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Hydrogeochemical Data Report: the Sampling of Selected Locations in the Republic of Khakassia, Kuznetsk-Alatau Oblast' and Kemerovo Oblast', Southern Siberia, Russian Federation

Geological Survey of Norway
NO-7491 Trondheim, Norway
Tel.: 47 73 90 40 00
Telefax 47 73 92 16 20

REPORT

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Hydrogeochemical Data Report: the Sampling of Selected Locations in the Republic of Khakassia, Kuznetsk-Alatau Oblast' and Kemerovo Oblast', Southern Siberia, Russian Federation

Authors: Banks, D., Parnachev, V.P., Frengstad; B.S., Karnachuk, O.V.	Client: NGU, Tomsk State University (Russia), Holymoor Consultancy, UK)
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Summary:

This report documents the hydrochemical analyses performed on water samples collected during field expeditions during the summers of 2006 and 2007 to the Republic of Khakassia, Kuznetsk-Alatau Oblast' and Kemerovo Oblast' (Russian Federation) in southern Siberia. Data have been obtained from groundwater (boreholes, wells), rivers, lakes and discharges from abandoned mines and mine wastes. Of particular interest are the following observations:

(i) That river water and groundwater samples from the former gold mining area of Malii Anzas *failed* to reveal significantly elevated Hg concentrations, despite the intensive use of Hg in the former mining operation and the known soil contamination in the area.

(ii) That mine water being pumped from the abandoned Komsomolskaya mine, near Tysul', and being used by the local population as a domestic water supply, contains 225 µg/L arsenic by ICP-AES techniques (215 µg/L by ICP-MS). It is recommended that Tomsk State University enter a dialogue with local health authorities to minimise risk to local populations.

(iii) That mine tailings deposits at the Novii Berikul mineral processing works are producing a leachate with pH as low as 2, sulphate up to 22,000 mg/L, Fe up to 9100 mg/L, Al up to 500 mg/L, Cu up to 35 mg/L, Zn up to 351 mg/L, Pb up to 8.5 mg/L, Cd up to 5.7 mg/L and As up to 1900 mg/L. Quantities of leachate produced are rather modest, however, and the impact on the nearby river system is not known.

The "Severnaya" coal mine borehole in Kemerovo is producing a highly alkaline (t-alkalinity = 34 meq/L, pH = 7.6), H_2S-rich, highly reducing mine water that supports a colony of suspected *Thiothrix* sulphide-oxidising bacteria, and ultimately discharges into the river Tom'.

Keywords: Geochemistry	Hydrogeology	Drilled well
Mine water	River water	Microbiology
Groundwater quality	Lakes	Arsenic

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1 INTRODUCTION

Tomsk State University (TGU) has long enjoyed an informal yet fruitful collaboration in the field of hydrochemistry with the Geological Survey of Norway (NGU) and Holymoor Consultancy (UK). This collaboration has primarily supported a joint project between TGU and the Khakassian State Committee for Environmental Protection (SCEP) to produce the geological section of an "Environmental Atlas of Khakassia" (Parnachev et al. 1998a,b, 2000). Previous groundwater sampling was carried out in Khakassia during the periods:

- 16th - 21st August 1996, by David Banks (NGU), Prof. Valery Petrovich Parnachev (Dept. of Dynamic Geology, Tomsk State University) and Alexander Y. Berezovsky (Tomsk State University / Shira Regional Administration). Results of this sampling round are published by Banks et al. (1998) and Parnachev et al. (1997, 1999).
- 9th-15th June 1999 by David Banks (Holymoor Consultancy), Prof. Valery Petrovich Parnachev (Dept. of Dynamic Geology, Tomsk State University), Bjørn Frengstad (NTNU/NGU) and Anatoly A. Vedernikov (Khakassian SCEP, Abakan office).
- 7th - 12th September 2000, by David Banks (Holymoor Consultancy), Prof. Valery Petrovich Parnachev (Dept. of Dynamic Geology, Tomsk State University), Wayne Holden (URS Dames & Moore, UK), Olga V. Karnachuk (Dept. of Plant Physiology and Biotechnology, Tomsk State University) and Anatoly A. Vedernikov (Khakassian SCEP, Abakan office). Results of these last two sampling rounds have been published by Banks et al. (2001) and by Banks et al. (2004).

In July 2006, this collaboration continued with staff from TGU, NGU and Holymoor being invited to carry out hydrochemical sampling at two localities in the Republic of Khakassia:

- therapeutic waters in the vicinity of Lake Shira
- waters in the vicinity of a former alluvial gold mining area at Malii Anzas, south of Abaza

Moreover, the scope of the fieldwork was extended to include sampling in oblasts neighbouring Khakassia:

- sampling of mine waters from a former underground gold mining area around Berikul', in Kuznetsk-Alatau oblast'
- sampling of mine waters from working and abandoned coal mines in the Kuzbas coal basin of Kemerovo oblast'.

In August 2007, staff from TGU and Holymoor Consultancy returned to two sampling localities to collect additional samples:

- mine waters from the former gold mining area around Berikul', in Kuznetsk-Alatau oblast'

- mine waters from the silver-gold-zinc mining area around Salair, on the western fringes of the Kuzbas.

During the sampling of July 2006, alkalinity, pH, electrical conductivity, temperature (and Eh, where meaningful) were measured in the field, while filtered (0.45 µm) water samples were returned to NGU for analysis by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES), Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and Ion Chromatography (IC) methods.

During the sampling of August 2007, pH, electrical conductivity and temperature were measured in the field, while filtered (0.45 µm) water samples were returned to the University of Newcastle's Hydrogeochemical Engineering Research & Outreach (HERO) group for analysis by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES) and Ion Chromatography (IC) methods.

Staff time has been provided to the project by:

- TGU (Professors Valery P Parnachev and Olga V Karnachuk)
- NGU (Dr Bjørn S Frengstad)
- Holymoor Consultancy, Chesterfield, UK (Mr David Banks)
- University of Newcastle-upon-Tyne (Mr David Banks, Ms Jane Davis, Mr Patrick Orme)

This report is intended to document the raw data produced during the study. This raw data report will form the documentation basis for scientific papers interpreting the data collected during the study.

2 SAMPLING AND ANALYSIS ROUTINES: YEAR 2006

The sampled sites in 2006 are detailed in Sections 3 to 6 of this Report.

2.1 Groundwater Sampling

As in the previous sampling rounds, groundwater samples were taken, to the extent possible, from flowing sources (springs), artesian (flowing) boreholes or regularly-used wells and boreholes, to ensure that "fresh" groundwater was sampled. For each sample site the following samples were taken:

- 2 x 100 ml polyethene flasks, of water filtered at 0.45 μm, using a Millipore filter capsule and hand-held polypropene syringe. No acidification was carried out in the field.
- a selection of samples for bacteriological analysis at TGU (not reported in this report)

2.2 Mine Water Sampling

Mine waters were sampled either from freely discharging adits or other mine openings, or from pumped shafts / boreholes. Samples were collected as in 2.1. However, in some cases, unfiltered aliquots of sample were collected in addition to filtered aliquots, in order to gain an impression of the total metals content of the water (i.e. colloidal (>0.45 μm) and particulate iron etc., in addition to microcolloidal and dissolved).

2.3 Lake Water Sampling

The lake water sample from Lake Utichie 3 was taken from a short jetty by submerging the sampling bottle to a depth of some 20-30 cm in water free of disturbed sediment.

The sample of mud from Lake Utichie 3 was collected from a bucket dredged from the Lake bottom by operatives present on the site.

The surface sample from Lake Shira (Xa105) was collected in a clean bucket from shallow depth (15-20 cm) from a floating pontoon, some 25 m from the shore of Shira *kurort*.

2.4 Field Measurements

Field measurements of groundwater were taken either in the flowing water source or, if this was not possible, in a large (c. 15 l) bucket filled directly from the source. In lakes, the electrodes were submerged to maximum extent below the lake surface (c. 5-10 cm) for measurements to be taken. In the case of alkalinity, reaction vessels were filled either from the flowing source, or (e.g. in the case of lakes) directly from the lake or from a large bucket filled with the water from the source. Field determinations included:

- determination of alkalinity (by average of multiple determinations, typically three determinations) using a AquaMerck 11109 alkalinity test kit, which employs titration against an acid solution with phenolphthalein (end-point pH=8.2) or mixed (end-point pH=4.3) indicators for p-alkalinity and t-alkalinity, respectively.
- pH and temperature (T) using a Holymoor Consultancy's Hanna Instruments HI98128 pH meter, regularly calibrated against solutions of known pH around 4, 7 or 10 as appropriate. pH was also measured using TGU's "ISFET" pH meter at most sites.
- Measurements of electrical conductivity (EC) and temperature, using a WTW meter.

2.5 Analysis at the Geological Survey of Norway (NGU)

Samples (typically two samples of filtered water from each site) were transported by Bjørn Frengstad to the NGU analytical laboratory in Trondheim. Prior to analysis, samples were stored in a refrigerator at around 4°C, except for brief periods of transport. Upon arrival, the samples were stored in the NGU cool-room at 4°C. For analysis, the following procedure was followed:

1. One flask was used directly for ion-chromatography (Dionex 120 DX machine) analyses of anions.
2. The second flask was acidified with 0.5% concentrated Ultrapur HNO_3 *in the original flask*. This was done to hinder absorption / precipitation (and dissolve already sorbed/precipitated) of elements. This acidified quantum was used for ICP-AES (Perkin Elmer Optima 4300 Dual View machine) and ICP-MS (Finnegan Mat machine with Meinhart Nebulizer CD-1) analyses.
3. In cases where unfiltered samples were collected for metals analysis, these were also acidified and analysed as in Step 2. The results from these analyses should therefore be regarded as the total acid-soluble contents of the water sample.

3 SHIRA (ШИРА) REGION; REPUBLIC OF KHAKASSIA (ХАКАССИЯ)

All the samples collected from the Shira region were taken on the 7th July 2006.

3.1 Sampling Sites

Sample Xa101: Lake Utichie 3. This lake has been sampled in previous years by the project team. However, in recent years, water levels have systematically risen in Kkakassia, due to excessive rain, and the level of Lake Utichie 3 has reportedly risen by some 2 metres (V.P.Parnachev, *pers. comm.*). The sample was thus taken to ascertain if the water quality had changed significantly. The lake is surrounded by rural, hilly terrain. A fault runs through the Lake, such that the geology is dominated by Vendian carbonate rocks on one side and Devonian volcanics and sandstones on the other. The water samples were collected from c. 15 cm below the lake surface. During filtration of samples, a slight yellow-brown precipitate was noted on the filter. During sampling, the weather was light rain.

Additionally, a sample of the black mud (*il*) from the lake bed (Xa102) was collected in a bucket and transferred to a sample bottle. The mud was clayey/silty in texture and has a strong H_2S smell. The mud is excavated by hand at the lake and exported to Shira's *kurort* for therapeutic use.

Sample Xa103: Shira Lake Water. This sample was taken in the bath-house of Shira's *kurort*, where water is pumped from an intake in Lake Shira (at a depth of some 14 m, located 300 m from shore). The water has a characteristic reddish colour due to the presence of micro-organisms (diatoms??). The water used in the *kurort* is thus filtered to remove these microorganisms. The sample was taken directly from the pump discharge prior to the *kurort*'s filtration equipment, however. During our filtration of the samples, a red colour was noted on the filters.

Sample Xa104: Shira Kurort Borehole. The kurort's borehole is located some 300 m from the kurort bath-house. The borehole is in Upper Devonian (D_3) "Old Red Sandstone" strata, is pumped by an electrical submersible pump and is around 10" in diameter at the well-head. The water was clear, with no discernable smell or colour.

Sample Xa105: Shira Lake Water. This sample was taken of water from c. 15 cm below the surface of Lake Shira from a floating recreational jetty, c. 25 m from the shore of the kurort complex. No smell was noted from the sample. A slight beige colour was noted on the filter used during sampling.

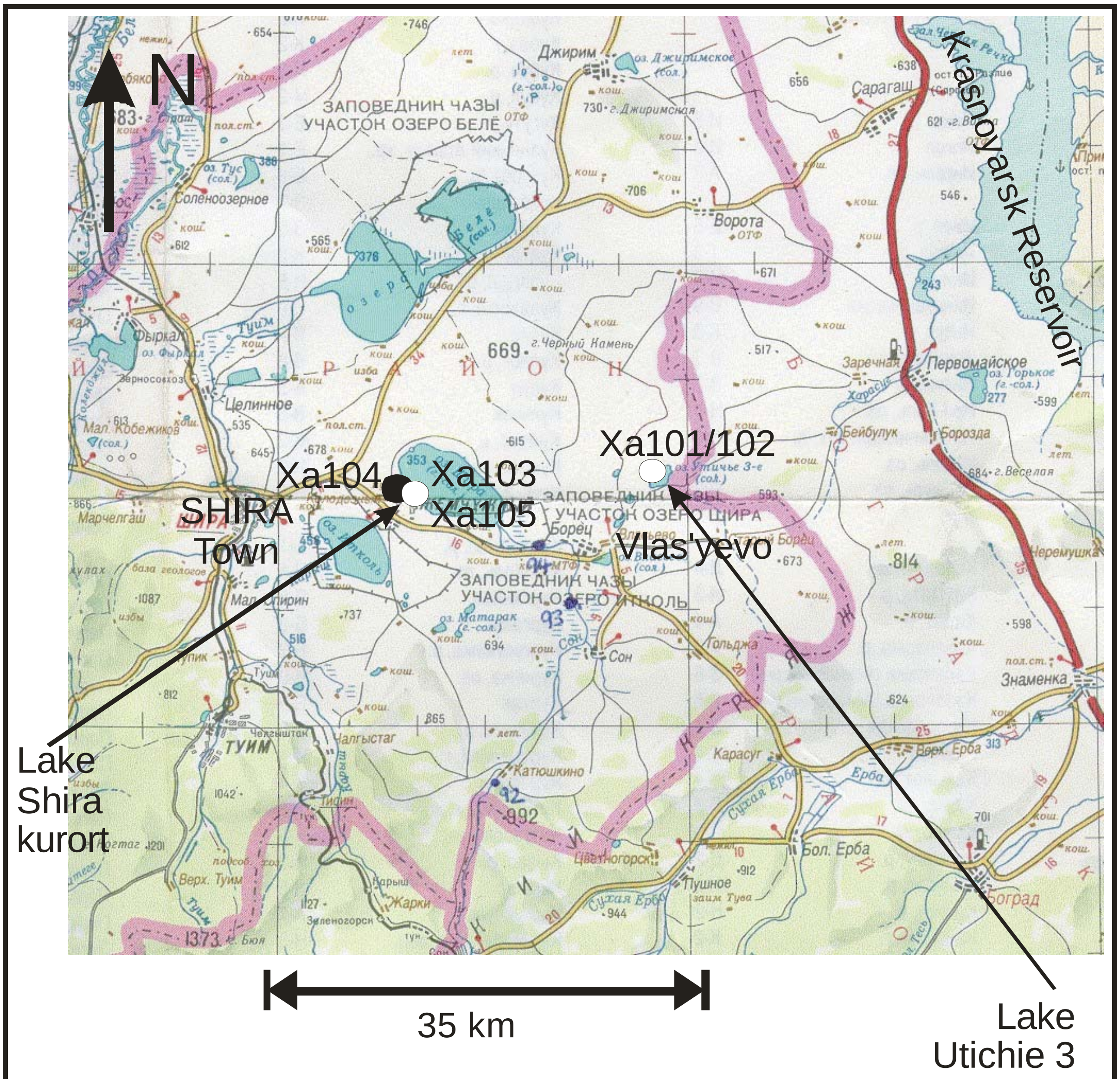

Figure 3.1. Sample locations, Shira region.

