	7.1117	3.65E-06	8.85E-02	4.12E-03
24	24-1	Sep 06	0.0144	15.141	5.85E-05	1.89E-01	8.78E-03
25		Sep 06	0.0102	7.0002	4.14E-05	8.72E-02	4.06E-03
26		Sep 06	0.0173	28.7788	7.02E-05	3.58E-01	1.67E-02
27		Sep 06	0.0015	6.2299	6.09E-06	7.76E-02	3.61E-03
28		Sep 06	0.0223	125.0593	9.05E-05	1.56E+00	7.25E-02
29		Sep 06	0.0052	0.1342	2.11E-05	1.67E-03	7.78E-05
30		Sep 06	0.0018	1.9063	7.31E-06	2.37E-02	1.11E-03
31		Sep 06	0.0006	0.3296	2.44E-06	4.10E-03	1.91E-04
32		Sep 06	0.001	11.7243	4.06E-06	1.46E-01	6.80E-03

Table 2: **Gamma-spectrometric results of water sample analyses. Green field: result above detection limit; yellow field: value is below decision limit, detection limit is given instead; white field: result is between detection and decision limit. Detection and decision limits were calculated according to DIN 25482-10; u(A) = measurement uncertainty**

Station No.	Sample-No.	Sampling date	U-238		Ra-226		Pb-210		U-235		Ra-228		Ra-224 (Th-228)		Cs-137		K-40	
			A	u(A)	A	u(A)	A	u(A)	A	u(A)	A	u(A)	A	u(A)	A	u(A)	A	u(A)
			Bq/l	Bq/l	Bq/l	Bq/l	Bq/l	Bq/l	Bq/l	Bq/l	Bq/l	Bq/l	Bq/l	Bq/l	Bq/l	Bq/l	Bq/l	Bq/l
3	3-2	Sep 06	1.8		0.2		2.5		0.1		0.3		0.2		0.07	0.02	1.5	0.0
4	4-2	Jul 06	4.6		0.30		5.2		0.20		0.4		0.4		0.13	0.04	2.7	
6	6-2	Jul 06	3.00	1.48	0.14	0.05	4.2		0.16	0.06	0.4		0.3		0.1		2.6	
7	7-2	Jul 06	6.4		2.39	0.11	4.6		0.23	0.08	0.4		0.3		0.2		2.6	
8	8-2	Jul 06	7.4		0.3		4.7		0.3		0.4		0.4		0.13	0.05	2.4	
9	9-2	Jul 06	5.0		0.3		5.0		0.3		0.6		0.3		0.10	0.03	2.4	
10	10-2	Jul 06	4.6		0.3		5.1		0.3		0.5		0.2		0.06	0.03	2.4	
11	11-1	Jul 06	99.6	10.0	0.3		5.6		5.76	0.05	0.5		0.5		0.1		3.3	
	11-3	Sep 06	135	7	0.21	0.05	2.8	1.2	6.75	0.42	0.3		0.2		0.1		1.6	0.2
13	13-1	Jul 06	2.24	1.30	0.3		5.0		0.19	0.07	0.5		0.4		0.1		2.7	
14	14-1	Jul 06	344	28	0.3		3.63	1.78	19.0	1.3	0.4		0.2		0.2		2.5	
	14-2	Sep 06	409	19	0.3		4.4	1.2	20.8	1.2	0.3		0.2		0.07	0.02	1.3	0.4
15	15-1	Jul 06	3.79	1.69	0.3		3.8		0.22	0.07	0.4		0.3		0.12	0.04	2.7	
	15-3	Sep 06	3.2	0.7	0.2		5.1		0.17	0.04	0.3		0.2		0.07	0.02	1.4	0.1
16	16-1	Jul 06	5.3		0.3		3.3		0.4		0.4		0.3		0.1		2.8	
17	17-1	Jul 06	4.8		0.3		5.0		0.2		0.4		0.3		0.2		2.4	
18	18-1	Sep 06	2.3		0.3		5.0		0.07	0.03	0.3		0.2		0.20	0.02	1.9	
19	19-1	Sep 06	1.9		0.2		2.4		0.085	0.05	0.3		0.2		0.08	0.02	1.0	0.2
20	20-1	Sep 06	2.6		0.35	0.06	2.2		0.1		0.3		0.2		0.07	0.02	1.5	0.7
21	21-1	Sep 06	2.3		0.3		1.4	0.7	0.09	0.04	0.3		0.2				1.2	0.3
24	24-1	Sep 06	2.5		0.3		5.2		0.1		0.3		0.2		0.1		2.0	

Table 3: Results of measurement of Po-210 concentrations (with LSC) and Pb-210 concentrations (with α-spectrometry).

