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IN THE BASINS OF AMUR AND USSURI TRIBUTARIES

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Introduction

The research was carried out in the frame of the Implementation Agreement on the Joint Research of the Amur River, its Estuary and the Sea of Okhotsk between the Institute of Water and Ecology Problems FEB RAS (Russia) and the Research Institute of Humanity and Nature (Japan), signed on April 19.2005 and based on the Agreement on Cooperation between the Far Eastern Branch of the Russian Academy of Sciences and the Research Institute of Humanity and Nature, signed on March 4, 2004.

Joint terrestrial expeditions in the basins of the Amur and Ussuri have been undertaken since 2005 under the annual contracts between IWEP FEB RAS and RIHN. 200-year research was focused on the basins of the Gassi Lake, Ussuri River, Anui River and Chayatynskoe Narrowing rivers.

1. RIVERS OF THE GASSI LAKE AND USSURI RIVER BASINS.

1.1. Landscape and Hydrological Characteristics of the Region under Research

The research was undertaken in the north-eastern part of the Middle Amur Lowland, in particular at the rivers Babchi, Katanga and Khaso with tributaries that belong to the Gassi Lake basin, and in the south-eastern part of this Lowland at the rivers Khor and Kiya (mostly in its lower reaches). The upper reaches of the above mentioned rivers (excluding the Babchi River) belong to the low-mountainous boundary of the Middle Amur Lowland that situates within the west macro slope of the Sikhote-Alin Mountain Range. The entire Babchi River drainage area is composed of a swampy alluvial plain that belongs to the ancient cone of the Anui River discharge.

The Gassi Lake is situated in the Amur flood plain 18.5 km north-west from the Sinda River. Water surface area is 27.5 km^2 and lake drainage area is 2420 km^2. The lake is of oblong shape and stretches from south-east to north-west for 12.5 km. Its maximum width is 4.5 km. The Gassinskaya and Naikhinskaya channels connect the lake with the Amur River. The mean water level is 25.2 m. Lake water level regime is entirely determined by the Amur water level. When the flood wave passes along the Amur River the Gassi Lake is overfilled, whereas in summer low water in the Amur the lake shrinks. During winter low water the lake is nearly completely frozen through, leaving a narrow passage of water along the lake bottom that is formed with water discharged from the lake tributaries. The lake banks are not high and in the north-eastern part they are covered with woods. Water transparency fluctuates within 60-100 cm [Resources…, 1970].

Table 1 presents the Gassi water balance data, including previously reported data [Mordovin, 1996]; [Resources…., 1970]. Precipitations and evaporations were estimated based on observation data for the Manoma River basin, which was taken as analogous to the Gassi Lake basin.

The Gassi Lake basin includes the basins of the rivers Khar, Pikhtsa and Babchi, as well as swampy plain areas, mostly not drained with streams. Between the Anui River and Lake Gassi there are swamps (45% of the area), woods (54%) and sparse-grown trees (1%) [Efremov et al., 1999]. The Kartanga River Basin (the biggest tributary of the River Khar) with its tributaries Burga and Uta has the area of 596 km^2. It is equally divided into mountainous and plain areas, and 82% of it is covered with forests (25% of which are the most valuable Korean pine forests). The River Khaso drainage area (the tributary of the River Khar) is of mountainous character.

Table 1. Assessment of the Components of the Average Annual Water Balance of the Gassi Lake

Water Balance Component Characteristics	Drainage area, km^2	Value	
		m^3/sec	l/sec·km^2
Surface inflow from the inner basin (rivers Khar and Pikhta)	2112	30.6	14.4
Kartanga River runoff (Khar R. tributary)	596	7.91	13.3
Burga River runoff (Kartanga R. tributary)	332	4.27	12.9
Khar River runoff	1250	17.8	14.2
		mm/year	
Surface inflow from the inner basin	2112		
Atmospheric precipitation in the drainage area	27.2	955	
Evaporation from the lake drainage area	27.2	545	
Underground inflow	-	0	
Underground runoff	-	0	