3.2 Field Analyses of Waters (pH, Temperature, EC, Alkalinity)

Sample		UTM Zone	Easting	Northing	EC	Temp	Temp	TAlk1	TAlk2	TAlk3	T_alk	PAlk1	PAlk2	P_alk	pH	pH
		Unit			µS/cm	°C	°C	meq/L	meq/L	meq/L	meq/L	meq/L	meq/L	meq/L		
		Meter			WTW	WTW	Hanna								Isfet	Hanna
Xa101	Utichie 3 lake water (LW)	46N	0335183	6043569	5950	23.5	23.5	7.8	7.6	7.7	7.7	0.6	0.6	0.6	8.4[A]	8.03
Xa102	Utichie 3 sediment	46N	0335183	6043569												
Xa103	Lake Shira deep (LW)	46N	0316240	6043329	20100	3.9	3.9	19.3	19.6		19.5	4.7	4.6	4.7	8.9	8.50
Xa104	Shira Kurort Borehole (GW)	46N	0315298	6043491	3510	5.9	6.0	3.3	3.4	3.3	3.3				7.8	7.10
Xa105	Lake Shira shallow (LW)	46N	0316028	6043117	16100	22.5		15.8	15.6		15.7	3.3	3.1	3.2	9.0	

TAlk1 etc. represent individual determinations of total alkalinity. T_alk is the average

PAlk1 etc. represent individual determinations of phenolphthalein alkalinity. P_alk is the average

[A]The pH determination by the Isfet meter is preferred, on the grounds that it gives a reading >8.2 for Xa101, for which a finite P_alk was determined (titration has an end point of 8.2).

LW = lake water

GW = ground water

3.3 Anions by Ion Chromatography at the Geological Survey of Norway

Sample		F^-	Cl^-	NO_2^-	Br^-	NO_3^-	PO_4^{3-}	SO_4^{2-}
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Xa101	Utichie 3 lake water (LW)	0.80	803	< 0.5	4.98	< 0.5	< 2.0	1874
Xa102	Utichie 3 sediment							
Xa103	Lake Shira deep (LW)	<.5.0	2032	< 5.0	27.3	< 5.0	< 20.0	9095
Xa104	Shira Kurort Borehole (GW)	0.86	189	< 0.5	1.15	16.0	< 2.0	1316
Xa105	Lake Shira shallow (LW)	< 5.0	1715	< 5.0	< 10.0	< 5.0	< 20.0	7096

All determinations on filtered samples at 0.45 µm
Note that concentrations of nitrite, nitrate, phosphate and sulphate are cited as mg/L NO_2^-, NO_3^-, PO_4^{3-} and SO_4^{2-} and *not* mg/L N, P amd S.

3.4 Analyses of 33 Elements by ICP-AES at the Geological Survey of Norway

Sample		Si	Al	Fe	Ti	Mg	Ca	Na	K	Mn	P	Cu	Zn	Pb	Ni	Co	V
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Xa101	Utichie 3 lake water (LW)	4.30	<0.2	0.0214	<0.01	378	128	883	30.2	0.0496	<0.5	<0.05	<0.02	<0.05	<0.05	<0.01	0.0895
Xa102	Utichie 3 sediment	2.02	<0.02	0.0223	0.0015	159	42.7	369	22.5	0.0455	0.420	<0.005	<0.002	<0.005	<0.005	<0.001	0.0184
Xa103	Lake Shira deep (LW)	2.95	<0.2	0.0265	<0.01	1360	68.8	3950	43.6	0.0445	<0.5	<0.05	<0.02	<0.05	<0.05	<0.01	0.161
Xa104	Shira Kurort Borehole (GW)	4.35	<0.02	<0.002	0.0017	93.4	205	512	3.34	0.0060	0.114	<0.005	0.0130	<0.005	<0.005	<0.001	0.0176
Xa105	Lake Shira shallow (LW)	1.82	<0.2	<0.02	<0.01	1050	59.9	3080	34.3	<0.01	<0.5	<0.05	<0.02	<0.05	<0.05	<0.01	0.145

Sample	Mo	Cd	Cr	Ba	Sr	Zr	Ag	B	Be	Li	Sc	Ce	La	Y	As	Sb	S*
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Xa101	<0.05	<0.005	<0.02	0.0558	3.26	<0.02	<0.05	0.725	<0.01	0.138	<0.01	<0.2	<0.05	<0.01	<0.1	<0.05	2350
Xa102	0.0838	<0.0005	<0.002	0.0434	1.23	<0.002	<0.005	0.953	<0.001	0.0843	<0.001	<0.02	<0.005	<0.001	0.030	<0.005	337
Xa103	<0.05	<0.005	<0.02	<0.02	8.22	<0.02	<0.05	2.58	<0.01	0.239	<0.01	<0.2	<0.05	<0.01	<0.1	<0.05	11600
Xa104	0.0187	<0.0005	<0.002	0.0041	6.37	<0.002	<0.005	0.982	<0.001	0.131	<0.001	<0.02	<0.005	<0.001	0.014	<0.005	1730
Xa105	<0.05	<0.005	<0.02	<0.02	6.50	<0.02	<0.05	2.05	<0.01	0.186	<0.01	<0.2	<0.05	<0.01	<0.1	<0.05	10100

All determinations on water samples were on samples filtered at 0.45 µm.
The determination on the lake sediment (Xa102) was on a distilled water equilibration with the lake mud according to NGU Standard Method NGU SD 2.19. Concentrations cited are for the water phase.

3.5 Analyses of 31 Elements by ICP-AES on acid digest of lake mud

Sample		Si	Al	Fe	Ti	Mg	Ca	Na	K	Mn	P	Cu	Zn	Pb	Ni	Co	V
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Xa102	Utichie 3 sediment	144	27000	25900	524	25800	88300	9820	7550	691	1100	24.9	76.2	10.4	25.0	7.54	48.2

Sample	Mo	Cd	Cr	Ba	Sr	Zr	Ag	B	Be	Li	Sc	Ce	La	Y	As
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Xa102	2.57	0.22	30.1	250	1610	5.3	<2	83.7	0.61	35.5	5.32	27.0	16.6	8.48	3.3

All determinations carried out by NGU's ICP-AES intrument on a 7N HNO_3 autoclave digestion of the lake mud, according to Norwegian Standard NS4770. Margin of uncertainty c.±10%.

4 MALII ANZAS (МАЛЫЙ АНЗАС): REPUBLIC OF KHAKASSIA

All the samples collected from the Malii Anzas region were taken on the 8th July 2006.

Malii Anzas village (population 5 families) lies several kilometers downstream along the River Ona from the village of Kubaika (Кубайка), at the junction of the smaller River Malii Anzas with the River Ona. The sampling team reached Kubaika by car and then travelled by motorised canoe to Malii Anzas (Figure 4.1).

The village lies on a small fluvial delta built out by the River Malii Anzas into the River Ona. The alluvial sands and gravels of the River Malii Anzas had been worked for gold for about 150 years until 1993. The site was a *gulag* in Stalinist times, when prisoners would work the deposits largely by hand.

The surrounding bedrock comprises lower Cambrian volcanics and the gold ore "motherlode" was worked at Kirovskii Mine, upstream along the River Malii Anzas.

During mining, large quantities of mercury were used for gold extraction and previous studies by Russian institutes have found the soils (top 40 cm) along the lower Malii Anzas river and delta to be significantly contaminated by mercury (at rates of >5 mg/kg). The main objective of sampling here was to determine whether the groundwater or the river water in the Malii Anzas or the Ona is also contaminated.

The weather during the 3 days prior to sampling had involved abnormally heavy rainfall and the rivers sampled were in a state of spate.

4.1 Sampling Sites

Location of sampling sites are shown in figure 4.2.

Sample Xa106: Bedrock Spring This is a spring at elevation 662 m asl that appears to arise from bedrock (or hillslope "head" deposits) on the northern bank of the River Malii Anzas c. 3 km upstream from the confluence with the Ona. The flow is estimated to be c. 2 L/s, increasing to c. 4 L/s as it approaches the Malii Anzas River. The water is clean and no residue was apparent on the 0.45µm filter following sampling.

Sample Xa107: River Malii Anzas. This sample was taken of river water from the north bank of the river, some 250 m upstream of the confluence with the Ona. The water was rather clear with only a very slight amount of turbidity being apparent.

Sample Xa108: River Ona; d/s confluence. This sample was taken of river water from the west bank of the River Ona, some 200 m downstream of the confluence with the Malii Anzas.

It is also downstream of Malii Anzas village and of pasture associated with the village. The water is relatively clear with a small amount of turbidity (small amount of residue on filter)

Sample Xa109: River Ona; u/s confluence. This sample was taken of river water from the River Ona, on the upstream edge of a mid-river island, a short distance upstream of the confluence with the River Malii Anzas.

Sample Xa110: Dug well, Malii Anzas village. The well was lined with logs. The depth to groundwater was c. 4 m with 1 m depth water in the base (total depth c. 5 m). Water was extracted for sampling using the well's *shaduf*. The well was located on one of the terraces of the River Malii Anzas, above most of the village's houses, but below one small cluster of cabins. The well was located 150 m south of the Malii Anzas River and 200 m west of the River Ona. The surrounding land use was village housing and pasture (some pigs). The sampled water had some visible brown colouration and contained some small wood fragments.

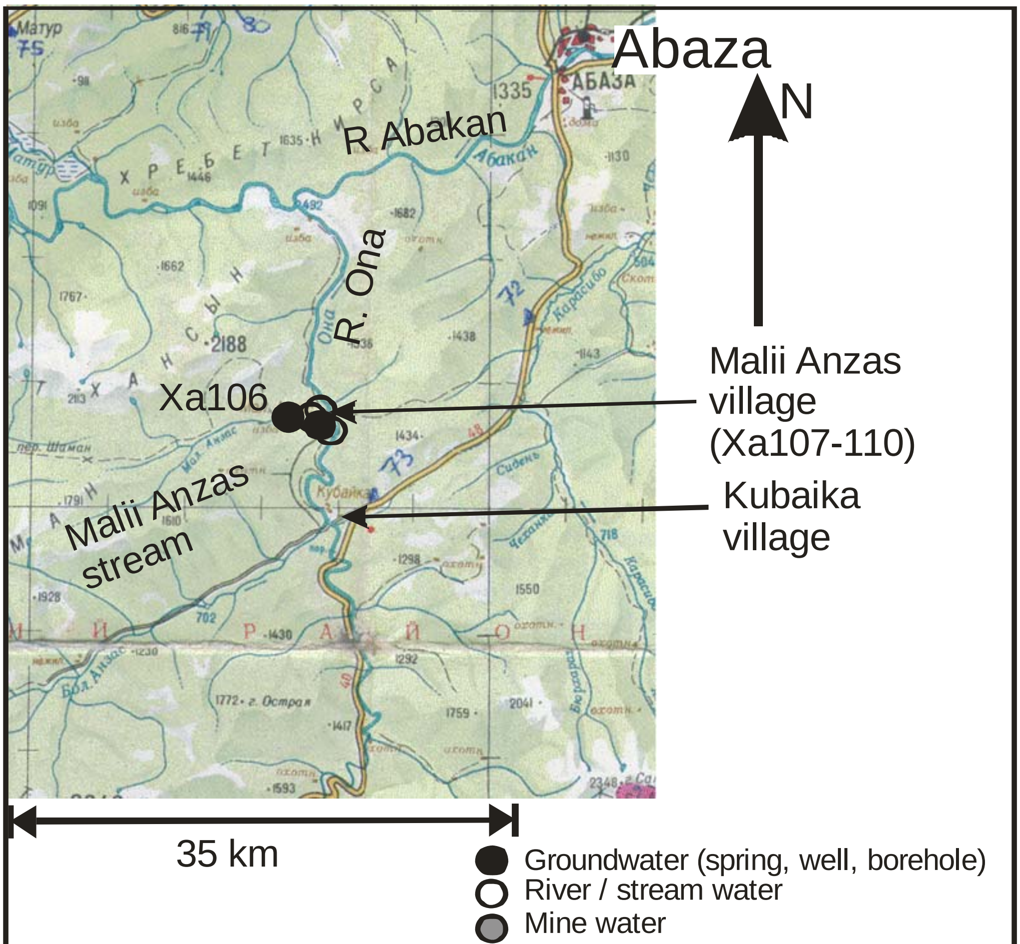

Figure 4.1. Sample locations at Malii Anzas

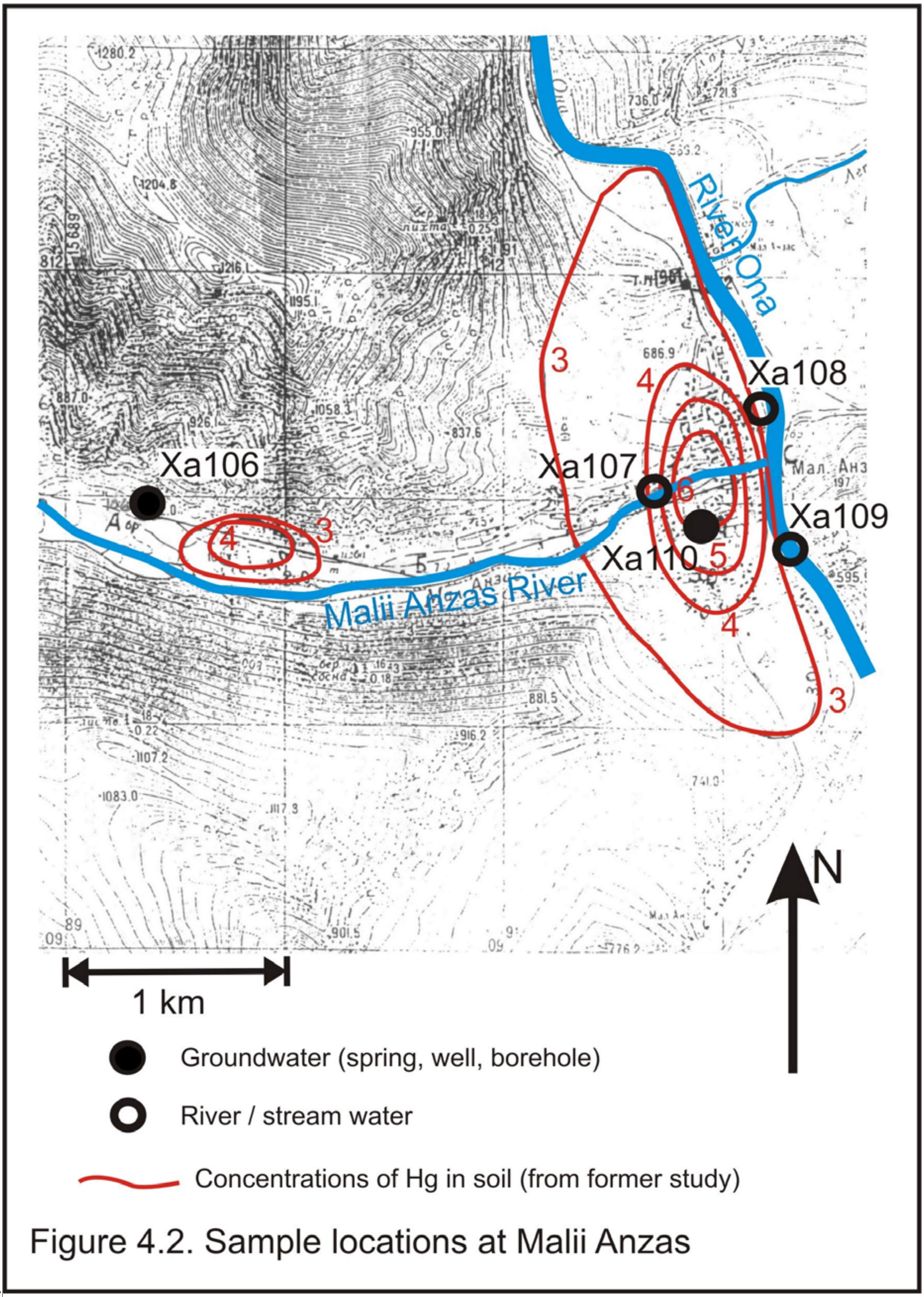

Figure 4.2. Detailed sampling locations at Malii Anzas. Concentration of Hg in soil are shown in contours of mg/kg soil and are derived from a study by Viacheslav M. Ermakov, State University of Khakasia, Abakan.