Station No.	Sample No.	Drinking water?	Sampling date	Pb-210 LSC	Uncer-tainty	Po-210 α-spectr.	Uncer-tainty
		(according		A_{Pb-210}	$u(A)_{Pb-210}$	A_{Po-210}	$u(A)_{Po-210}$
		to BGR)		Bq/l	Bq/l	Bq/l	Bq/l
1	1-1	yes	Jan. 06	0.1532	0.0118	0.0100	0.0020
2	2-1	yes	Jan. 06	0.1663	0.0126	0.0099	0.0017
3	3-1	no	Jan. 06	0.0812	0.0069	0.0123	0.0019
4	4-1	no	Jan. 06	0.1764	0.0133	0.0194	0.0028
	4-2		Jul. 06	0.0243	0.0018	0.0044	0.0005
5	5-1	no	Jan. 06	0.1784	0.0132	0.0142	0.0028
6	6-1	no	Jan. 06	0.1624	0.0121	0.0086	0.0020
	6-2		Jul. 06	0.0221	0.0017	0.0033	0.0007
7	7-1	no	Jan. 06	0.2482	0.0168	0.0287	0.0034
	7-2		Jul. 06	0.0985	0.0051	0.0712	0.0036
8	8-1	no	Jan. 06	0.1635	0.0122	0.0090	0.0018
	8-2		Jul. 06	0.0208	0.0016	0.0028	0.0005
9	9-1	no	Jan. 06	0.0908	0.0078	0.0162	0.0028
	9-2		Jul. 06	0.0345	0.0024	0.0104	0.0014
10	10-1	yes	Jan. 06	0.2182	0.0162	0.0112	0.0018
	10-2		Jul. 06	0.0278	0.0020	0.0093	0.0009
11	11-1	no	Jul. 06	0.1185	0.0058	0.1795	0.0056
13	13-1	no	Jul. 06	0.0174	0.0014	0.0072	0.0010
14	14-1	no	Jul. 06	0.0181	0.0015	0.0396	0.0030
15	15-1	no	Jul. 06	0.0096	-	0.0059	0.0010
16	16-1	no	Jul. 06	0.0221	0.0017	0.0130	0.0014
17	17-1	no	Jul. 06	0.0311	0.0022	0.0052	0.0006