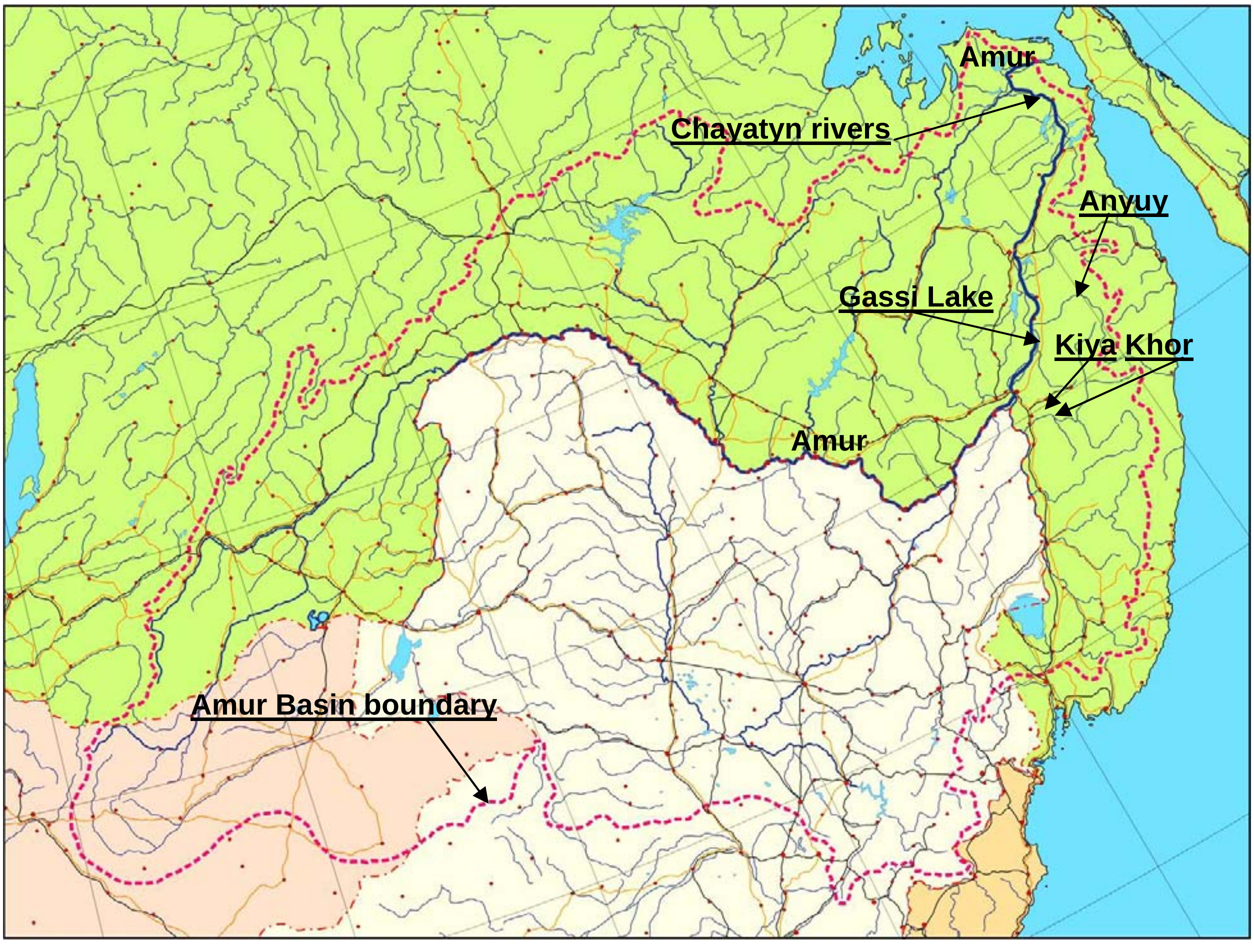

Fig. 1. Field Works Sites in 2007 in basins of Gassi Lake and rivers Anui, Kiya, Khor and the Chayatynskoe Narrowing of the Amur Valley.

The water regime of the rivers studied is described as the far-eastern type, which specific feature is a marked predominance of the rainfall run-off. The share of the rain in the annual run-off is 60-85%. In the warm time of the year (April – October) water amount is increased due to abundant rainfalls and run-off fluctuations are significant, making the form of the hydrograph ridge-like. Five or six floods are usually observed in the Gassi Basin rivers in the warm time of the year [Resources…, 1970].

The rivers Khor and Kiya within the southern part of territory under research flow in the terraced plain. Its boundary parts and adjacent to them mountain slopes are abundant in forest podbels covered with small-leaved forest with larch. They are formed on the weakly water-permeable loam and clay deposits. In mountain water divines brown mountain forest soils are covered with coniferous and broad-leaved forests. Eluvium and delivium of bedrock of different composition serve as a soil forming rock here. Due to high content of rock debris they are easily penetrated with water. Vast areas on the terraces are covered with wet meadows (sedge and reedgrass), low and transitional bogs with meadow gley, peat and peat-gley soils. The Khor River has a developed floodplain composed of alluvial soddy and plain stratified well-drained soils covered with forests abundant in ash, walnut, elm. The groundwater level is rather close to the plain surface. Economic activity in recent hundred years has been developed on the major part of the described territory. The banks of the rivers mentioned have been settled with people, including rather big communities like Pereyaslovka and Khor settlements.