4.2 Field Analyses of Waters (pH, Temperature, EC, Alkalinity)

Sample		UTM Zone	Easting	Northing	EC	Temp	Temp	TAlk1	TAlk2	TAlk3	T_alk	PAlk1	PAlk2	P_alk	pH	pH
		Unit			µS/cm	°C	°C	meq/L	meq/L	meq/L	meq/L	meq/L	meq/L	meq/L		
		Meter			WTW	WTW	Hanna								Isfet	Hanna
Xa 106	Malii Anzas spring (GW)	45N	0689403	5808575	226	4.0	4.0	1.7	2.1	2.1	2.0				7.9	7.3
Xa 107	Malii Anzas river (RW)	45N	0691777	5808805	76	10.5	10.5	0.8	0.8	0.9	0.8				7.9	7.6
Xa 108	Ona River downstream (RW)	45N	0691902	5809159	64	10.4	10.6	0.7	0.7	0.7	0.7				7.8	7.44
Xa 109	Ona River upstream (RW)	45N	0692326	5808323	43.5	9.0	9.4	0.4	0.5	0.4	0.4				7.5	7.32
Xa 110	Malii Anzas well (GW)	45N	0691896	5808308	235	3.9	4.1	2.1	1.9	2.0	2.0				6.6	6.66

TAlk1 etc. represent individual determinations of total alkalinity. T_alk is the average
PAlk1 etc. represent individual determinations of phenolphthalein alkalinity. P_alk is the average

RW = river water
GW = ground water

4.3 Anions by Ion Chromatography at the Geological Survey of Norway

Sample		F^-	Cl^-	NO_2^-	Br^-	NO_3^-	PO_4^{3-}	SO_4^{2-}
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Xa 106	Malii Anzas spring (GW)	0.07	0.39	< 0.05	< 0.1	2.82	< 0.2	16.5
Xa 107	Malii Anzas river (RW)	< 0.05	0.11	< 0.05	< 0.1	0.67	< 0.2	2.75
Xa 108	Ona River downstream (RW)	< 0.05	0.14	0.12	< 0.1	0.62	< 0.2	2.14
Xa 109	Ona River upstream (RW)	< 0.05	0.15	0.13	0.22	0.54	< 0.2	1.46
Xa 110	Malii Anzas well (GW)	< 0.05	3.08	< 0.05	< 0.1	15.5	0.46	7.62

All determinations on filtered samples at 0.45 µm
Note that concentrations of nitrite, nitrate, phosphate and sulphate are cited as mg/L NO_2^-, NO_3^-, PO_4^{3-} and SO_4^{2-} and *not* mg/L N, P amd S.

4.4 Analyses of 33 Elements by ICP-AES at the Geological Survey of Norway

Sample		Si	Al	Fe	Ti	Mg	Ca	Na	K	Mn	P	Cu	Zn	Pb	Ni	Co	V
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Xa 106	Malii Anzas spring (GW)	4.00	<0.02	0.0043	<0.001	2.15	45.7	2.46	<0.5	<0.001	0.059	<0.005	0.0040	<0.005	<0.005	<0.001	<0.005
Xa 107	Malii Anzas river (RW)	3.24	<0.02	0.0118	<0.001	0.839	13.0	1.31	<0.5	<0.001	<0.05	<0.005	0.0020	<0.005	<0.005	<0.001	<0.005
Xa 108	Ona River downstream (RW)	3.07	0.032	0.0238	0.0011	0.812	11.3	1.28	<0.5	0.0035	<0.05	<0.005	<0.002	<0.005	<0.005	<0.001	<0.005
Xa 109	Ona River upstream (RW)	2.67	0.059	0.0372	0.0014	0.768	7.07	1.14	<0.5	0.0042	<0.05	<0.005	<0.002	<0.005	<0.005	<0.001	<0.005
Xa 110	Malii Anzas well (GW)	4.62	<0.02	0.0520	0.0012	3.09	38.8	5.03	4.64	0.0060	0.291	<0.005	0.0045	<0.005	<0.005	<0.001	<0.005

Sample	Mo	Cd	Cr	Ba	Sr	Zr	Ag	B	Be	Li	Sc	Ce	La	Y	As	Sb	S*
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Xa 106	<0.005	<0.0005	<0.002	0.0040	0.242	<0.002	<0.005	<0.02	<0.001	<0.005	<0.001	<0.02	<0.005	<0.001	<0.01	<0.005	27.5
Xa 107	<0.005	<0.0005	<0.002	0.0036	0.0578	<0.002	<0.005	<0.02	<0.001	<0.005	<0.001	<0.02	<0.005	<0.001	<0.01	<0.005	8.04
Xa 108	<0.005	<0.0005	<0.002	0.0041	0.0481	<0.002	<0.005	<0.02	<0.001	<0.005	<0.001	<0.02	<0.005	<0.001	<0.01	<0.005	6.63
Xa 109	<0.005	<0.0005	<0.002	0.0033	0.0264	<0.002	<0.005	<0.02	<0.001	<0.005	<0.001	<0.02	<0.005	<0.001	<0.01	<0.005	5.00
Xa 110	<0.005	<0.0005	<0.002	0.0175	0.181	<0.002	<0.005	<0.02	<0.001	<0.005	<0.001	<0.02	<0.005	<0.001	<0.01	<0.005	17.9

All determinations on water samples were on samples filtered at 0.45 µm.

4.5 Analyses of Hg by CETAC M-6000A Hg Analyzer at the Geological Survey of Norway

Sample		Hg
		µg/L
Xa 106	Malii Anzas spring (GW)	< 0.01
Xa 107	Malii Anzas river (RW)	< 0.01
Xa 108	Ona River downstream (RW)	0.02
Xa 109	Ona River upstream (RW)	0.02
Xa 110	Malii Anzas well (GW)	< 0.01

All determinations on water samples were on samples filtered at 0.45 µm.

4.6 Analyses of 42 Elements by ICP-MS at the Geological Survey of Norway

Sample		Y	Nb	Ag	In	Sb	Cs	Nd	Sm	Ho	Yb	Ta	W	Tl
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Xa 106	Malii Anzas spring (GW)	<0.005	<0.05	<0.01	<0.01	0.036	0.0092	<0.01	<0.002	<0.001	<0.002	<0.01	<0.05	<0.05
Xa 107	Malii Anzas river (RW)	0.0136	<0.05	<0.01	<0.01	0.027	<0.002	<0.01	<0.002	<0.001	<0.002	<0.01	<0.05	<0.05
Xa 108	Ona River downstream (RW)	0.0832	<0.05	<0.01	<0.01	0.022	0.0024	0.057	0.0122	0.0026	0.0089	<0.01	<0.05	<0.05
Xa 109	Ona River upstream (RW)	0.0828	<0.05	<0.01	<0.01	0.026	0.0054	0.053	0.0111	0.0027	0.0103	<0.01	<0.05	<0.05
Xa 110	Malii Anzas well (GW)	0.0312	<0.05	<0.01	<0.01	0.135	<0.002	0.015	0.0035	<0.001	0.0034	<0.01	<0.05	<0.05

Sample	Bi	Th	V	Mn	Cu	Zn	Ga	Ge	Li	Be	B	Rb	Zr	Mo
	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Xa 106	<0.01	<0.02	0.106	<0.05	0.261	0.47	<0.01	<0.05	<0.5	<0.01	8.2	<0.05	<0.05	0.49
Xa 107	<0.01	<0.02	0.202	0.521	0.658	0.44	<0.01	<0.05	<0.5	<0.01	<5	0.075	<0.05	<0.2
Xa 108	<0.01	<0.02	0.213	2.43	0.973	0.57	<0.01	<0.05	<0.5	<0.01	<5	0.217	<0.05	<0.2
Xa 109	<0.01	<0.02	0.264	3.75	1.32	0.39	0.01	<0.05	<0.5	<0.01	6.7	0.541	0.063	0.24
Xa 110	<0.01	<0.02	0.524	0.495	3.6	0.74	<0.01	<0.05	<0.5	<0.01	20.6	0.399	0.05	0.51

Sample	Cd	La	Ce	Pb	Al	Cr	Co	Ni	U	P	I	K	As	Se
	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Xa 106	<0.03	<0.01	<0.01	<0.05	<2	0.11	0.026	<0.2	0.221	<5	<5	250	0.838	<1
Xa 107	<0.03	<0.01	0.01	<0.05	13.4	0.1	<0.02	<0.2	0.00252	<5	<5	200	0.341	<1
Xa 108	<0.03	0.047	0.059	<0.05	26.5	0.17	0.021	<0.2	0.0153	<5	<5	281	0.3	<1
Xa 109	<0.03	0.044	0.073	<0.05	41.2	0.26	0.043	0.24	0.0123	<5	<5	358	0.183	<1
Xa 110	<0.03	0.017	<0.01	<0.05	7.4	0.11	0.071	0.5	0.0262	157	<5	see ICP-AES	2.71	<1

All determinations on water samples were on samples filtered at 0.45 µm.

5 TYSUL' / MARTAIGA (ТИСУЛЬ / МАРТАЙГА) MINING REGION: KEMEROVSKAYA OBLAST'

Water samples were collected at two mining localities: Komsomolsk (Комсомольск) and Berikul' (Берикуль), both lying a short distance south-west of Tysul' in the Mariinskaya Taiga (Martaiga) region of Kemerovo oblast'. The Martaiga region is geologically a bedrock terrane of the Kuznetsk Alatau mountain belt (Figure 5.1).

The Mines

Both mining areas are associated with quartz sulphide ore deposits, with a high content of arsenopyrite. The mineralisations are found at the edge of a Cambro-Ordovician granite massif, intruded into Precambrian-Cambrian host rocks. A short distance north of Komsomolsk, the Precambrian/Palaeozoic basement becomes covered with a sequence of Jurassic-Quaternary sediments of the West Siberian Basin, on the fringes of which the town of Tysul' is situated.

The Komsomolskii mines were reportedly up to 300 m deep and worked only for gold. The quartz-pyrite-gold mineralisation is at the boundary of the granite massif, intruded into country rocks of the Riphean-Vendian Yeniseiskii Carbonate Formation (dolomitised limestones).

The Berikul' mines were up to 500 m deep in a polymetallic sulphide quartz-pyrite/arsenopyrite-gold deposit, but were also worked only for gold. The ore mineralisation at Berikul' is associated with effusive volcanic rocks (the middle Cambrian Berikulskaya Suite) bordering a granite massif. Environmental sampling at the Berikul' processing works has been documented by Bortnikova et al. (2001), Gieré et al. (2003) and Sidenko et al. (2005)

The mining areas were all closed in the period 1996 to 1998. Flotation and cyanide processes were used to extract the gold ore.

Berikul' Processing Works

Ore material from the mines at Berikul' was transported to the Berikul' processing works for concentration (floatation and cyanidisation). The works lies on the left (west) bank of the Mokrii Berikul (Мокрый Берикуль) River. The slopes and river flood plain on the west bank of the river are underlain by fine-grained tailings from the ore processing. The tailings comprise 40-45% fine-grained sulphide (dominated by pyrite, with minor arsenopyrite and smaller amounts of pyrrhotite, sphalerite, chalcopyrite, galena, quartz, albite, chlorite, muscovite, and dolomite - Sidenko et al. 2005). The tailings have been present since 1952. In the most recent years (2-3 years ago), they have been covered by a layer of coarse grained (pebble-boulder sized) mine spoil (waste rock). The waste rock appears to largely consist of dolerite (and some marble) rock fragments.

At the foot of the hill-slope it is possible to observe both pools of relatively clear water and seepages of acidic, orange-yellow water from the tailings. On the flood plain below the hill-slope, pools of bright orange water have accumulated. Some of these pools seep or discharge slowly (but visibly) to the Mokrii Berikul River.

The Komsomolsk area was sampled on 11th July 2006 and the Berikul' area on 12th July 2006.

5.1 Sampling Sites

Sample Xa111: Komsomolskii mine shaft. The mine shaft is pumped from the northernmost (lowest) of two shafts, to a water tank some 70 m away. The tank is also believed to be connected to a series of standpipes providing domestic and irrigation water supply to nearby inhabitants. The total flow is not known but could easily be several L/s. The water was sampled from a leakage in the water tank. The water has a slight smell indicative of reducing conditions. The water also has a brownish black precipitate (with a slight white-grey precipitate at the edges) as it runs away over the ground from the tank. A slight greyish residue was noted on the filter following filtration of the water samples.

Sample Xa112: Komsomolskii mine shaft adit. A short distance (c. 200 m) downslope from the water tank and shaft, a small adit can be seen discharging from the hillside. It is believed that this adit connects to the same mine shaft sampled by Xa111. The flow from the adit is low, only some 0.1 L/s. The water leaves a slight brownish-grey precipitate at its discharge point, but left no residue on sample filtration. No odour could be detected. Very little spoil remains at the mine site and this is believed to be an adit rather than leachate from spoil.

Sample Xa113: Starii Berikul' (Old Berikul') mine adit: This sample was taken from a mine adit which discharges water at c. 20 L/s, from 8-9 m above the foot of a steep hillside, to the Sukhoi Berikul' (Сухой Берикуль) River, about 50 m downstream of the last houses of Starii Berikul' village. The adit is on the north bank of the Sukhoi Berikul'. At the point of discharge, there is an orange ochreous (presumed iron oxyhydroxide) precipitate on the rocks (on filtration of the sampled water, only a little such orange precipitate was observed on the filter). In addition to the filtered sample, an unfiltered aliquot (Xa113b) was also collected for metals analysis by ICP.

Sample Xa114: Berikul' Processing Works: A sample was taken from a pool of water at the foot of the mine-waste-covered hillside. The water has no obvious surface water inflow or outflow, but the coarse nature of the mine waste rock suggests that there may be groundwater throughflow. There is no orange or yellow colour, staining or precipitate associated with the pool. The high pH and low metals content observed in this water suggest that the pool is not in contact with fine grained tailings and merely results from seepage through the coarse grained mine waste cover. Samples were taken from 5-10 cm below the water surface: the water had no odour. There was some resistance to filtration and a slight greyish residue was left on the filter.

Sample Xa115: Berikul' Processing Works "Big Orange": A sample was taken from an ochreous-stained, pooled area of orange water (the so-called "Big Orange") on the flood plain of the Mokrii Berikul' river. The site appears to be underlain by mine spoil and tailings. No flow could be observed in the pool. Samples were taken from 10-15 cm depth in the pool. The water was a clear orange colour. No precipitation was observed on sampling filters (too acidic). The rock fragments around the pool area were stained orange-yellow and, underneath, a greyish green colour (which may be due to a yellowish jarosite precipitate overlying the greyish-black colour of the dolerite fragments). Leachate from the mine wastes on the flood plain, such as this, appears to have a significant visual impact on the river Mokrii Berikul', especially towards its left bank. The pH of the River near Xa115 was measured as 6.5-6.6, with a temperature of 14.2°C. Upstream of the mining site, pH values as high as 7.2 were determined in the River.