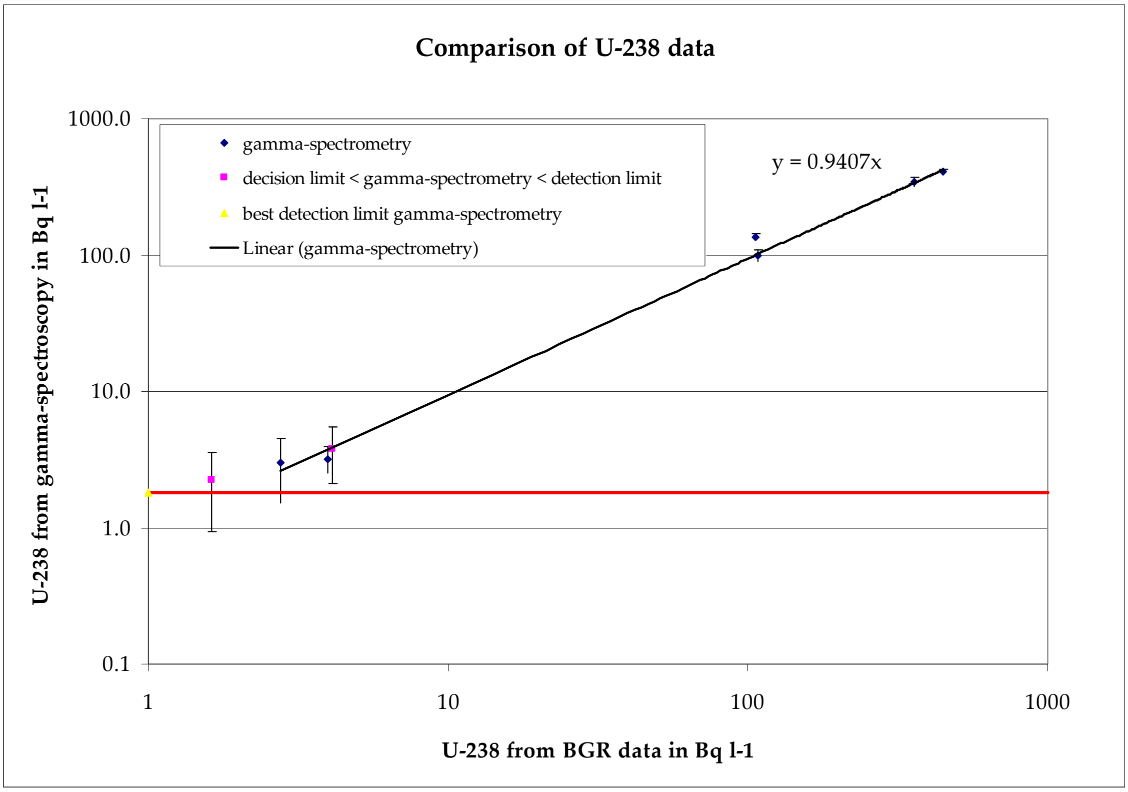


Figure 1: **Comparison of chemical (BGR) and gamma-spectrometric (ZSR) uranium analyses.**

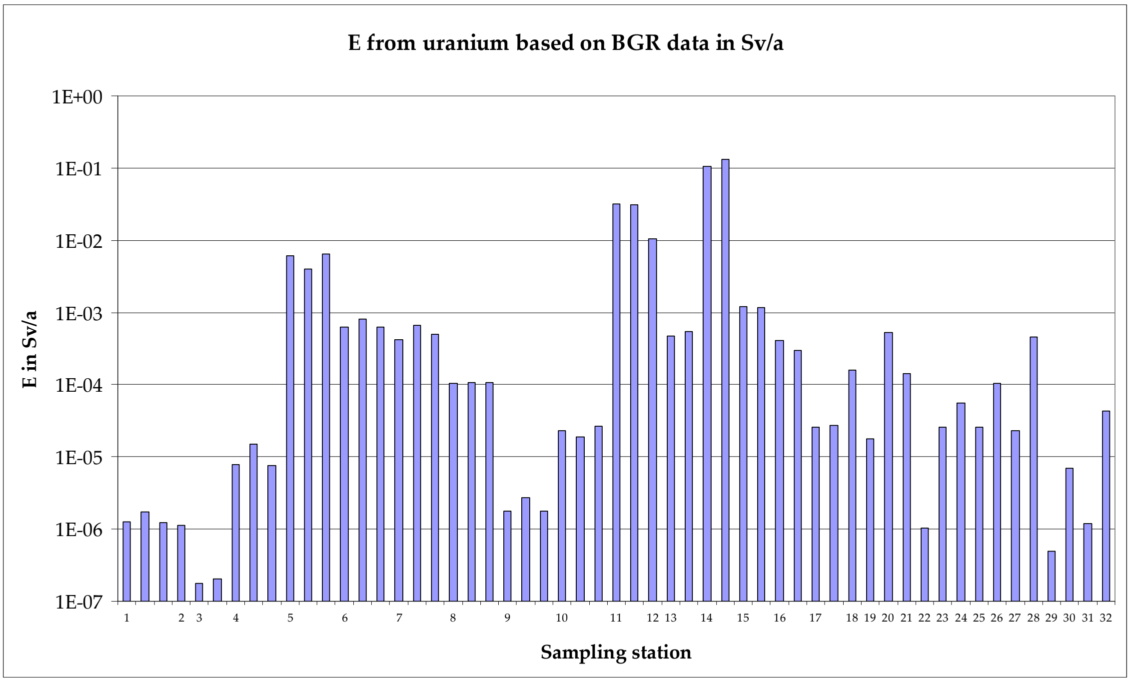


Figure 2: **Effective annual doses E for adults due to ingestion of uranium isotopes and their decay products (Ac-227, Pa-231, Th-230) according to chemical analyses by BGR for a consumption rate of 750 l water/a.**