1.2. Research Objects and Methods

In 2007 water discharge in the Gassi basin rivers was measured on foot with a hydrometric rotator GR-21M (factory serial number 1041), texted in the Far Eastern Center for Hydrometeorology and Environmental Monitoring in August 2006.

River water was sampled form the close to surface horizons in the stream middle in the low water period.

Such physical and chemical characteristics of water mass as temperature (t ºC) and water pH were measured.

To describe different water components the following methods were applied:

- a complex method for water hardness (Ca^{2+}+Mg^{2+});
- titration for Ca^{+2};
- photometry for Si in the yellow form of molibdic silicic acid;
- titration with mercury salt for chlorides (Cl^{-});
- titration with photometry to follow for sulfates (SO_4^{2-});
- a flame photometry for Na^{+}+K^{+};
- a bi-chromatic method for dissolved organic carbon (DOC);
- inductively coupled plasma mass spectrometry (ICP-MS) for bulk content of iron and manganese.

1.3. Results of Research in the Gassi Lake Basin

Hydrological characteristics of Surface Water in July 2007

Background conditions in June 2007 were drier compared to July 2006 (Fig. 1 and 2, Table 2). The field work in 2006 took place in the period between rains and in 2007 the sampling and measurements were made on the first day after the cyclone rain.

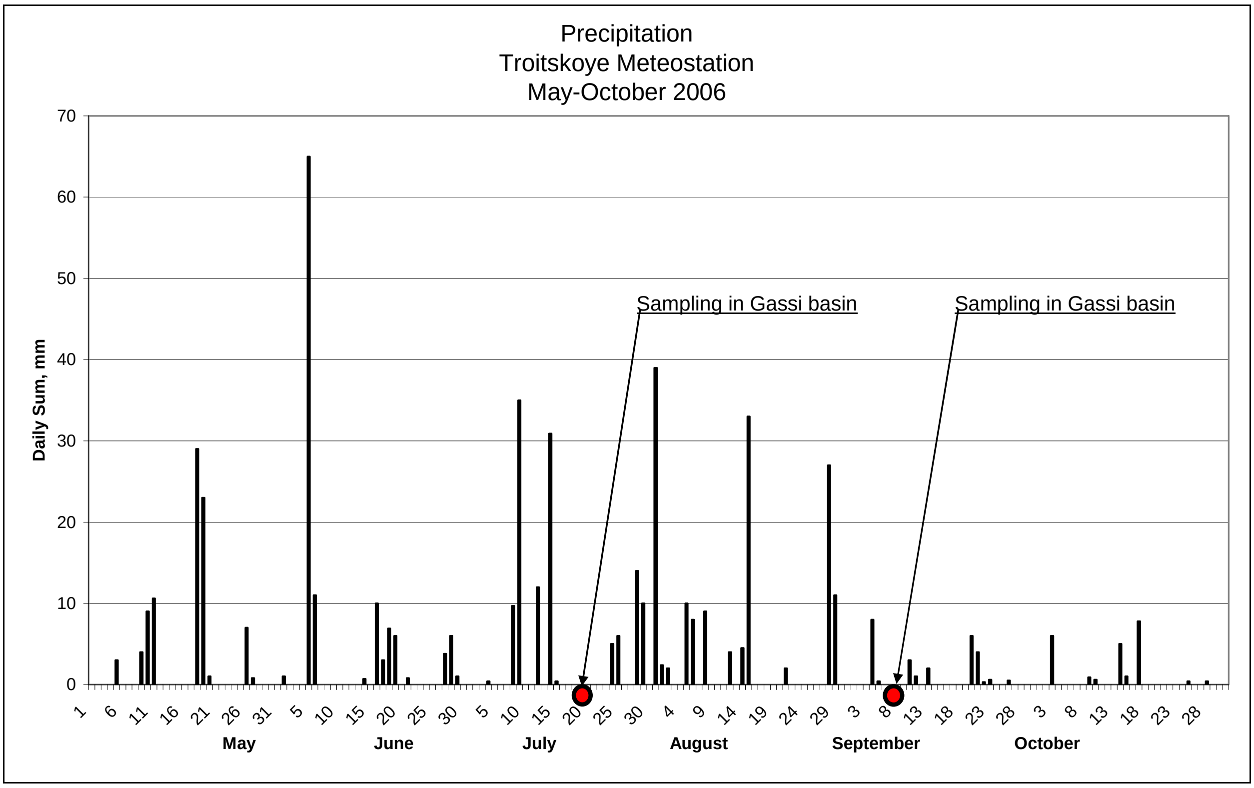

Fig. 2. Inter-seasonal Distribution of Daily Precipitation Sums at Troitskoe Meteostation in 2006.