Sample Xa116: Berikul' Processing Works "Little Red": This sample was taken from a small (20x35 cm) pool of red-coloured water at the edge of the flood plain. The flood plain is underlain largely by mine tailings. The pool is fringed by whitish/pale yellow/orange precipitates (most likely to be aluminium salts). During filtration of the sample, there was a tendency for the filter to clog, with an orange residue on the filter. No odour was associated with the water.

Sample Xa117: Serebryanii Klyuch (серебряный ключ) Borehole: This sample was taken at an artesian, 200 m deep borehole, drilled at 5" diameter (125 mm) into the diorite bedrock for gold exploration. It is located near Gavrilovskaya Mine, not far from the Berikul' processing works. It is located in the base of the Mokrii Berikul' Valley and is not believed to penetrate any mine workings. The artesian overflow was measured at 0.061 L/s.

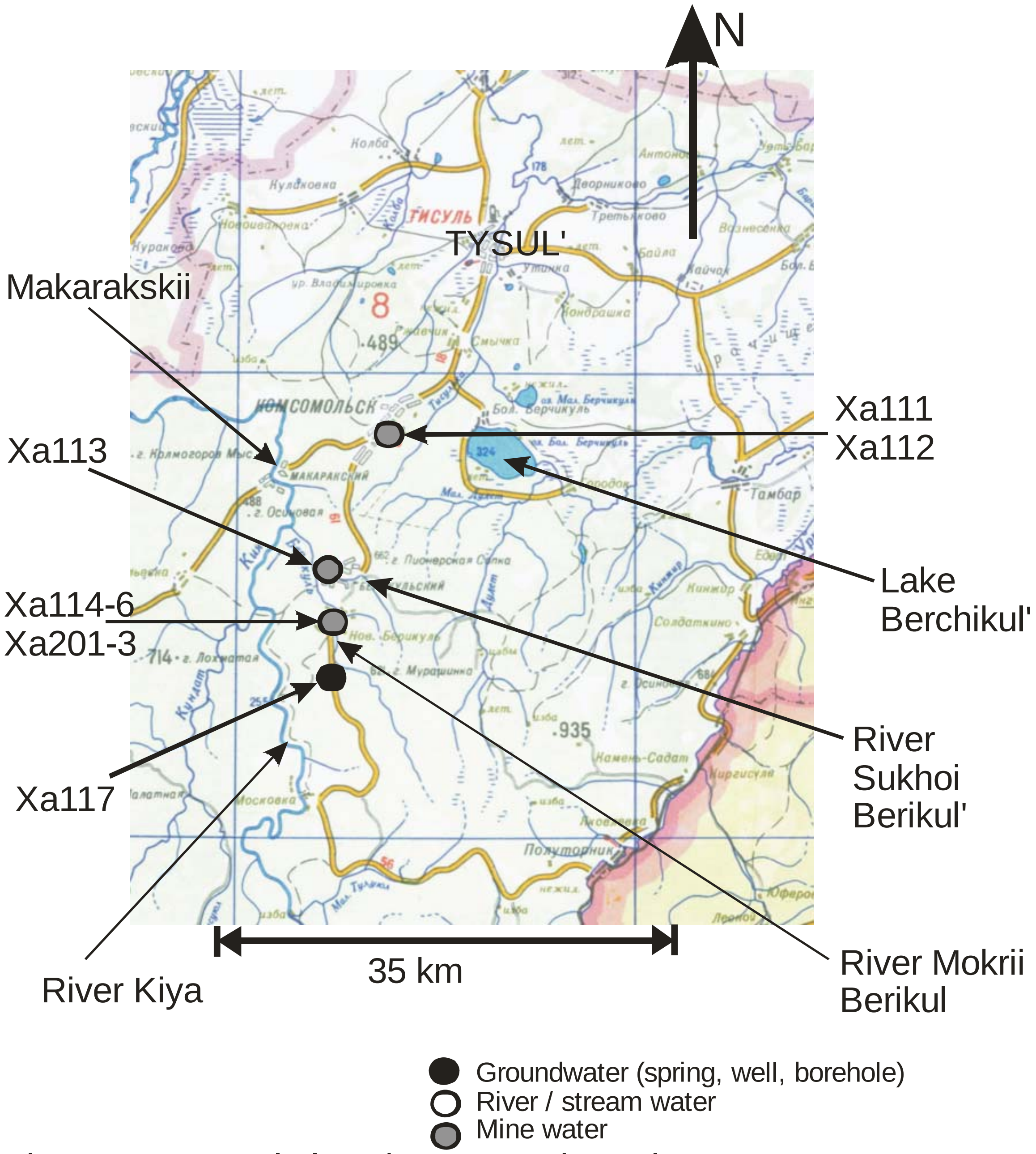

Figure 5.1. Sample locations around Tysul’

5.2 Field Analyses of Waters (pH, Temperature, EC, Alkalinity)

Sample		UTM Zone	Easting	Northing	EC	Temp	Temp	TAlk1	TAlk2	TAlk3	T_alk	PAlk1	PAlk2	P_alk	pH	pH
		Unit			µS/cm	°C	°C	meq/L	meq/L	meq/L	meq/L	meq/L	meq/L	meq/L		
		Meter			WTW	WTW	Hanna								Isfet	Hanna
Xa 111	Komsomolskii shaft (MW)	45N	0574829	6165313	1063	8.9	9.2	9.0	9.0	9.2	9.1				7.2	6.94
Xa 112	Komsomolskii adit (MW)	45N	0574705	6165480	859	7.0	7.2	7.8	7.6	7.6	7.7				7.0	6.8
Xa 113	Starii Berikul' adit (MW)	45N	0570327	6154164	678	5.1	5.1	3.5	3.6	3.6	3.6				7.5	7.00
Xa 114	Berikul' works: clear pool (top of pool)[A]	45N	0571106	6150290	460	8.8	10.0	1.7	1.7	1.7	1.7	0.0	0.0	0.0	8.5[B]	8.04
Xa 114	Berikul' works: clear pool (near base of pool)[C]	45N	0571106	6150290	572	5.9										
Xa 115	Berikul' works: 'Big orange' (LW)	45N	0571142	6150270	6700	20.9	21.3				0.0				2.8	2.43
Xa 116	Berikul' works: 'Small red' (LW)	45N	0571154	6150258	8500[D]	20.4	20.5				0.0				2.4	1.97
Xa 117	Serebryanii klyuch (GW)	45N	0570764	6145944	229	5.3	5.3	2.1	2.2	2.2	2.2	0.0		0.0	7.9[E]	7.2[F]

TAlk1 etc. represent individual determinations of total alkalinity. T_alk is the average
PAlk1 etc. represent individual determinations of phenolphthalein alkalinity. P_alk is the average
MW = mine water
LW = mine waste leachate water
GW = ground water

Notes: [A]measurements at 5-10 cm depth; [B] unstable reading: started at 8.1 and rose to 8.5. Note that the zero p-alkalinity implies that the true pH must be <8.2; [C] taken at base of pool at around 60 cm depth; [D]unstable reading; [E] unstable reading, pH measurement rose from 7.6 to 7.9; [F] unstable reading, pH measurement rose from 6.6 to 7.2 and still increasing slowly.

5.3 Anions by Ion Chromatography at the Geological Survey of Norway

Sample		F^-	Cl^-	NO_2^-	Br^-	NO_3^-	PO_4^{3-}	SO_4^{2-}
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Xa 111	Komsomolskii shaft (MW)	0.08	9.92	< 0.05	< 0.1	< 0.05	< 0.2	161
Xa 112	Komsomolskii adit (MW)	0.09	7.45	< 0.05	< 0.1	< 0.05	< 0.2	128
Xa 113	Starii Berikul' adit (MW) filtered	0.11	2.76	< 0.05	< 0.1	< 0.05	< 0.2	187
Xa 114	Berikul' works: clear pool (top of pool)	0.05	0.34	0.14	< 0.1	5.31	< 0.2	149
Xa 115	Berikul' works: 'Big orange' (LW)	3.89	10.2	< 2.5	< 5.0	< 2.5	< 10.0	8448
Xa 116	Berikul' works: 'Small red' (LW)	5.25	15.2	< 2.5	5.23	< 2.5	< 10.0	22876
Xa 117	Serebryanii klyuch (GW)	1.29	1.70	< 0.05	< 0.1	0.30	< 0.2	18.0

All determinations on filtered samples at 0.45 µm
Note that concentrations of nitrite, nitrate, phosphate and sulphate are cited as mg/L NO_2^-, NO_3^-, PO_4^{3-} and SO_4^{2-} and *not* mg/L N, P amd S.

5.4 Analyses of 33 Elements by ICP-AES at the Geological Survey of Norway

Sample		Si	Al	Fe	Ti	Mg	Ca	Na	K	Mn	P	Cu	Zn	Pb	Ni	Co	V
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Xa 111	Komsomolskii shaft	8.58	<0.02	0.0475	0.0020	30.8	173	47.6	4.30	1.36	0.121	<0.005	0.0070	<0.005	<0.005	<0.001	0.0092
Xa 112	Komsomolskii adit	8.63	<0.02	0.0437	0.0020	26.1	138	27.8	3.11	1.44	0.116	<0.005	0.0064	<0.005	<0.005	0.0028	0.0094
Xa 113	Starii Berikul' adit filtered	5.76	<0.02	0.0562	0.0014	11.7	122	11.6	3.15	0.661	0.102	<0.005	0.0104	<0.005	<0.005	0.0018	0.0059
Xa 113b	Starii Berikul' adit unfiltered	5.94	<0.02	0.0364	0.0013	12.0	125	11.8	3.24	0.440	0.118	<0.005	0.0126	<0.005	<0.005	<0.001	0.0078
Xa 114	Berikul' works: clear pool	1.55	<0.02	0.0034	0.0011	7.49	73.9	5.27	1.75	0.0162	0.086	<0.005	0.0178	<0.005	<0.005	<0.001	<0.005
Xa 115	Berikul' works: 'Big orange'	75.5	286	2020	0.0272	267	502	25.7	<5	32.9	0.716	12.6	133	1.27	4.29	2.35	<0.5
Xa 116	Berikul' works: 'Small red'	72.4	518	9100	2.23	445	375	6.89	<5	50.5	28.0	35.2	351	8.49	4.88	4.77	1.49
Xa 117	Serebryanii klyuch	9.54	<0.02	0.0029	<0.001	5.05	30.1	10.5	2.19	0.0021	0.103	<0.005	0.0110	<0.005	<0.005	<0.001	<0.005

Sample	Mo	Cd	Cr	Ba	Sr	Zr	Ag	B	Be	Li	Sc	Ce	La	Y	As	Sb	S*
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Xa 111	<0.005	<0.0005	<0.002	0.0339	0.852	<0.002	<0.005	<0.02	<0.001	<0.005	<0.001	<0.02	<0.005	<0.001	0.225	<0.005	261
Xa 112	<0.005	<0.0005	<0.002	0.0304	0.601	<0.002	<0.005	<0.02	<0.001	<0.005	<0.001	<0.02	<0.005	<0.001	0.077	<0.005	228
Xa 113	<0.005	<0.0005	<0.002	0.0184	0.495	<0.002	<0.005	<0.02	<0.001	0.0055	<0.001	<0.02	<0.005	<0.001	0.050	<0.005	361
Xa 113b	<0.005	<0.0005	<0.002	0.0170	0.507	<0.002	<0.005	0.022	<0.001	<0.005	<0.001	<0.02	<0.005	<0.001	0.108	<0.005	383
Xa 114	<0.005	<0.0005	<0.002	0.0141	0.330	<0.002	<0.005	0.025	<0.001	<0.005	<0.001	<0.02	<0.005	<0.001	0.100	<0.005	274
Xa 115	<0.5	2.03	0.347	<0.02	1.00	0.0341	<0.05	0.416	<0.1	0.518	<0.1	<2	<0.5	0.246	24.2	<0.05	2400
Xa 116	<0.05	5.72	2.73	0.0326	0.921	0.289	<0.05	<0.2	<0.1	0.684	0.130	<2	0.844	0.271	1910	<0.5	7020
Xa 117	<0.005	<0.0005	<0.002	0.0041	0.227	<0.002	<0.005	<0.02	<0.001	0.0059	<0.001	<0.02	<0.005	<0.001	<0.01	<0.005	6.39

All determinations on water samples were on samples filtered at 0.45 µm; except Xa113b which was performed on an unfiltered aliquot (which was acidified in the laboratory, like the other samples).

5.5 Analyses of Hg by CETAC M-6000A Hg Analyzer at the Geological Survey of Norway

Sample		Hg
		µg/L
Xa 111	Komsomolskii shaft	< 0.01

All determinations on water samples were on samples filtered at 0.45 µm.

5.6 Analyses of 42 Elements by ICP-MS at the Geological Survey of Norway

Sample		Y	Nb	Ag	In	Sb	Cs	Nd	Sm	Ho	Yb	Ta	W	Tl
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Xa 111	Komsomolskii shaft	0.149	<0.05	<0.01	<0.01	0.126	0.0292	0.017	0.0062	0.0032	0.015	<0.01	0.783	<0.05

Sample	Bi	Th	V	Mn	Cu	Zn	Ga	Ge	Li	Be	B	Rb	Zr	Mo
	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Xa 111	<0.01	<0.02	1.94	see ICP-AES	0.091	0.72	<0.01	<0.05	2.38	<0.01	38.9	2.98	0.623	0.67

Sample	Cd	La	Ce	Pb	Al	Cr	Co	Ni	U	P	I	K	As	Se
	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Xa 111	<0.03	<0.01	0.023	<0.05	8	<0.1	0.094	0.22	2.15	5.3	<5	see ICP-AES	215	<1

All determinations on water samples were on samples filtered at 0.45 µm.

6 COAL MINE WATERS OF THE KUZBAS NEAR KEMEROVO (КЕМЕРОВО): KEMEROVSKAYA OBLAST'

Water samples were collected of mine water discharging from abandoned and working coal mines in the Kuzbas coalfield in and around Kemerovo (Кемерово) city (Figure 6.1).

The Vladimirovskaya and Konyukhtinskaya mines were sampled by Bjørn Frengstad and Olga Karnachuk on 13/7/06. The Yagunovskaya and Severnaya sites were sampled by David Banks and Olga Karnachuk on 14/7/07.

6.1 Sampling Sites

Sample Xa118: Vladimirovskaya mine shaft: The mine is actively dewatered via a pumping shaft 90 m deep. The average pumping rate is reported as 90 m^3/h or 25 L/s (with a maximum of 150 m^3/h or 42 L/s). Two pumps installed in the shaft operate regularly during spring and autumn and on demand during summer and winter. The worked coal seam is 4.2 m thick. Due to it being a working mine, there is a lot of coal dust within the pumped water and three filters were required during sampling. No visible chemical precipitation and no particular smell are associated with the discharge.

Sample Xa119: Konyukhtinskaya mine shaft: The mine is actively dewatered via the shaft by two pumps, installed at 140 and 120 m depth, respectively. The sampled water was taken from the 140 m deep pumping line. The total discharge is some 90,000 m^3/month (=125 m^3/h or 35 L/s) in total. Water is pumped into settling ponds in gravel pits c. 50 m away from the shaft. The mine water was taken from the discharge stream using a stainless steel cup prior to filtering etc. Again, the large amount of suspended coal dust in the water necessitated the use of four filters during sampling: these were effective in removing the black colour of the water was removed in the filters. The water had no noticeable odour, but contained gas bubbles. The 120 m discharge was not sampled but field measurements were taken: EC=748 µS/cm, pH = 8.1 (Isfet meter), T= 14.4°C.