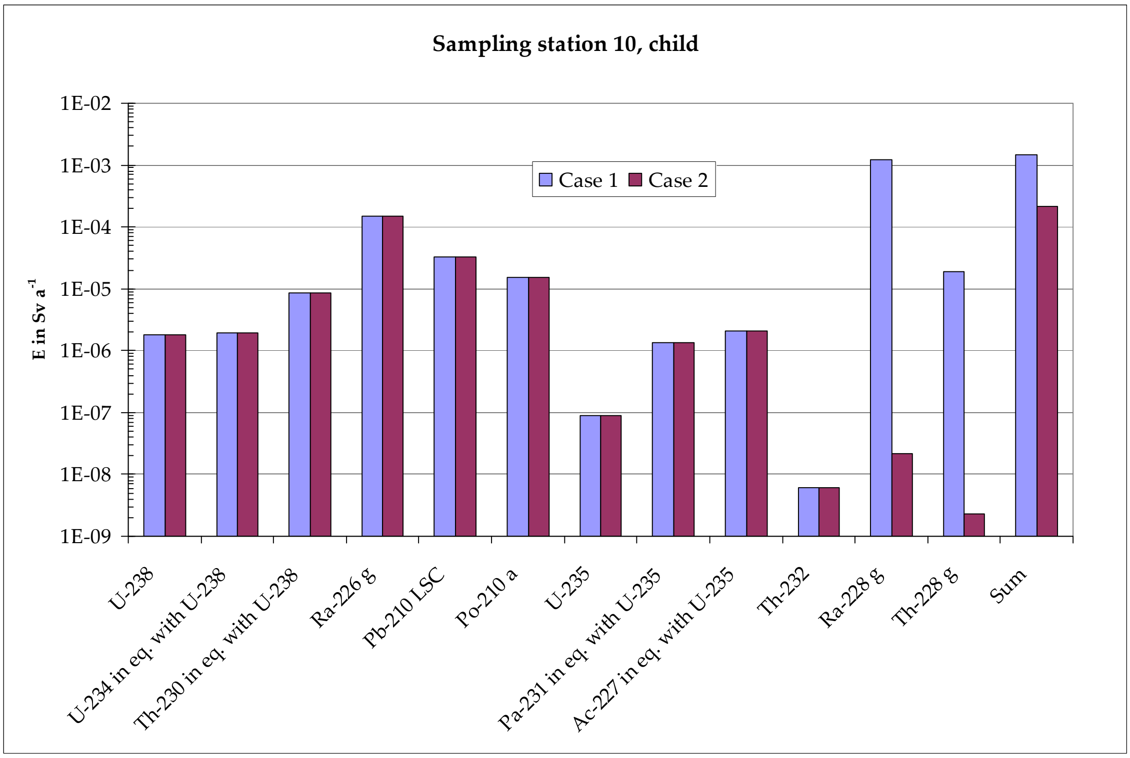


Figure 3: Effective annual doses E for children due to ingestion of natural radionuclides for a consumption rate of 630 l water/a; conservative (Case 1) or for an assumed radioactive equilibrium between Th-232, Ra-228 and Th-228 (Case 2). (eq.: Radioactive equilibrium, g: Value from γ-Spectrometry, a: Value from α-Spectrometry)