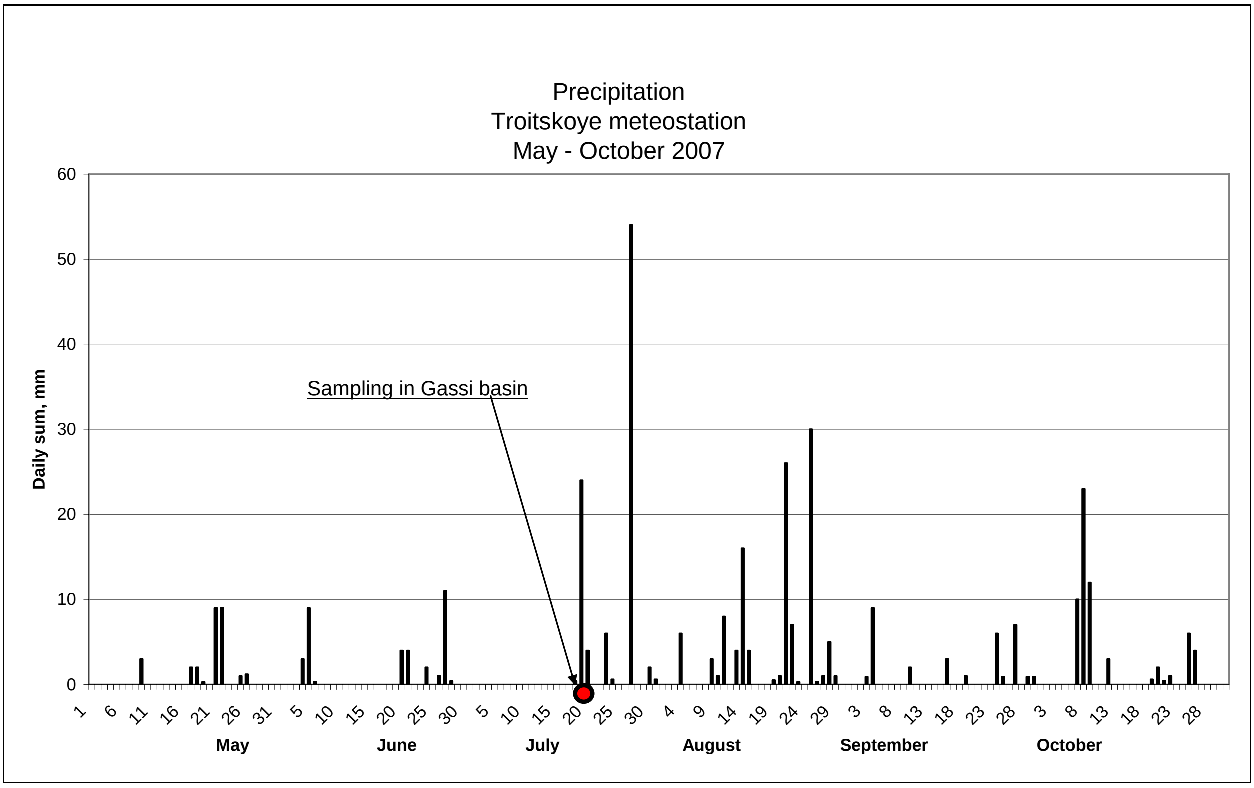

Fig. 3. Interseasonal Distribution of Daily Precipitation Sums at Troitskoe Meteostation in 2007.

This fact influenced the slight increase of the River Khoso discharge in July 2007 compared to that one in the "dry" September of the previous year. High river water discharge in July 2006 was determined by the preceding significant atmospheric moistening in the first half of the warm period.

Table 2. Characteristics of Atmospheric Moistening in the Gassi Lake Basin in the Warm Periods of 2006 and 2007 (Troitskoe Meteorological Station data)

Month	2006	2007	Mean for the 1932-1999 observation period [Petrov et al., 2000]
	Total precipitation, mm		
May	87	28	55
June	115	35	74
July	162	92	113
August	113	114	124
September	26	32	89
October	22	62	46
Total	525	362	501

Water discharge data in 2006 and 2007 are given in Table 3.

Table 3. Water Discharge (m^3/sec) in the Rivers of the Gassi Lake Basin, 2006-2007.

№	River - Station	July 2006	September 2006	July 2007
1	Kartanga – bridge	51.4	7.17	2.37
2	Left Khaso – 100 m upper the bridge	no data	1.03	0.92
3	Khaso –upper bridge	1.70	1.15	1.31
4	Khaso –lower bridge	6.76	0.90	1.29
5	Babchi – bridge	1.59	1.20	0.22
6	Burga – 56 m upper the bridge	9.71	0.76	no data
7	Uta – bridge	4.59	0.81	no data
8	Malina - bridge	0.27	0.06	no data
9	Gassi Lake – bridge	41.7	21.3	15.90

Hydrochemical Characteristics of Surface Water in July 2007

Hydrochemical characteristics of surface water includes such parameters as pH values, main ion concentrations (Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}), silicon compounds that belong to biogenic substances and values of main cation (Na^+/ K^+, Ca^{2+}/ Mg^{2+}) ratios in mg-equiv. dm^{-3}. Table 4 presents these results.