Sample Xa120: Yagunovskaya mine shaft: Mine water overflows from this abandoned mine shaft at a rate of some 95 m^3/h (26 L/s). The shaft is reported to be 360 m deep. The shaft drains the Kemerovskii, Volkovskii, Vladimirovskii and two smaller coal seams. The water overflows via a large discharge pipe into the Bolshaya Kommisionarnaya River. There is little visible sign of the former mine in the area, except that the discharge occupies a 6 m deep, large depression in the terrain. The water itself has no smell, colour or turbidity, but some precipitation of iron oxyhydroxide (ochre) can be observed in the discharge stream and a small amount was observed on the filter used for sample filtration. An H_2S smell has previously been reported from the site. Following sampling and sample storage of a few hours, a faint yellow colour could be noted in the samples (hydrolysis and precipitation of iron hydroxide as a colloid). An unfiltered aliquot was also taken for acidification at the laboratory and parallel analysis by ICP-AES.

Sample Xa121: Severnaya Borehole: This sample was taken from the discharge of a (reportedly) 260 m deep borehole, drilled in 1998 to control potential water outflow from the mine workings of West Severnaya mine and thus to protect houses on top of the low river cliffs from flooding. The discharge is located around 45 m from the River Tom' in central Kemerovo, in a short ravine in the low river cliffs in the north-eastern bank of the Tom', c. 600 m downstream of the new bridge. The borehole is located some 10 km away from the main Severnaya mine shaft. The discharge rate from the borehole (which is believed to be artesian, rather than pumped) is estimated at 160-170 m3/h (44-47 L/s). The water emits a very strong H_2S smell. The H_2S is presumed to accumulate in the ravine, to such an extent that silver jewellery worn by the samplers turned black-brown with silver sulphide. A lot of white filamentous, and some black, microbial growth was noted in the bed of the stream carrying the discharge water down to the Tom'. The white growth is suspected to be of the genus *Thiothrix*, a sulphide oxidising bacteria which oxidises hydrogen sulphide to sulphate via an intermediary elemental sulphur step (producing a characteristic creamy white colour). During sampling of the water, no precipitate or colour was noted on the filter. The Severnaya mine extends to a depth of some 360 m and worked the same three seams as at Yagunovskaya (Xa120): the geological succession is dominated by sandstones and siltstones.

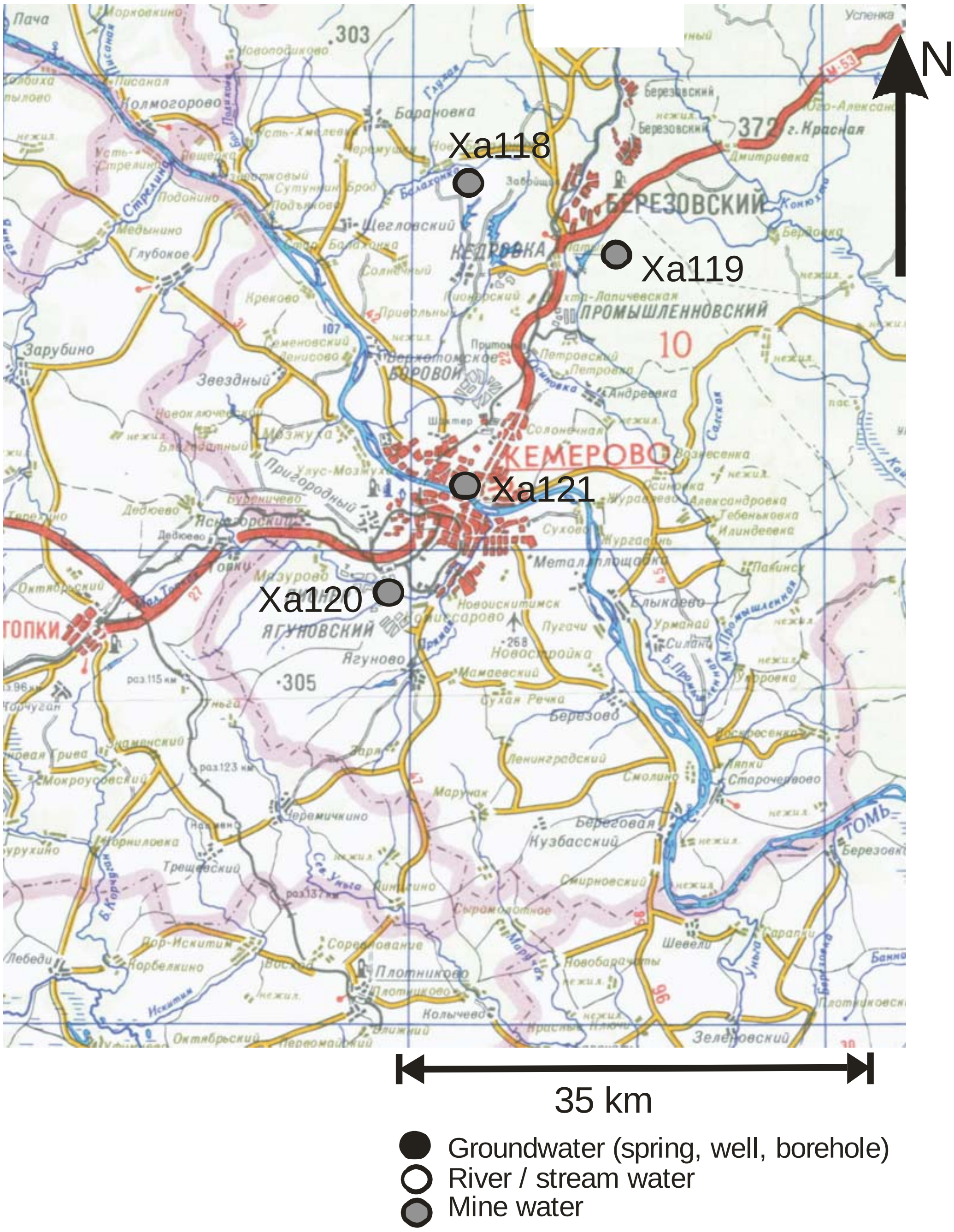

Figure 6.1. Sample locations in Kemerovo (Xa118-121)

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6.2 Field Analyses of Waters (pH, Temperature, EC, Alkalinity)

Sample		UTM Zone	Easting	Northing	EC	Temp	Temp	TAlk1	TAlk2	TAlk3	T_alk	PAlk1	PAlk2	P_alk	pH	pH
		Unit			µS/cm	°C	°C	meq/L	meq/L	meq/L	meq/L	meq/L	meq/L	meq/L		
		Meter			WTW	WTW	Hanna								Isfet	Hanna
Xa 118	Vladimirovskaya shaft (MW)	45N	0441281	6160358	648	10.2		6.0	6.1	6.2	6.1				7.5	6.91[A]
Xa 119	Konyukhtinskaya shaft (140 m) (MW)	45N	0453614	6155960	780	12.5		8.5[B]	7.4[B]	8.3[B]	8.4[C]				7.7	7.46
Xa 120	Yagunovskaya shaft (MW)	45N	0435313	6129018	1628	13.6	13.7	14.3	14.8		14.6				7.1	6.8
Xa 121	Severnaya mine borehole (MW)	45N	0440893	6136970	2660	13.1	13.8[D]	33.6	33.7		33.7	0.0		0.0	7.6	7.58

TAlk1 etc. represent individual determinations of total alkalinity. T_alk is the average
PAlk1 etc. represent individual determinations of phenolphthalein alkalinity. P_alk is the average
MW = mine water

Notes: [A] pH still rising at time of measurement with Hanna meter; [B] alkalinity measured on filtered samples due to large quantity of coal dust obscuring colour changes; [C] for calculation of average, the lowest alkalinity reading was ignored; [D] prefer WTW temperature reading (Hanna reading taken on a sample that had been standing for some time following sampling)

6.3 Anions by Ion Chromatography at the Geological Survey of Norway

Sample		F^-	Cl^-	NO_2^-	Br^-	NO_3^-	PO_4^{3-}	SO_4^{2-}
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Xa 118	Vladimirovskaya shaft	0.24	26.5	< 0.05	< 0.1	0.25	< 0.2	56.9
Xa 119	Konyukhtinskaya shaft (140 m)	0.12	0.18	1.47	< 0.1	0.33	< 0.2	20.7
Xa 120b	Yagunovskaya shaft (filtered)	0.20	23.0	< 0.05	0.12	< 0.05	< 0.2	275
Xa 121	Severnaya mine borehole	0.47	19.0	< 0.2	< 0.1	< 0.05	< 0.2	21.8

All determinations on filtered samples at 0.45 µm.
Note that concentrations of nitrite, nitrate, phosphate and sulphate are cited as mg/L NO_2^-, NO_3^-, PO_4^{3-} and SO_4^{2-} and *not* mg/L N, P amd S.

6.4 Analyses of 33 Elements by ICP-AES at the Geological Survey of Norway

Sample		Si	Al	Fe	Ti	Mg	Ca	Na	K	Mn	P	Cu	Zn	Pb	Ni	Co	V
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Xa 118	Vladimirovskaya shaft	8.86	<0.02	0.0039	0.0016	16.1	105	18.5	1.33	0.447	0.214	<0.005	0.0175	<0.005	<0.005	0.0029	<0.005
Xa 119	Konyukhtinskaya shaft (140 m)	8.08	<0.02	0.0095	0.0012	16.0	86.8	51.5	1.81	0.0386	0.073	<0.005	0.0055	<0.005	0.0056	0.0017	<0.005
Xa 120	Yagunovskaya shaft (filtered)	5.90	<0.02	0.0324	0.0018	68.1	217	89.4	4.42	1.84	0.119	<0.005	0.0103	<0.005	0.0062	0.0041	0.0118
Xa 120b	Yagunovskaya shaft (unfiltered)	5.72	<0.02	0.136	0.0017	65.0	204	85.5	4.27	0.109	0.119	<0.005	0.0077	<0.005	<0.005	<0.001	0.0102
Xa 121	Severnaya mine borehole	4.83	<0.02	0.0474	0.0024	12.5	30.5	558	3.52	0.0903	0.070	<0.005	0.0031	<0.005	<0.005	<0.001	<0.005

Sample	Mo	Cd	Cr	Ba	Sr	Zr	Ag	B	Be	Li	Sc	Ce	La	Y	As	Sb	S*
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Xa 118	<0.005	<0.0005	<0.002	0.289	0.782	<0.002	<0.005	<0.02	<0.001	0.0106	<0.001	<0.02	<0.005	<0.001	0.020	<0.005	19.4
Xa 119	0.0055	<0.0005	<0.002	2.16	3.26	<0.002	<0.005	0.041	<0.001	0.0636	<0.001	<0.02	<0.005	<0.001	0.019	<0.005	50.6
Xa 120	<0.005	<0.0005	<0.002	0.136	2.66	<0.002	<0.005	0.063	<0.001	0.100	<0.001	<0.02	<0.005	<0.001	0.044	<0.005	525
Xa 120b	<0.005	<0.0005	<0.002	0.0975	2.51	<0.002	<0.005	0.060	<0.001	0.0969	<0.001	<0.02	<0.005	<0.001	0.039	<0.005	537
Xa 121	<0.005	<0.0005	<0.002	1.55	1.77	0.0086	<0.005	0.182	<0.001	0.805	<0.001	<0.02	<0.005	<0.001	0.099	<0.005	42.3

All determinations on water samples were on samples filtered at 0.45 μm; except Xa120b which was performed on an unfiltered aliquot (which was acidified in the laboratory, like the other samples).

7 SAMPLING AND ANALYSIS ROUTINES: YEAR 2007

The mine sites sampled in 2007 are detailed in Section 8 of this Report.

7.1 Mine Water Sampling

Mine waters were sampled either from seeps or pools of leachate (from spoil or tailings), from pools of mine water in the base of opencast workings or from flowing discharges from tailings dumps. For each sample site the following aliquots were taken:

- 2 x 50 ml polyethene flasks, of water filtered at 0.45 µm, using a cellulose acetate filter capsule and hand-held polypropene syringe. No acidification was carried out in the field.
- a selection of samples for bacteriological analysis at TGU (not reported in this report)

7.2 Field Measurements

Field measurements of water were taken directly in the water source to be sampled. The electrodes were typically submerged to maximum extent below the water surface (c. 5-10 cm) for measurements to be taken.

No alkalinity determinations were performed in the field (and, in all but one cases, the pH of the samples was so low that bicarbonate alkalinity will have been zero, by definition).

pH and temperature (T) were determined using a Holymoor Consultancy's Hanna Instruments HI98128 pH meter, regularly calibrated at against solutions of known pH around 4 and 7. pH and temperature were also determined using Tomsk State University's Hanna Instruments HI8314 meter at all sites.

7.3 Analysis at University of Newcastle

The samples (typically two aliquots of filtered water from each site) were transported by David Banks to the analytical laboratory of the Hydrogeochemical Engineering Research and Outreach (HERO) group at the University of Newcastle. Prior to analysis, samples were stored in a refrigerator at around 4°C, except for brief periods of transport. For analysis, the following procedure was followed:

1. Aliquot 1 of each sample

    - Determination of anions by ion chromatography (Dionex DX320 for Gradient Anion Analysis).

- On Xa204, determination of t-alkalinity

2. Aliquot 2 of each sample

    - Aliquot acidified with conc. ultrapure nitric acid in order to resolubilise any precipitated or sorbed metals.
    - Analysis of acidified aliquot using ICP-AES techniques (Varian Vista MPX with simultaneous charged coupled device).

Jane Davis and Patrick Orme are to be thanked for organising sample analysis at the University of Newcastle.

8 METAL MINE WATERS SAMPLED IN 2007: KEMEROVSKAYA OBLAST'

In 2007, two sites were visited for sampling. Firstly, the processing works at Novii Berikul' (near Tysul') was visited to take a repeat set of samples. See Section 5 for a further description of this region.

Secondly, the Salair (Салаир) Zn/Ag mine was visited. (Figure 8.1). This opencast mine lies to the west of the city of Belovo (Белово) just beyond the western fringes of the Kuzbas coal basin. While the Belovo region does contain coal mines related to the Carboniferous strata of the Kuzbas, it also contains a major Zn orefield within the underlying basement (Sidenko et al. 2001).

The ore at Salair is a polymetallic sulphide containing sphalerite, galena, pyrite and chalcopyrite. The country rock comprises Cambrian metasediments of greenschist facies. The rocks at Salair are phyllites/schists and marbles that have been subject to hydrothermal berezitization[1] by the ore.

The Salair mine is currently owned by the company "Ural Non-Ferrous Metals", but has a 220 year mining history. Historically, the deposit was mined for silver and gold. Silver was mined via an underground mine which is now flooded. More recently, mining has focussed on Au, Zn and Pb via opencasting (there are two visible opencasts: one completed opencast that is currently being backfilled, and one currently working opencast). There are two processing plants in the area, one for gold and one for zinc and lead.

The current opencast mine is not dewatered by pumping. Mine water largely drains downwards into the underlying galleries of the flooded former Ag mine. The underground mine is pumped at a rate of 300-400,000 m^3/year (820-1100 m^3/d or 9-13 L/s on average). The pumped mine water is reported to contain rather elevated concentrations of Zn and Mn.

The pumped water is led across the valley towards the south of the town and discharged in the tailings dam, which lies on top of the slope to the south of the valley. The pumped water forms a lake some 11 m deep. Water is then led from the lake down to the flotation plant in the valley floor where it is employed for flotation, before being pumped *back* up to the tailings dam with a loading of tailings slurry. Surplus water from the tailings dam drains by gravity down the valley side to discharge in the stream in the base of the valley.

The lake within the tailings dam was tested for pH and temperature at its western margin on 28/8/07 and found to be rather alkaline. The following results were obtained:

[1] quartz-sericite-albite-pyrite alteration; associated with quartz veining and gold mineralization

	HI98128 (Holymoor)	HI8314 (TGU) (*preferred*)
pH	8.1 (but still rising)	8.75
T (°C)	12.4	12.6

8.1 Sampling Sites

Sample Xa201: Novii Berikul "Small Orange". The sample was collected from a small puddle of bright orange leachate related to the southern end of the tailings dump. The sampled water had an orange colour but was clear and non-turbid (hence the iron is probably present as dissolved Fe^{III} ions).