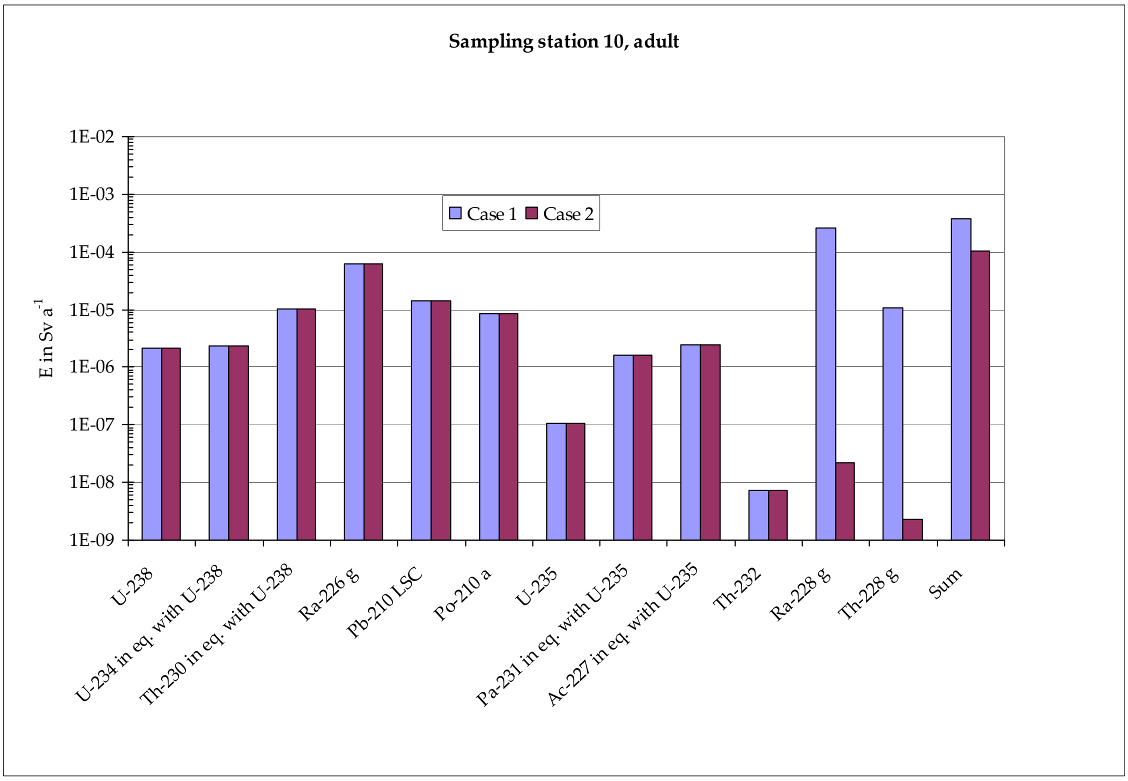
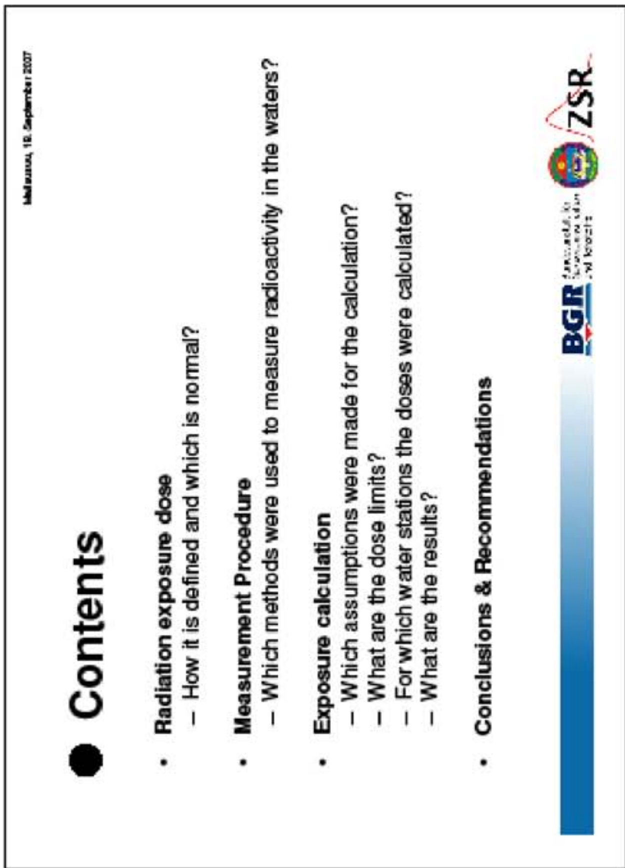
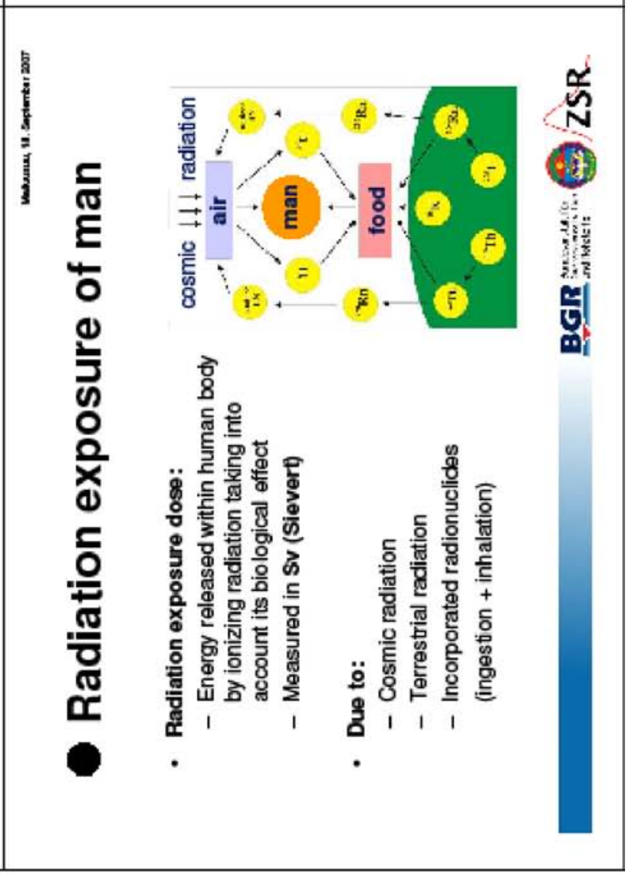
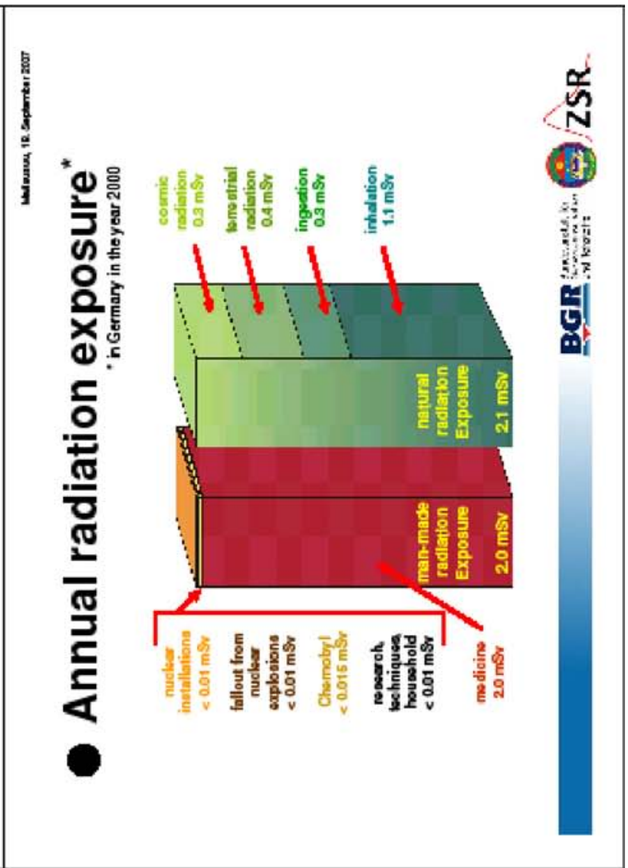