Table 4. Hydrochemical Parameters of water (mg dm^{-3}) from Gassi Lake and its Tributaries, June 2007.

№ пробы	River - Station	pH	Na^+	K^+	Ca^{2+}	Mg^{2+}	SO_4^{2-}	Cl^-	Si
1	Kartanga – bridge	7.20	1.80	0.67	4.9	2.8	2.58	0.5	6.59
2	Left Khaso – 100 m upper the bridge	7.40	1.56	0.60	3.7	2.7	4.21	0.4	8.17
3	Khaso –upper bridge	6.75	1.90	0.77	3.9	2.8	2.49	0.4	7.98
4	Khaso –lower bridge	6.68	1.50	0.68	4.1	2.6	2.37	0.5	7.44
5	Babchi – bridge	6.66	2.26	0.66	4.1	2.5	4.56	0.3	5.68
6	Gassi Lake – bridge	7.80	1.54	0.76	3.9	2.6	2.62	0.3	6.71

Hydrogen indicator (pH) is an important characteristic of water quality. Its value in the rivers of the Gassi Lake in 2007 changed within the range 6.66 – 7.80.

The permissible concentration value of pH for water in the water objects with fishing capacity is determined as 6.5 – 8.5. The observed pH values did not exceed the permissible level. In 2007 the shift of pH value towards alkalization was observed. Values of pH in waters of the Lower Amur fluctuate within 6.4 – 6.9 (these waters are ranked as pH neutral).

Cations mostly have the following successions $Mg^{2+} \geq Ca^{2+} > Na^{+} > K^{+}$ (in 5 cases out of 6 in the Gassi Lake drainage area, excluding the Katanga River) and $Ca^{2+} > Mg^{2+} > Na^{+} > K^{+}$.

Water hardness ($Ca^{2+}+Mg^{2+}$) in the Gassi Basin rivers was 0.407-0.475 mmol/dm^3 of equivalent. Minimal water hardness values were observed in the Kartanga River and its maximum values were found in Lake Gassi and the rivers Left Khaso and Babchi. Calcium ion concentration in the rivers fluctuated within the range 3.7 – 4.9 mg dm^{-3}.

The ion form (Ca^{2+}) is specific to only weakly mineralized water. Calcium ions form rather strong complex compounds with organic substances. In some weakly mineralized colored waters up to 90 – 100% of calcium ions may be fixed with humic acids. Ca^{2+} concentrations reveal marked seasonal fluctuations. When mineralization decreases (spring) calcium ions dominate. It can be explained with easy alkalization of soluble calcium salts from the surface soils and rocks. Magnesium ion content in the Gassi Basin rivers was 2.5 – 2.8 mg dm^{-3}. In the surface waters it noticeably varies and as a rule maximum values are observed in low water periods and minimum values – in flood periods.

The ratio Ca^{2+}/Mg^{2+} is the chief indicator of a metamorphosed water composition. In weakly mineralized natural waters the calcium ion is the chief component of the chemical composition, whereas the magnesium ion appears with metamorphization. The value of Ca^{2+}/Mg^{2+} ratio in waters under research was most1y 1 and agrees with the interval specific to weakly mineralized waters (1-2).

Natrium is also one of the chief components that determines the type of natural waters. Physical and geographic conditions and geological specifics of the water object basins impact natrium ion concentrations is surface water. The main sources of Na^{+} in surface waters are volcanic sedimentary rocks and soluble chloride, sulfurous and carbonic salts of natrium. Biological processes in the drainage area are also important as some of them produce soluble natrium salts as well. Natrium ion content in the Gassi Basin rivers was registered 1.50 – 2.26 mg dm^{-3}.

The sources of potassium, another important chemical component in natural waters, are geological rocks and soluble salts. Different soluble potassium components may also be the product of various biological processes that take place in soils and residuum. Potassium has the tendency to be sorbed on the high-dispersed particles of soil, rocks, bottom sediments and caught by plants in the growth and nutrition processes. As potassium is less mobile compared to natrium its concentrations in surface waters are smaller than that of natrium. The content of K^{+} in the Gassi Basin rivers was 0.60 – 0.77 mg dm^{-3}. Na^{+}/K^{+} ratio was 3-6.