Sample Xa202: Novii Berikul "Medium Orange": Sample collected from a medium-sized accumulation of tailings leachate on the lowermost terrace of the southern end of the site. While the puddle appears orange in colour due to precipitated iron hydroxide, the water itself is both clear (non-turbid) and uncoloured.

Sample Xa203: Novii Berikul "Big Orange": This is essentially the same leachate accumulation sampled last year as Xa115, although the exact location and configuration is slightly different in 2007. The sampled water, even after filtration, retains an orange colouration, indicating the presence of iron as dissolved Fe^{III} ions.

Sample Xa204: Run-off from Salair Tailings Dam: The run-off from the tailings dam was sampled just before it entered the stream in the base of the valley. A small amount of visible ochre precipitation could be seen on the bed of the stream. On sampling, a small amount of iron oxyhydroxide precipitate could also be seen on the filter capsule.

Sample Xa205: Salair mine water; current opencast: A sample was taken from a small accumulation of mine water in one part of the base of the current opencast. Some iron oxyhydroxide precipitation can be seen in the base of the pond. At the location of the sample, the pH of the mine water was recorded as 3.24 and the temperature 17.8°C. The sampled water was clear and uncoloured.

Sample Xa206: Salair mine water; current opencast: The accumulation of water in the base of the opencast (Xa205) is fed by a small trickle of water from the base of the opencast. At the point where this trickle enters the pond, *Typha* reeds can be observed to be thriving and the sediment in this area is blackish in colour (possibly indicating some sulphate reduction processes). A sample of sediment was recovered from this area and designated Xa206. The pH of the water in this area was recorded as 6.03 and that of the sediment 6.7. The temperature of the water was 19.5°C.

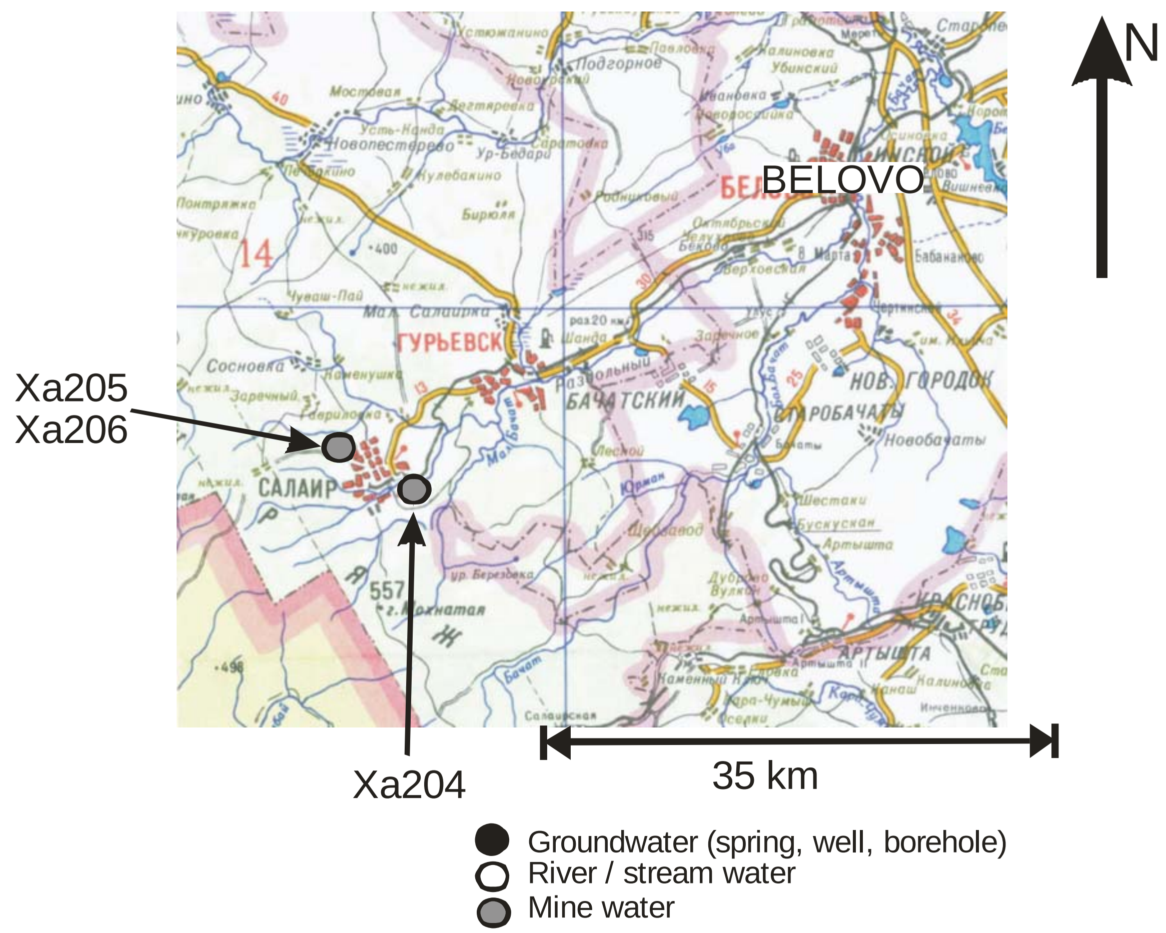

Figure 8.1. Sample locations in Salair

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8.2 Field Analyses of Waters (pH, Temperature)

Sample ID	Location	Sampling date	Temp	Temp	T_alk	pH	pH
			°C	°C	meq/L		
			HI8314	HI98128		HI8314[C]	HI98128
Xa114	Berikul' works: clear pool (top of pool)	26/08/2007	3.8 to 4.3			8.2 to 8.3	
Xa201	Berikul' works: "Small Orange"	26/08/2007	17.0	16.6	*0.0*[B]	2.46	2.36
Xa202	Berikul' works: "Medium Orange"	26/08/2007			*0.0*[B]		
Xa203	Berikul' works: 'Big orange'	26/08/2007	16.2	17.1	*0.0*[B]	2.66	2.52
Xa204	Run-off from Salair tailings dam	28/08/2007	8.5	8.4		8.25	7.75
	Lake on Salair tailings dam	28/08/2007	12.6	12.4		8.75	8.1[A]
Xa205	Pond in Salair current opencast	28/08/2007	17.8		*0.0*[B]	3.24	
Xa206	Pond in Salair current opencast (Typha area)	28/08/2007	19.5			6.03	

T_alk is the presumed total alkalinity of the water (zero, by definition in waters of pH<4.2)

Notes: [A] pH still rising at time of measurement with Hanna HI98128 meter; [B] t-alkalinity is presumed to be zero by definition (i.e. not measured) when water pH<4.2; [C] prefer pH readings by TGU's Hanna HI8314 pH meter.

8.3 Anions by Dionex Ion Chromatography and t-Alkalinity by Laboratory Titration at University of Newcastle

Sample		F^-	Cl^-	Br^-	NO_3^-	$SO_4^=$	PO_4^{3-}	Alkalinity	Alkalinity
		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l as $CaCO_3$	meq/L
Xa201	Berikul' works: "Small Orange"	<1	23	<5	<5	5287	<10		
Xa202	Berikul' works: "Medium Orange"	<1	24	<5	<5	7789	<10		
Xa203	Berikul' works: 'Big orange'	<1	18	<5	<5	4018	<10		
Xa204	Run-off from Salair tailings dam	<1	20	<5	<5	928	<10	150	3.0
Xa205	Pond in Salair current opencast	<1	20	<5	<5	1480	<10		

All determinations by University of Newcastle on field-filtered samples at 0.45 µm

Note that concentrations of nitrate, phosphate and sulphate are cited as mg/L NO_3^-, PO_4^{3-} and SO_4^{2-} and *not* mg/L N, P amd S.

8.4 Analyses of 20 Elements by ICP-OES at University of Newcastle

Sample		Ca	Mg	Na	K	Fe	Mn	Al	Zn	Si
		mg/L	mg/L	mgL	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Xa201	Berikul' works: "Small Orange"	343	193	1.2	0.4	1525	24.3	223	162	27.5
Xa202	Berikul' works: "Medium Orange"	482	371	31.1	3.8	2290	50.6	242	151	45.7
Xa203	Berikul' works: 'Big orange'	507	123	18.7	0.7	793	13.1	114	31.3	62.5
Xa204	Run-off from Salair tailings dam	349	53.0	44.3	15.4	1.2	1.8	<0.5	2.0	5.4
Xa205	Pond in Salair current opencast	310	133	7.4	1.9	12.9	14.6	5.9	113	9.4

Sample	B	Li	Sr	As	Pb	Cd	Co	Cr	Cu	Ni	Ag*
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Xa201	0.3	0.1	0.4	178	0.5	2.8	2.3	0.3	12.5	4.9	ND
Xa202	1.9	0.2	1.0	6.5	<0.2	1.7	2.7	<0.1	7.1	5.0	ND
Xa203	1.6	0.2	0.6	3.2	<0.2	0.5	0.7	0.1	3.9	1.6	ND
Xa204	<0.2	<0.1	0.4	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1	<0.1	ND
Xa205	<0.2	<0.1	0.5	<0.1	0.6	0.4	0.1	<0.1	1.5	0.2	ND

All determinations on water samples were on samples field-filtered at 0.45 µm and subsequently laboratory acidified with HNO_3.
*Ag not detected (ND) in any sample – no Ag standard available but detection limit estimated as 0.1 mg/L.

9 SUMMARY: MAJOR ION CHEMISTRY

9.1 Interpretation

The following tables summarise the major ion chemistry of the water samples. Note that, for some of the acidic mine water samples, other elements than those cited here may form part of the major ion composition of the water.

The samples from the Shira area of Khakassia are all somewhat saline and have a Na-(Mg)-SO_4-(Cl) water chemistry. The Devonian strata of the area contain evaporite minerals that are subject to evapoconcentration in the lacustrine environment, and the semi-arid climate, as described by Parnachev et al. (1999).

In contrast, the water samples from Malii Anzas are all very dilute waters. The surface waters contain only 0.1 to 0.15 mg/L chloride. The two groundwaters possess a slightly higher content of dissolved solids. The overall water chemistry is calcium bicarbonate.

The two samples from Komsomolskii mine are also of calcium bicarbonate composition. Elevated sulphate (130-160 mg/L) is suggestive of sulphide oxidation, but the high alkalinity and circumneutral pH suggest that any acidity generated by this means has been neutralised in the mine. The high pH and alkalinity also mean that most dissolved "heavy" metals are rather low in concentration, although concentrations of 1.4 mg/L manganese are observed. The waters contain arsenic at concentrations of 225 µg/L (shaft) and 77 µg/L (adit).

In the waters from Starii Berikul' mine and Novii Berikul' tailings dump, pyrite oxidation plays a clearly more dominant role, resulting in calcium-sulphate waters or, in the extreme cases, iron-aluminium-sulphate waters.

The Starii Berikul adit emits a water of elevated sulphate but circum-neutral pH and low to modest concentration of iron, aluminium and other heavy metals. Arsenic is present at 50-108 µg/L, however.

At Novii Berikul' the high-pH pool of clear water exhibits a calcium-sulphate signature, elevated sulphate and arsenic but otherwise low concentrations of Fe, Al and heavy metals. This water is interpreted as a mixture of leachate from the tailings deposit, and neutral-alkaline shallow groundwater, neutralised by contact with alkaline host rocks or the rock cover over the tailings.

Sample ID	Location	T_alk	pH	Cl^-	NO_3^-	$SO_4^=$	Ca	Mg	Na	K	Fe	Al	Mn	Zn
		meq/L		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Xa 101	Utichie 3 water	7.7	8.40	803	< 0.5	1874	128	378	883	30.2	0.0214	<0.2	0.0496	<0.02
Xa 103	Lake Shira	19.5	8.70	2032	< 5.0	9095	68.8	1360	3950	43.6	0.0265	<0.2	0.0445	<0.02
Xa 104	Shira Kurort Bh 10	3.3	7.45	189	16.0	1316	205	93.4	512	3.34	<0.002	<0.02	0.0060	0.0130
Xa 105	Shira beach	15.7	9.00	1715	< 5.0	7096	59.9	1050	3080	34.3	<0.02	<0.2	<0.01	<0.02
Xa 106	Malii Anzas spring	2.0	7.60	0.39	2.82	16.5	45.7	2.15	2.46	<0.5	0.0043	<0.02	<0.001	0.0040
Xa 107	Malii Anzas river	0.8	7.75	0.11	0.67	2.75	13.0	0.839	1.31	<0.5	0.0118	<0.02	<0.001	0.0020
Xa 108	Ona River downstream	0.7	7.62	0.14	0.62	2.14	11.3	0.812	1.28	<0.5	0.0238	0.032	0.0035	<0.002
Xa 109	Ona River upstream	0.4	7.41	0.15	0.54	1.46	7.07	0.768	1.14	<0.5	0.0372	0.059	0.0042	<0.002
Xa 110	Malii Anzas well	2.0	6.63	3.08	15.5	7.62	38.8	3.09	5.03	4.64	0.0520	<0.02	0.0060	0.0045
Xa 111	Komsomolskii shaft	9.1	7.07	9.92	< 0.05	161	173	30.8	47.6	4.30	0.0475	<0.02	1.36	0.0070
Xa 112	Komsomolskii adit	7.7	6.90	7.45	< 0.05	128	138	26.1	27.8	3.11	0.0437	<0.02	1.44	0.0064
Xa 113	Starii Berikul' adit, filtered	3.6	7.25	2.76	< 0.05	187	122	11.7	11.6	3.15	0.0562	<0.02	0.661	0.0104
Xa 113b	Starii Berikul' adit unfiltered	3.6	7.25	2.76	< 0.05	187	125	12.0	11.8	3.24	0.0364	<0.02	0.440	0.0126
Xa 114	Berikul' works: clear pool (top of pool)	1.7	8.04	0.34	5.31	149	73.9	7.49	5.27	1.75	0.0034	<0.02	0.0162	0.0178
Xa 115	Berikul' works: 'Big orange'	0.0	2.62	10.2	< 2.5	8448	502	267	25.7	<5	2020	286	32.9	133
Xa 116	Berikul' works: 'Small red'	0.0	2.19	15.2	< 2.5	22876	375	445	6.89	<5	9100	518	50.5	351
Xa 117	Serebryanii klyuch	2.2	7.55	1.70	0.30	18.0	30.1	5.05	10.5	2.19	0.0029	<0.02	0.0021	0.0110
Xa 118	Vladimirovskaya	6.1	7.50	26.5	0.25	56.9	105	16.1	18.5	1.33	0.0039	<0.02	0.447	0.0175
Xa 119	Konyukhtinskaya shaft (140 m)	8.4	7.58	0.18	0.33	20.7	86.8	16.0	51.5	1.81	0.0095	<0.02	0.0386	0.0055
Xa 120	Yagunovskaya shaft filtered	14.6	6.95	23.0	< 0.05	275	217	68.1	89.4	4.42	0.0324	<0.02	1.84	0.0103
Xa 120b	Yagunovskaya shaft unfiltered	14.6	6.95	23.0	< 0.05	275	204	65.0	85.5	4.27	0.136	<0.02	0.109	0.0077
Xa 121	Severnaya mine borehole	33.7	7.59	19.0	< 0.05	21.8	30.5	12.5	558	3.52	0.0474	<0.02	0.0903	0.0031
Xa201	Berikul' works: "Small Orange"	0.0	2.46	23	<5	5287	343	193	1.2	0.4	1525	223	24.3	162
Xa202	Berikul' works: "Medium Orange"	0.0		24	<5	7789	482	371	31.1	3.8	2290	242	50.6	151
Xa203	Berikul' works: 'Big orange'	0.0	2.66	18	<5	4018	507	123	18.7	0.7	793	114	13.1	31.3
Xa204	Run-off from Salair tailings dam	3.0	8.25	20	<5	928	349	53.0	44.3	15.4	1.2	<0.5	1.8	2.0
Xa205	Pond in Salair current opencast	0.0	3.24	20	<5	1480	310	133	7.4	1.9	12.9	5.9	14.6	113