Figure 4: Effective annual doses E for adults due to ingestion of natural radionuclides for a consumption rate of 630 l water/a; conservative (Case 1) or for an assumed radioactive equilibrium between Th-232, Ra-228 and Th-228 (Case 2). (eq.: Radioactive equilibrium, g: Value from γ-Spectrometry, a: Value from α-Spectrometry)

ANNEX 8: "Radiological Evaluation of Waters from Mailuu-Suu, Kyrgyzstan", ZSR-Presentation held during Public Information workshop, 18.9.2007, Mailuu-Suu







● Radiological Measurement Procedure

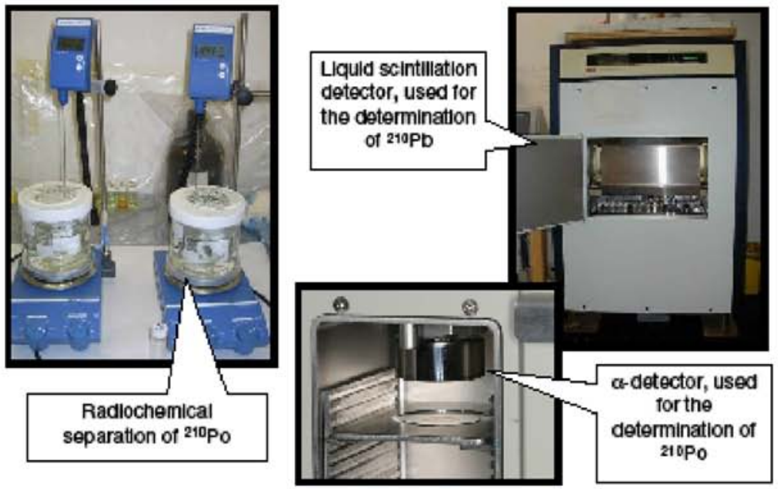
- γ– Spectrometry
- Radiochemical separation of ^{210}Pb and ^{210}Po
- Liquid Scintillation Spectrometry for the determination of ^{210}Pb
- α - Spectrometry for the determination of ^{210}Po