Sulfates are present practically in all surface waters and are one of the main anions. The main sources of sulfates in surface waters are processes of chemical weathering and solution of sulfur-containing minerals, mostly gypsum; sulfur and sulfide oxidation; organism destruction; oxidation of substances of plan and animal origin; underground flow. The ion form (SO_4^{2-}) is specific to weakly mineralized waters. Sulfate ion content in the solution is limited by the comparatively low solubility of calcium sulfate. When calcium sulfate content is low and also when other salts are present, sulfate concentrations may increase. Plant and other autotrophic organisms extract dissolved-in-water sulfates to built protein. SO_4^{2-} content in surface waters has seasonal fluctuations. The most important factor to determine sulfate regime is the changing correlation between surface run-off and subsurface drainage. The redox situation and economic activities in the water object also impact sulfate regime. SO_4^{2-} content in the Gassi Basin rivers was 2.37 – 4.56 mg dm^{-3}. Usually SO_4^{2-} concentrations in the Amur River fluctuate within the range 1.3 – 7.7 mg dm^{-3}.

To reveal possible sources of sulfates in water the correlation between pH and SO_4^{2-} values was studied. The analysis of all data available showed that there is no significant correlation. When sulfate ion content was maximal (4.56 mg dm^{-3}), pH value was 6.66, and when it was minimal (1.08 mg/ mg dm^{-3}), pH value was 7.35.

Chloride ions are main ions. The sources of them in water objects are salt-bearing deposits, magmatic rocks, volcanic ejectamenta, saline soils, industrial and household water waters. Chlorides do not tend to form ion pairs. They have a high migration capacity to be sorbed by suspended matter and bottom sediments, but are practically not accumulated by hydrobionts. Chloride ion content in the Gassi Basin rivers was 0.3 – 0.5 mg dm^{-3}. Maximum values were observed in Kartanga and Khaso (lower bridge) water and minimum values were registered in the Babchi River and Lake Gassi.

Silicon is always present in natural water chemical composition as it is widely present in the mountain rocks. The sources of silicon in water include chemical processes of weathering and dissolving of silicon-containing minerals, decomposition of ground and water plant organisms, atmospheric precipitations, and sewage waters. Silicon content in slightly contaminated waters has seasonal fluctuations. The important factors that determine silicon regime are the changing correlation between surface runoff and subsurface drainage, intensity of biological consumption of silicon by water organisms, development peculiarities of diatoms and their decomposition. Dissolved silicon concentrations in the Gassi Lake water objects are 5.68 – 8.17 mg dm^{-3}.

In the Amur water silicon content varies from 0.1 to 7.0 mg $dm^{-3}$and its mean value is 5.3 mg dm^{-3}. The highest concentrations are reported in the utmost upper reaches of the Amur. Significant amounts of dissolved silicon compounds are discharged with the Shilka, where silicon content reaches 9.9 mg dm^{-3}.

Increased concentrations of biogenic substances may indicate natural (water run-off from the swampy areas) and anthropogenic (chemical pollution) factors of unfavorable conditions of rivers and lakes. As a rule, they increase water mass productivity, which does not always indicate a favorable ecological situation

Table 5 presents estimated discharge data of soluble mineral substances in the Gassi Lake drainage area. Total inflow of soluble mineral substances was calculated based on the mineralization value (M) – the sum of the main ions (Na^+, K^+, Ca^{2+}, Mg^{2+}, SO_4^{2-}, Cl^-, HCO_3^-) and biogenic substances (NO_3^-, NO_2^-, NH_4^+, HPO_4^{2-}, SiO_2).

Table 5. Dissolved Mineral Substance Discharge (t day^{-1}) in the Gassi Lake Basin, July 2007.

Sample №	Sampling station	Na^+	K^+	Ca^{2+}	Mg^{2+}	SO_4^{2-}	Cl^-	Si	M
1	Kartanga	0.37	0.14	1.00	0.57	0.53	0.10	1.35	7,92
2	Left Khaso	0.12	0.05	0.29	0.21	0.33	0.03	0.65	2,86
3	Khaso –upper bridge	0.22	0.09	0.44	0.32	0.28	0.05	0.90	3,95
4	Khaso –lower bridge	0.17	0.08	0.46	0.29	0.26	0.06	0.83	3,87
5	Babchi	0.04	0.01	0.08	0.05	0.09	0.01	0.11	0,70
6	Gassi Lake	2.12	1.04	5.36	3.57	3.60	0.41	9.22	47,92

The received data show that main ions and silicon compounds in maximum concentrations are discharged by the Kartanga River and in minimum concentrations they come from the Babchi River.

Organic Matter

Landscape structure of the Gassi Lake territory, dynamic and amount of precipitation, character and specifics of soils determine certain regularities of geochemical migration of organic matter and chemical elements (especially such hydrogenic elements as iron, manganese, etc.).