Sample ID	Location	T_alk	H+	Cl	NO3	SO4	Ca	Mg	Na	K	Fe	Al	Mn	Zn
		meq/L	meq/L	meq/L	meq/L	meq/L	meq/L	meq/L	meq/L	meq/L	meq/L	meq/L	meq/L	meq/L
Xa 101	Utichie 3 water	7.70	0.00	22.65		39.01	6.39	31.10	38.41	0.77	0.00		0.00	
Xa 103	Lake Shira	19.45	0.00	57.32		189.35	3.43	111.89	171.81	1.12	0.00		0.00	
Xa 104	Shira Kurort Bh 10	3.33	0.00	5.33	0.26	27.40	10.23	7.68	22.27	0.09			0.00	0.00
Xa 105	Shira beach	15.70	0.00	48.38		147.73	2.99	86.38	133.97	0.88				
Xa 106	Malii Anzas spring	1.97	0.00	0.01	0.05	0.34	2.28	0.18	0.11		0.00			0.00
Xa 107	Malii Anzas river	0.83	0.00	0.00	0.01	0.06	0.65	0.07	0.06		0.00			0.00
Xa 108	Ona River downstream	0.70	0.00	0.00	0.01	0.04	0.56	0.07	0.06		0.00	0.00	0.00	
Xa 109	Ona River upstream	0.43	0.00	0.00	0.01	0.03	0.35	0.06	0.05		0.00	0.01	0.00	
Xa 110	Malii Anzas well	2.00	0.00	0.09	0.25	0.16	1.94	0.25	0.22	0.12	0.00		0.00	0.00
Xa 111	Komsomolskii shaft	9.07	0.00	0.28		3.35	8.63	2.53	2.07	0.11	0.00		0.05	0.00
Xa 112	Komsomolskii adit	7.67	0.00	0.21		2.66	6.89	2.15	1.21	0.08	0.00		0.05	0.00
Xa 113	Starii Berikul' adit, filtered	3.57	0.00	0.08		3.89	6.09	0.96	0.50	0.08	0.00		0.02	0.00
Xa 113b	Starii Berikul' adit unfiltered	3.57	0.00	0.08		3.89	6.24	0.99	0.51	0.08	0.00		0.02	0.00
Xa 114	Berikul' works: clear pool (top of pool)	1.70	0.00	0.01	0.09	3.10	3.69	0.62	0.23	0.04	0.00		0.00	0.00
Xa 115	Berikul' works: 'Big orange'	0.00	2.43	0.29		175.88	25.05	21.97	1.12		72.34	31.80	1.20	4.07
Xa 116	Berikul' works: 'Small red'	0.00	6.53	0.43		476.26	18.71	36.61	0.30		325.87	57.60	1.84	10.74
Xa 117	Serebryanii klyuch	2.17	0.00	0.05	0.00	0.37	1.50	0.42	0.46	0.06	0.00		0.00	0.00
Xa 118	Vladimirovskaya	6.10	0.00	0.75	0.00	1.18	5.24	1.32	0.80	0.03	0.00		0.02	0.00
Xa 119	Konyukhtinskaya shaft (140 m)	8.40	0.00	0.01	0.01	0.43	4.33	1.32	2.24	0.05	0.00		0.00	0.00
Xa 120	Yagunovskaya shaft filtered	14.55	0.00	0.65		5.73	10.83	5.60	3.89	0.11	0.00		0.07	0.00
Xa 120b	Yagunovskaya shaft unfiltered	14.55	0.00	0.65		5.73	10.18	5.35	3.72	0.11	0.00		0.00	0.00
Xa 121	Severnaya mine borehole	33.65	0.00	0.54		0.45	1.52	1.03	24.27	0.09	0.00		0.00	0.00
Xa201	Berikul' works: "Small Orange"	0.00	3.47	0.65		110.07	17.12	15.88	0.05	0.01	54.61	24.80	0.88	4.96
Xa202	Berikul' works: "Medium Orange"	0.00		0.68		162.16	24.05	30.52	1.35	0.10	82.01	26.91	1.84	4.62
Xa203	Berikul' works: 'Big orange'	0.00	2.19	0.51		83.65	25.30	10.12	0.81	0.02	28.40	12.68	0.48	0.96
Xa204	Run-off from Salair tailings dam	3.00	0.00	0.56		19.32	17.42	4.36	1.93	0.39	0.04		0.07	0.06
Xa205	Pond in Salair current opencast	0.00	0.58	0.56		30.81	15.47	10.94	0.32	0.05	0.46	0.66	0.53	3.46

Sample ID	Location	Sum anion (meq/L)s	Sum cations (meq/L)	IBE (%)*	Type
Xa 101	Utichie 3 water	69.37	76.67	5.0	Na-Mg-SO4-(Cl)
Xa 103	Lake Shira	266.12	288.25	4.0	Na(-Mg)-SO4
Xa 104	Shira Kurort Bh 10	36.32	40.27	5.2	Na-SO4
Xa 105	Shira beach	211.81	224.22	2.8	Na(-Mg)-SO4
Xa 106	Malii Anzas spring	2.37	2.56	4.0	Ca-HCO3
Xa 107	Malii Anzas river	0.90	0.78	-7.7	Ca-HCO3
Xa 108	Ona River downstream	0.76	0.69	-4.7	Ca-HCO3
Xa 109	Ona River upstream	0.48	0.47	-0.3	Ca-HCO3
Xa 110	Malii Anzas well	2.50	2.53	0.7	Ca-HCO3
Xa 111	Komsomolskii shaft	12.70	13.40	2.7	Ca-HCO3
Xa 112	Komsomolskii adit	10.54	10.38	-0.8	Ca-HCO3
Xa 113	Starii Berikul' adit, filtered	7.54	7.66	0.8	Ca-SO4-HCO3
Xa 113b	Starii Berikul' adit unfiltered	7.54	7.84	2.0	Ca-SO4-HCO3
Xa 114	Berikul' works: clear pool (top of pool)	4.90	4.58	-3.4	Ca-SO4
Xa 115	Berikul' works: 'Big orange'	176.17	159.96	-4.8	Fe-(Al)-SO4
Xa 116	Berikul' works: 'Small red'	476.68	458.20	-2.0	Fe-(Al)-SO4
Xa 117	Serebryanii klyuch	2.59	2.43	-3.3	Ca-HCO3
Xa 118	Vladimirovskaya	8.04	7.42	-4.0	Ca-HCO3
Xa 119	Konyukhtinskaya shaft (140 m)	8.84	7.94	-5.4	Ca-HCO3
Xa 120	Yagunovskaya shaft filtered	20.92	20.50	-1.0	Ca-HCO3
Xa 120b	Yagunovskaya shaft unfiltered	20.92	19.36	-3.9	Ca-HCO3
Xa 121	Severnaya mine borehole	34.64	26.92	-12.5	Na-HCO3
Xa201	Berikul' works: "Small Orange"	110.72	121.77	4.8	Fe-(Al)-SO4
Xa202	Berikul' works: "Medium Orange"	162.84	171.40	2.6	Fe-SO4
Xa203	Berikul' works: 'Big orange'	84.16	80.95	-1.9	Fe(-Ca)-SO4
Xa204	Run-off from Salair tailings dam	22.88	24.27	2.9	Ca-SO4
Xa205	Pond in Salair current opencast	31.38	32.46	1.7	Ca-(Mg)-SO4

*IBE = Ion Balance Error

The leachate emerging from the tailings at Novii Berikul' is highly acidic and rich in a wide range of heavy metals, to the extent that several of these take on the role of major cations.

The water from the borehole at Serebryanii klyuch is a more typical calcium bicarbonate, circumneutral groundwater.

The waters from the Kemerovo coal mines are all calcium bicarbonate waters with a circumneutral pH and a rather high alkalinity, with the exception of Severnaya which is sodium bicarbonate. It is likely that the Severnaya water is so alkaline that calcium solubility is limited by a calcite saturation ceiling having been reached. The waters are not especially saline in terms of chloride content, and only exhibit somewhat elevated sulphate content in Yagunovskaya mine. Concentrations of Fe are low to modest; Al is undetectable, while Mn exceeds 1 mg/L in only one sample. The mine waters are therefore not characterised by a high degree of pyrite oxidation or leaching of pyrite oxidation products. Contents of arsenic are in the range 20-100 µg/L. In the waters with the lowest sulphate contents (Severnaya and Konyukhtinskaya), rather high barium contents in the range 1.5 - 2 mg/L are noted. If we assume that barium concentrations are related to a barite solubility ceiling, then these two waters may reflect a sulphate-reducing environment (the prominent H_2S odour at Severnaya confirms this).

The mine waters at Salair are both calcium sulphate waters, suggestive of the leaching of products of sulphide oxidation. The water from the tailings deposit is slightly alkaline, however, and low in most dissolved metals (although it contains around 2 mg/L of Mn and Zn), suggesting that it has been effectively neutralised either underground or in the tailings dam. The water from the opencast is, however, rather acidic and contains high concentrations of Fe, Al, Zn and Mn.

9.2 Quality Control

Ion Balance Error

From the tables above, it can be seen that the ion balance error is, in almost all cases, less than 5%, indicating good analytical quality. In a small minority of cases, the error exceeded 5%. For the Malii Anzas River, the error reached 7.7%, which figure is not regarded as unacceptable bearing in mind the rather low ionic strength of the water. The ion balance error for the Severnaya mine borehole reached 12.5% with a strong excess of anions. It is likely that this error can be ascribed to the difficulty in performing a reliable field titration of alkalinity on such a highly alkaline water, and where a share of the alkalinity could have been due to potentially volatile sulphide species.

Field versus Laboratory Measurements

For the determination of temperature, there is generally an excellent correlation between the Hanna Instruments HI98128 electrode employed by Holymoor Consultancy and the electrodes employed by TGU for field determinations.

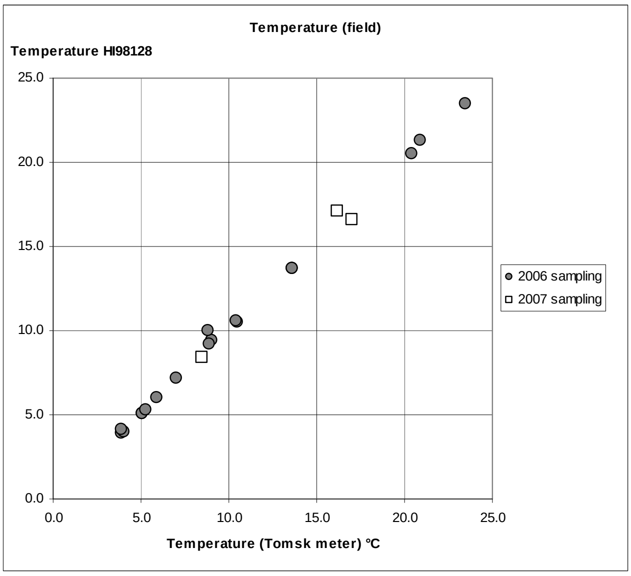
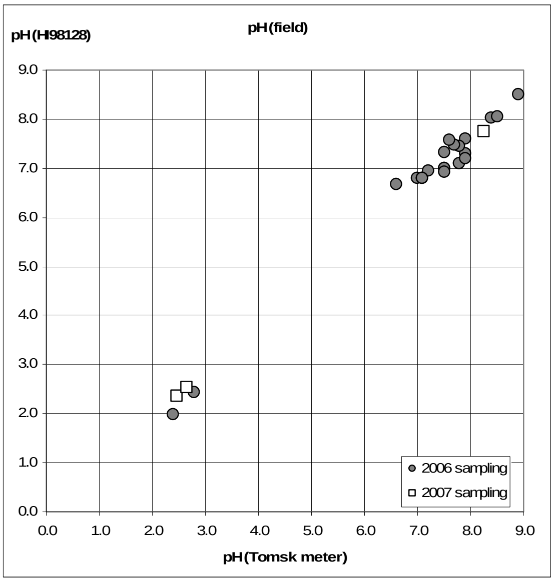


Figure 9.1. Comparison field measurements of temperature made using Holymoor Consultancy's HI98128 meter and Tomsk University's meters.



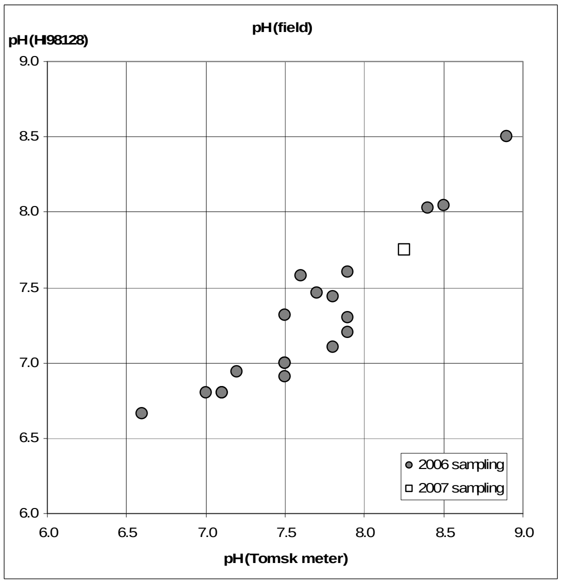


Figure 9.2. Comparison field measurements of pH made using Holymoor Consultancy's HI98128 meter and Tomsk University's meters.

For the determination of pH in the field, there was a somewhat poorer, but generally acceptable, degree of correlation between the Hanna Instruments HI98128 electrode employed by Holymoor Consultancy and the electrodes employed by TGU for field determinations.

If alkalinity is plotted against field pH, no clear relationship can be observed, except for the expected fact that t-alkalinity = 0 for samples where pH<4.3 and p-alkalinity = 0 for samples where pH<8.3.