● γ - Spectrometry

- Measurement of γ-rays (= photons) with semiconductor detectors made of high purity germanium
- Water samples were filtered and measured in special containers
- Radionuclides determined:
  ^{235}U, ^{238}U, ^{224}Ra, ^{226}Ra, ^{228}Ra, ^{210}Pb

● γ - detector system

● Measurement of ^{210}Pb and ^{210}Po



Mailuusuu, 18. September 2007

γ - spectrometric results

- In many cases the activities were too low to be determined by γ-spectrometry
- In that cases we use ***detection limits*** for exposure calculations: we can be sure that the activities are lower than the detection limits.
- For Uranium and Thorium we have additional data from chemical measurements done by the BGR that fit the data from γ-spectrometry very well

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Calculation of the potential radiation exposure

- Assumed annual water consumption:
  750 Liter for adults and 630 Liter for children, according to the TACIS report
- Calculation using dose conversion factors from publication 72 of the ICRP (International commission on radiation protection)

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Exposure calculation

- Nuclides assessed:
  ^{234}U, ^{235}U, ^{238}U, ^{231}Pa, ^{227}Ac, ^{230}Th, ^{232}Th, $^{228}Th(^{224}Ra)$, ^{226}Ra, ^{228}Ra, ^{210}Pb, ^{210}Po
- Activities of the nuclides were obtained as results from chemical or radioactivity measurements or calculated

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Modelling of the Exposure

Modelling for realistic case:

- Activities of ^{228}Ra and ^{224}Ra are calculated from the concentration of ^{232}Th
- Elevated contents of ^{228}Ra and ^{224}Ra are not evident

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Exposure limits

- **1 mSv per year** (millisievert = 0.001 Sv) is the **limit** in the EU **for the exposure from activities** like uranium mining and processing for members of the public according to guideline 96/29/EURATOM
- **0.1 mSv per year** is the **guideline value** in the EU for the **exposure from drinking water consumption** according to guideline 98/83/EG and the Guidelines for Drinking Water Quality of the WHO
- **What are the limits in Kyrgyzstan?**

BGR ZSR

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Assessed sampling stations

- Station 4: Spring in Mailuusuu (close to bus-station)
- Station 10: Private dug well in southern valley (village Kok-Tash)
- Station 17: Water well near mosque in Mailuusuu
- Station 19: River Maili-Say downstream of tailings № 5,6 and 7
- Station 24: Private dug well in Mailuusuu, eastern city (Ul. Tuleberdieva)

BGR ZSR

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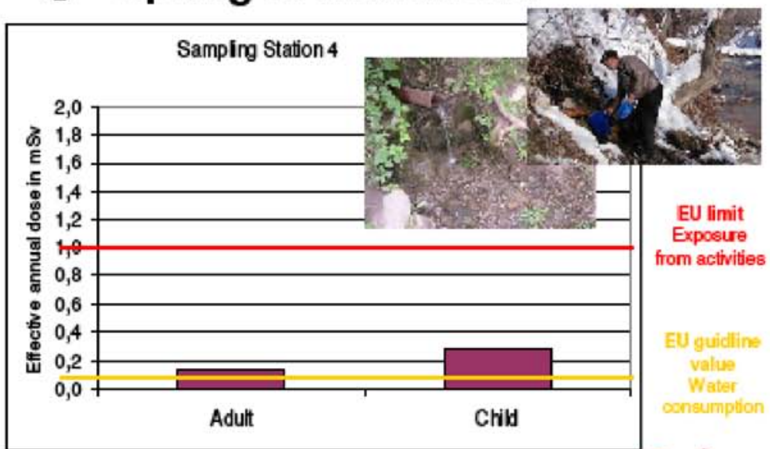
Spring in Mailuusuu