The research conducted in 2006 showed that the rivers of the north-eastern part of the Gassi Lake drainage system significantly differ in their dissolved organic carbon (DOC) content. In the river middle passages organic matter content was noticeably lower (4-5 times) than in the river lower reaches. In the Gassi Lake itself organic matter concentrations were rather high (30 mg C dm^{-3}), and the highest concentrations were observed in swamp waters (51.2 mg C dm^{-3}) in the low water period.

The facts mentioned above indicated significant discharge of organic matter into the Gassi Lake from its drainage area, especially in July 2006 (in the high water period).

The second water sampling and analysis in 2007 showed that organic matter content in the studied rivers was noticeably lowed that in 2006 (Table 6). At the same time, DOC concentrations varied significantly. The Khaso River, which runs through foothill and low-hill territory, had relatively low DOC concentrations that correspond to low Colority values. Kartanga River, which runs mostly through the swamped accumulative plain, had DOC concentrations that exceeded those found in the Khaso River more than two times. DOC content in the swamped Babchi River was 40.0 mg C dm^{-3}, very close to DOC values in swamp waters.

Table 6. Some Hydrochemical Indicators of Waters in Lake Gassi and its Tributaries in July 2007.

Sample №	River - Station	pH	Colority, degree	DOC, mg C dm^{-3}
1	Kartanga – bridge	7.20	130	6.15
2	Left Khaso – 100 m upper the bridge	7.40	47	3.40
3	Khaso –upper bridge	6.75	60	3.60
4	Khaso –lower bridge	6.68	65	2.7
5	Babchi – bridge	6.66	120	40.0
6	Gassi Lake – bridge	7.80	65	3.7

Gassi lake water in 2007 revealed not high values of DOC, 4.0 mg C dm^{-3}, which is much lower than in 2006. That is why the colority of water was low as well, i.e. 65 degrees. The decrease of organic matter content in 2007 in the studied waters (except the Babchi River) is explained by the low water in the rivers and as the result of it very high input of humic substance from the mountainous and the plain parts of the Gassi Lake drainage system. High DOC content in the Babchi River is due to swamp waters with relevant chemical and physical parameters (pH).

Iron and Manganese

Iron content in the Gassi Lake basin rivers in July 2007 changed within the rate from dozens to thousands micrograms per litre (Table 7).

Significant values that exceeded the permissible levels for the fishing objects (100 mcg dm^{-3}) [Sanitary…,2000) were registered in the Khaso River (the upper bridge) as 1.3 of the permissible level [Sanitary norms…2000]. Maximum values were registered in the Kartanga River as 13.3 of the permissible level. Most iron is present as organic complexes (60% of dissolved iron). This is explained by the noticeable swamping of the area.

The content of the dissolved manganese in water samples was within the first dozen, rarely the first scores of microgram per litre. Maximal concentrations were registered in Kartanga water 23.03 mcg dm^{-3}. Most probably the dissolved manganese migrated in ion form. The role of it organic complexes is low.

Table 7. Manganese and Total Iron Concentrations (mcg dm^{-3}) in the Gassi Basin Rivers in July 2007.

Sample №	River - Station	Fe	Mn
1	Kartanga – bridge	1333.15	23.03
2	Left Khaso – 100 m upper the bridge	52.70	2.40
3	Khaso –upper bridge	132.82	4.58
4	Khaso –lower bridge	19.81	0.89
5	Babchi – bridge	52.85	11.60
6	Gassi Lake – bridge	27.97	4.62

Conclusion

Hydrochemical research in the Gassi Lake drainage area revealed water chemical composition heterogeneity in pH value, concentrations of silicon compound and sulfate, natrium and potassium ions. Both natural and anthropogenic factors, including physical and geographic conditions and geological specifics of water objects, drainage area landscape, hydrological regime phases, correlation of surface run-off and subsurface drainage, economic activities influence the formation of water chemical composition in the Gassi Lake Basin.

Transportation of dissolved organic matter from soils is regulated to a great extend by the amount of atmospheric precipitation. In years with much precipitation it is also high and in years with insufficient rainfalls it is lower. Bog ecosystems have a more stable situation, as bogs have a high organic matter accumulation capacity. A noticeable dissolved organic matter flow from them takes place only in high-water period.

1.4. Results of the Khor and Kiya Rivers Research in July 2007

Hydrochemical characteristics

Hydrochemical characteristics of surface water include such parameters as pH values, main ion concentrations (Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}), silicon compounds that belong to biogenic substances and values of main cation (Na^+/ K^+, Ca^{2+}/ Mg^{2+}) ratios. Cation ratios were calculated based on weight concentrations of ions in mg-equiv./dm^3. Table 8 presents the research results.