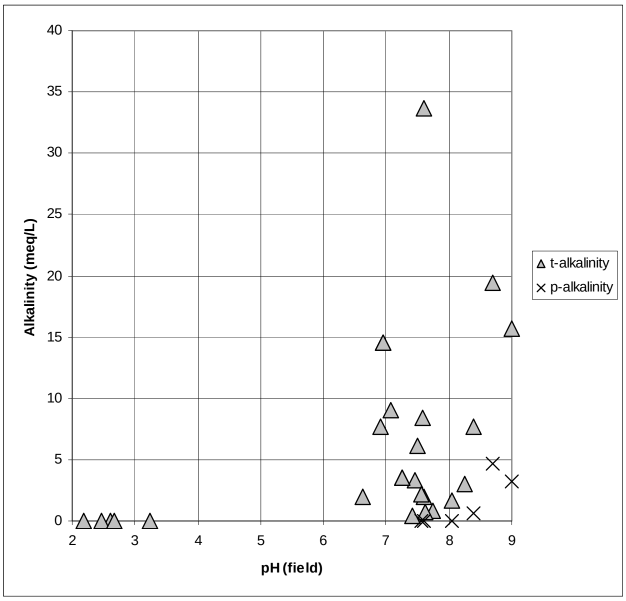


Figure 9.3. Plot of alkalinity versus pH (field) for samples from 2006 and 2007

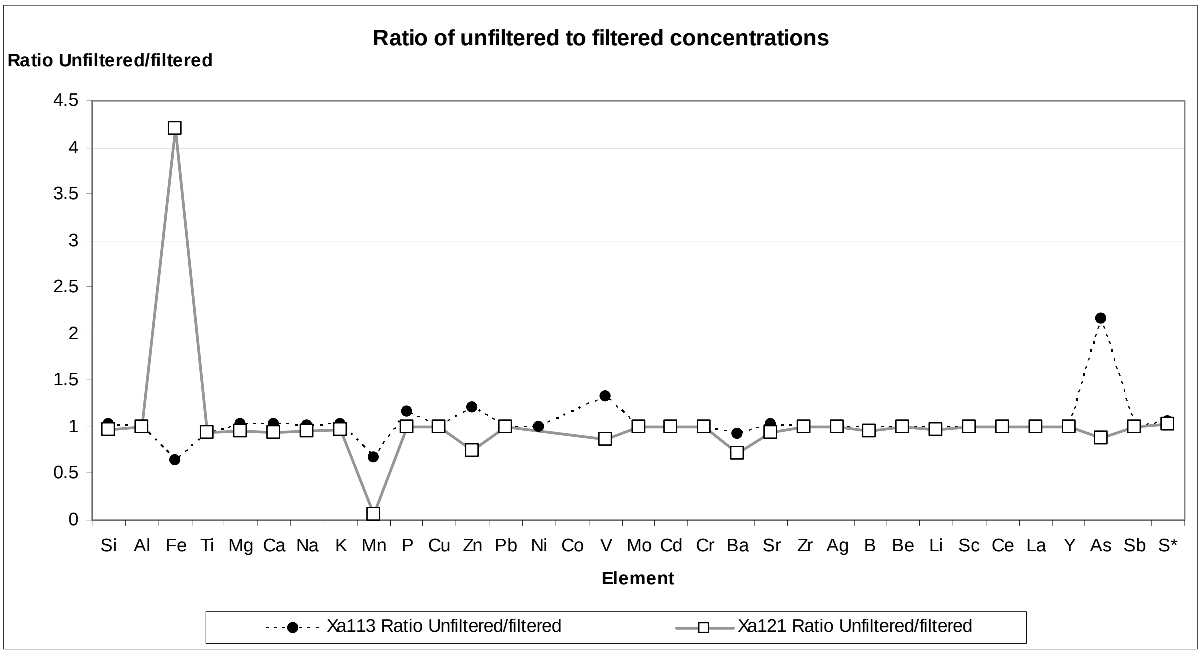


Figure 9.4. Comparison of results for selected elements between ICP-AES, ICP-MS and ion chromatography (IC) analytical methods.

Filtered versus Unfiltered Concentration

For the two samples (Xa113 and Xa121) where both filtered (0.45 µm) and unfiltered samples were taken for analysis by ICP-AES, the ratio between unfiltered and filtered element concentrations can be calculated (Figure 9.4). If the ratio is significantly > 1, it demonstrates that the element was either (a) substantially present in macro-colloidal or particulate form in the sample, or (b) that the element was precipitated out on the filter. If the ratio is significantly <1, it suggests either (a) poor sampling or analytical reproducibility or (b) that the element was released by the filtration process.

For most elements, the ratio is typically around 1. For sample Xa121, the ratio is substantially >1 for iron, suggesting that filtration has removed colloidal or particulate iron from the sample, or has caused nucleation and precipitation on the filter of iron oxyhydroxide. For sample Xa113, the ratio for As is also >1. It is known that arsenic can sorb to precipitated iron hydroxide but, as there is no evidence of particulate or precipitated iron hydroxide in this sample, this seems an unlikely explanation. Slightly worryingly, Mn exhibits a ratio of <1 for both samples, with Mn concentrations being higher in filtered samples than unfiltered. No clear explanation can be found for this phenomenon.

ICP-AES versus ICP-MS concentrations

For a six samples and a few elements, it has also been possible to evaluate analytical reliability by comparing concentrations analysed by differing analytical techniques. For aluminium and arsenic (Figure 9.5) concentrations analysed by ICP-MS and ICP-AES exhibit no serious discrepancies.

For boron, all six samples (where both ICP-MS and ICP-AES were run) returned concentrations of <20 µg/L by ICP-AES, compared with four samples returning concentrations of less than or around 20 µg/L by ICP-MS. One sample analysed by ICP-MS, however, returned a concentration of around 39 µg/L.

For manganese, one sample exhibits a substantially lower concentration when analysed by ICP-MS than by ICP-AES.

As regards phosphorus, both phosphorus by ICP-MS and phosphate by IC exhibited very poor correlations with phosphorus by ICP-AES. Phosphorus by ICP-MS and phosphate by IC exhibited a good correlation with each other, however, suggesting that phosphorus by ICP-AES is unreliable.

As regards sulphur by ICP-AES and sulphate by ion chromatography, the degree of correlation is generally acceptable, but there is a tendency for total sulphur by ICP-AES to exceed that which would be expected for sulphate by IC.

For vanadium, almost all samples return < 5 µg/L by ICP-AES, which is compatible with ICP-MS determinations. For a single sample, there is a poor correlation between ICP-MS (1.9 µg/L) and ICP-AES (9 µg/L).

For zinc, the degree of correlation between ICP-MS and ICP-AES is surprisingly poor. There is very little variation in the ICP-MS results, suggesting that ICP-AES may be more reliable.

For the elements Cu and K, no inconsistencies were exhibited between results for ICP-AES and ICP-MS.

The correspondence between ICP-MS and ICP-AES can perhaps be regarded as a little disappointing. However, most of the samples where ICP-MS was run were from Malii Anzas: hence the waters were very dilute. For several of the elements, the concentrations measured were thus very low (near or below analytical detection limit), where uncertainties in determination will be proportionately larger.

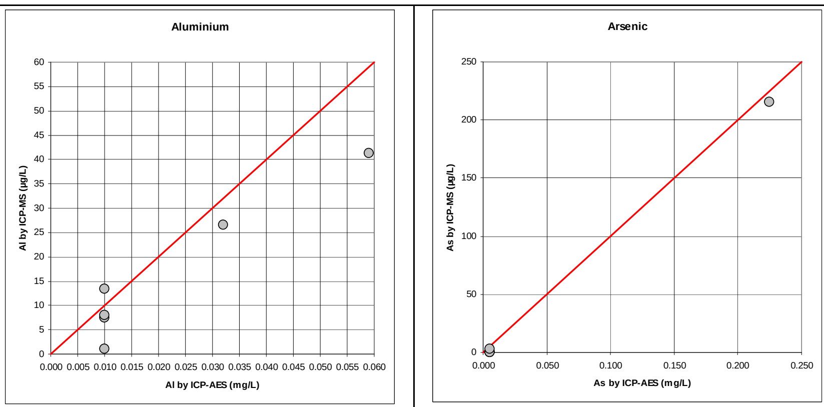
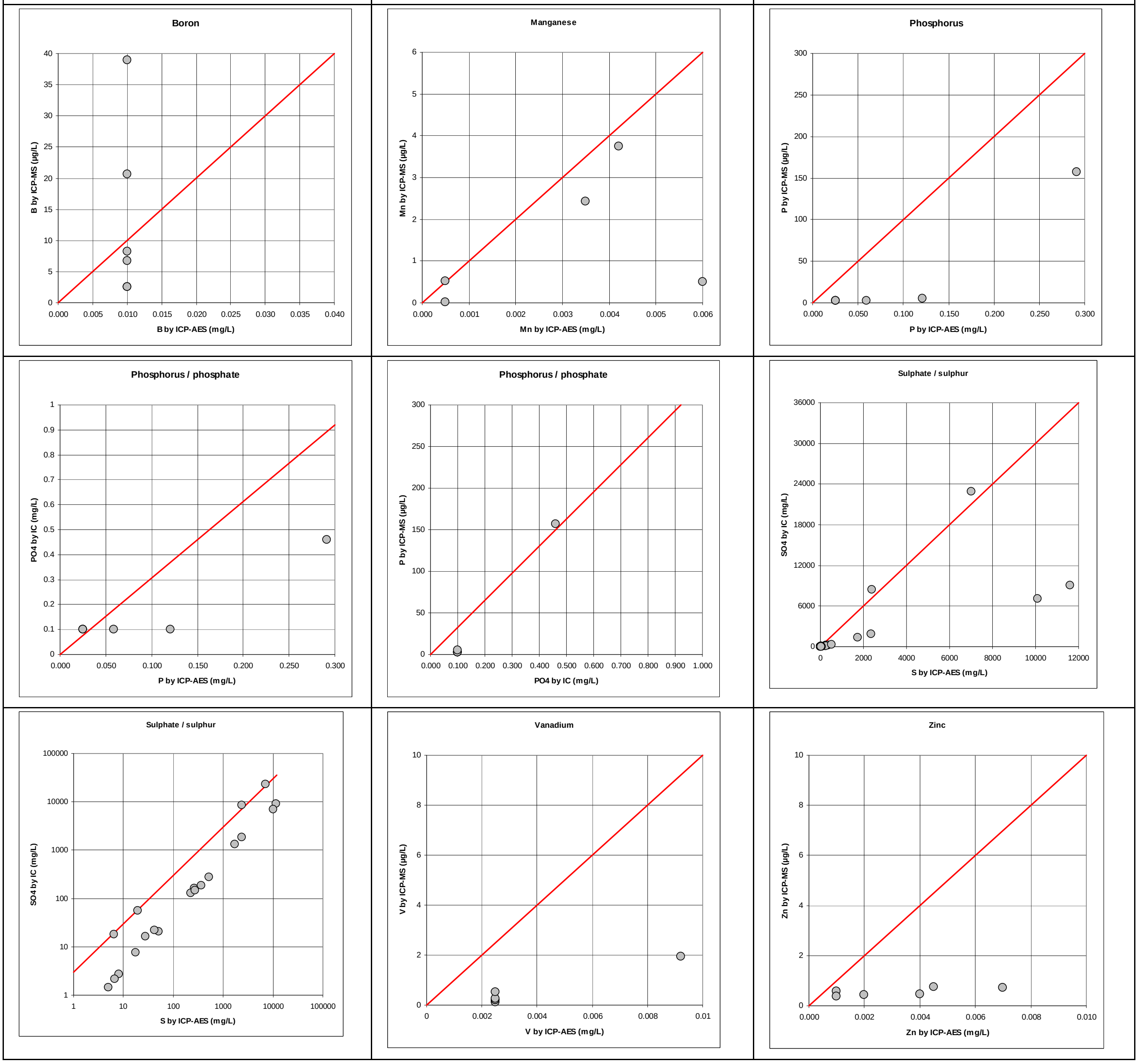


Figure 9.5. Comparison of results for selected elements between ICP-AES, ICP-MS and ion chromatography (IC) analytical methods. The red line illustrates a 1:1 correlation in each diagram. Where concentration is below analytical detection limit (DL), a value of 0.5 x DL has been assigned to the sample for plotting.



10 CONCLUSIONS

This report documents the hydrochemical analyses performed on water samples collected during field expeditions during the summers of 2006 and 2007 to the Republic of Khakassia, Kuznetsk-Alatau Oblast' and Kemerovskaya Oblast' (Russian Federation) in southern Siberia. Data have been obtained from groundwater (boreholes, springs, wells), rivers, lakes, mine waters and mine wastes. It is not the purpose of this report to indulge in detailed interpretation of the data presented.

The following main observations may be noted:

(i) River water and groundwater samples from the former gold mining area of Malii Anzas *failed* to reveal significantly elevated Hg concentrations, despite the intensive use of Hg in the former mining operation and the known soil contamination in the area. Apart from samples from the River Ona, samples returned concentrations of <0.01 µg/L Hg. The samples from the River Ona returned 0.02 µg/L both upstream and downstream of the mouth of the River Malii Anzas, making it extremely unlikely that these small quantities of Hg are related to the Malii Anzas mining activity.

(ii) Mine water being pumped from the abandoned Komsomolskaya mine, near Tysul', and being used by the local population as a domestic water supply, contains 225 µg/L arsenic by ICP-AES techniques (215 µg/L by ICP-MS). It is recommended that Tomsk State University enter a dialogue with local health authorities to minimise risk to local populations.

(iii) Mine tailings deposits at the Novii Berikul mineral processing works are producing a leachate with pH as low as 2, sulphate up to 22,000 mg/L, Fe up to 9100 mg/L, Al up to 500 mg/L, Cu up to 35 mg/L, Zn up to 351 mg/L, Pb up to 8.5 mg/L, Cd up to 5.7 mg/L and As up to 1900 mg/L. Quantities of leachate produced are rather modest, however, and the impact on the nearby river system is not known.

(iv) The "Severnaya" coal mine borehole in Kemerovo is producing a highly alkaline (t-alkalinity = 34 meq/L, pH = 7.6), H_2S-rich, highly reducing mine water that supports a colony of suspected *Thiothrix* sulphide-oxidising bacteria, and ultimately discharges into the river Tom'.

Figure 10.1. DB samples mud at Lake Utichie-3 (Xa102)

Figure 10.2. DB samples mud at Lake Utichie-3 (Xa102)

Figure 10.3. Borehole house at Lake Shira kurort (Xa104)

Figure 10.4. The sampling jetty at Lake Shira (Xa105)

Figure 10.5. The bedrock spring at Malii Anzas (Xa106)

Figure 10.6. The River Malii Anzas (Xa107)

Figure 10.7. River Ona downstream of Malii Anzas (Xa108)

Figure 10.8. Dug well at Malii Anzas (Xa110)


Figure 10.9. DB titrates alkalinity at Starii Berikul' adit (Xa113)


Figure 10.10. "Big Orange" at Novii Berikul' works (Xa115)


Figure 10.11. "Little Red" at Novii Berikul' works (Xa116)


Figure 10.12. Serebryanii Klyuch borehole (Xa117)


Figure 10.13. Active dewatering of Konyukhtinskaya mine shaft (Xa119)


Figure 10.14. Severnaya borehole (Xa121). *Thiothrix*(?) in stream.


Figure 10.15. Salair Mine tailings lagoon


Figure 10.16. OV Karnachuk in the base of Salair opencast (Xa205)

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12 AFTERWORD

The Ballad of Anastasia from Chernogorsk (Part II)

Respublik Khakassia
et sted midt i Asia,
mesteparten vilt og ukjent land.
Vi trosset alle farer,
tok med oss to gitarer
og reiste med tog til Abakan.
Med Valeri Petrovitsj
og Anatoli Anatolivitsj
skulle vi undersøke vann.
Dobryj djen - og go' morn
Dr Banks Dr Bjorn
Værsågod ta en stol og vent
Ta en vodka og svelg
med konfekt - tørket elg
Vi kan jobbe når det er blitt sent.

Khakassias grunnvannsårer
like salt som tårer
Natriumsulfat så vidt vi vet.
Vi hentet 30 prøver
fra brønner og fra sjøer,
tok pH, red-oks og alkalitet.
Vi spiste lunsj på Kolkhoz,
og David han var tolk hos
Bjørn som sa spasiba da og njet.
Dåbryj vjetsjir god kveld
Da svidania Farvel
Vi er ferdig i Abakan
Så vi tar vår gitar
under armen og drar
hjem igjen med sekken full av vann.

(Ytterligere tilståelser:)

Respublik Khakassia
der bor Anastasia
i en by som heter Chernogorsk.
Hun kalles bare "Nasty"
Hun har mye å holde fast i
selv om hun kan være ganske dorsk.
På månelyse stepper
Hennes lepper var som pepper.
Det er godt å være norsk i Chernogorsk!!
Dåbryj vjetsjir god kveld
Da svidania Farvel
Jeg er ganske tummelumsk.
Fra Khakassia hvor
Anastasia bor
går et jernbanespor til Tomsk.

Frengstad under dårlig innflytelse av Banks, Gostinitsa Druzhba, Abakan, juni 1999.