BGR ZSR

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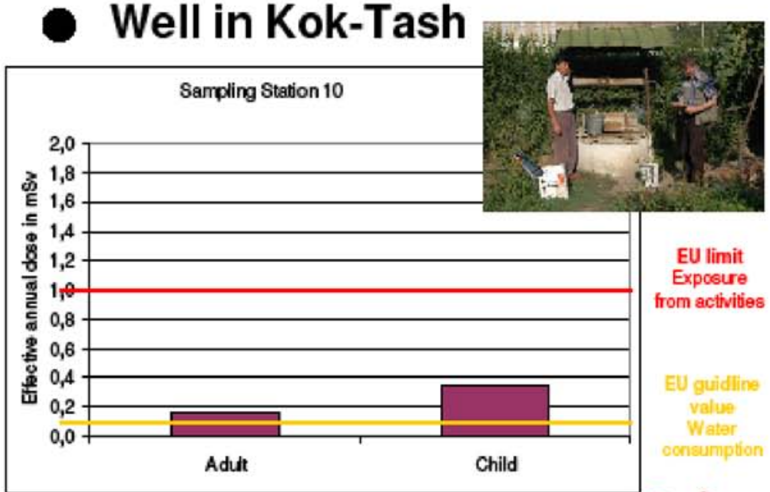
Well in Kok-Tash



BGR ZSR

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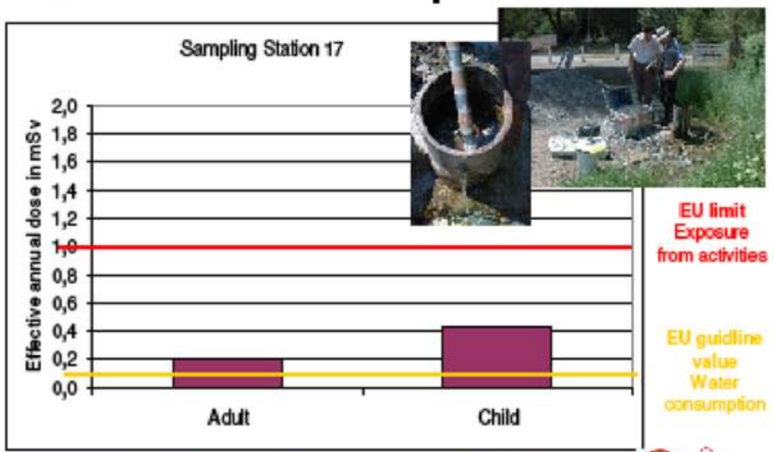
Well near mosque



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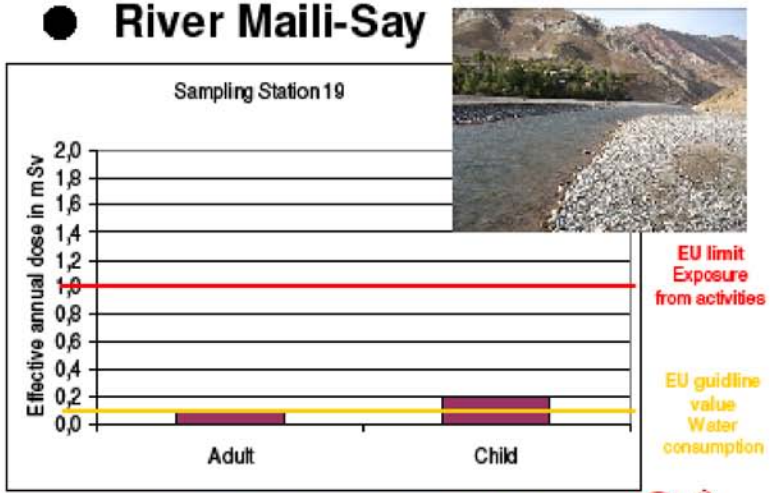
River Maili-Say



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Well in Mailuusuu

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Conclusions

Avoid contamination!

Ground water as well as surface water may be affected by contamination

Use mainly water from the Central Water Supply for Drinking/Cooking purposes

Use bottled Water (Mineral Water) for the needs of Children

Watch the food chain!

Don´t let animals feed close to the tailing impoundments and their seepage waters

Don´t grow fruits and vegetables close to the Tailing impoundments

Don´t use seepage water for irrigation purposes

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Conclusions

Rise public awareness!

Signpost the known wells with information about water quality

Signpost the seepage water inflows with information about possible dangers

Take responsibility!

Check water quality of water wells which are not observed so far

Assure long-term and periodical monitoring of selected water wells used for Drinking Water supply

Remember the difficulties of comparison!

Various water types (ground water, surface water, seepage water) possess different water qualities in Mailusuu

Even water wells in close vicinity may supply very different water types, so do not infer from one well to another

Mailuusuu, 19. September 2007

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