Table 8. Water hydrochemical parameters (mg dm^{-3}) of the Khor and Kiya Rivers, July 2007

River - Station	pH	Na^+	K^+	Ca^{2+}	Mg^{2+}	SO_4^{2-}	Cl^-	Si
Kiya – Marusino village	7.18	2.08	0.97	5.2	2.3	1.63	2.0	1.39
Kiya – Pereyaslovka settlement	7.22	2.41	0.90	5.2	2.3	1.76	2.0	4.68
Kiya – Chernyaevo village	8.55	1.50	0.61	2.8	3.5	1.59	3.3	5.48
Khor – Khor settlement	7.35	1.30	0.59	4.0	1.6	1.08	0.5	2.00

The value of pH in the Khor and Kiya Rivers in 2007 fluctuated between 7.18 and 8.55 and did not exceed the permissible level. Only in the Kiya River near Chernyaevo village pH value was increased to 8.55.

Water hardness (Ca^{2+}+Mg^{2+}) in the Khor and Kiya Rivers was 0.331-0.449 mmol dm^{-3} equivalent. Water there is characterized as soft. Maximal hardness values were registered in Kiya water near Marucino village and Pereyaslavka settlement and minimal values were found in the Khor River near Khor settlement. Calcium ion concentrations in the Khor and Kiya Rivers were 2.8-5.2 mg dm^{-3}.

Magnesium ion concentrations were 1.6 - 3.5 mg dm^{-3}. Maximal Mg^{2+} concentrations were registered in the Kiya River water near Chernyaevo village and minimal values were registered in the Khor River near Khor settlement. Natrium ion concentrations in both rivers fluctuated within the range 1.30 - 2.41 mg dm^{-3} and potassium ion concentrations were 0.59 - 0.97 mg dm^{-3}.

Concentrations of SO_4^{2-} in the Khor and Kiya Rivers were 1.08-1.76 mg dm^{-3} and chloride ion concentrations were 0.5-3.3 dm^{-3}. Maximal concentrations were observed in the Kiya River water near Chernyaevo village and minimal values were observed in the Khor River near Khor settlement.

Dissolved silicon concentrations in both rivers fluctuated within 1.39-5.48 mg dm^{-3}.

Organic Matter

Organic Matter content in the Khor and Kiya Rivers was not high (Table 9). The lowest concentrations were observed in the Kiya River near Marucino village and down the river increased two times. This fact may be explained with intensive agriculture developments in this area. The pH increase to 8.55 in this area may be also explain with agriculture impact. Near Khor settlement significant differences in organic matter concentrations were not observed. Khor River waters are weakly colored and dissolved organic matter content is not high there.

Table 9. Some Hydrochemical Parameters of Khor and Kiya waters in July 2007.

№	River - Station	pH	colority, degree	DOC, mg C dm^{-3}
1	Khor – bridge	7.35	30	3.1
2	Kiya – Marusino village	7.18	65	1.9
3	Kiya – Pereyaslovka settlement	7.22	60	2.2
4	Kiya – Chernyaevo village	8.55	70	3.5

Iron and Manganese

Iron was not found in the Khor River water (values do not exceed the device response limit) (Table 10). Iron content in the Kiya River fluctuated in a small range of the first hundreds of micrograms per litre. The permissible level was exceeded in the Kiya River near Marucino village (3.0 permissible level) and near Chernyaevo village (3.1 permissible level). Such concentrations are rather characteristic for Priamurje waters.

Manganese concentrations in water samples were not high and changed from 1 to 2 tens of micrograms per litre. Rather low concentrations were ob served in the Khor River. In the Kiya River manganese decreased down the river nearly 3 times. Here, as well as in the rivers of the Gassi Lake Basin, manganese migrated mostly in the ion form and the role of its organic complexes in low.

Table 10. Total Iron and Manganese Concentrations (mcg l^{-1})in Waters of the Khor and Kiya Rivers in July 2007.

№	River - Station	Fe	Mn
1	Khor – Khor settlement	<0.001	1.38
2	Kiya – Marusino village	298.75	21.16
3	Kiya – Pereyaslovka settlement	95.79	9.87
4	Kiya – Chernyaevo village	313.02	7.55

Conclusion

Not high values of dissolved organic matter in the Khor and Kiya waters may be explain with the specifics of natural conditions of the territory under research, including soil and humus formation specifics: the content of humic acids is relatively not high, they are fixed in the soil profile with calcium and iron oxides and poorly migrate beyond the soil profile [Ivanov, 1976].

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2. RIVERS OF THE ANUI RIVER BASIN AND THE CHAYATYNSKOE NARROWING

2.1. The Anui River Basin

2.1.1. Landscape and hydrological characteristic of the studied area

The Anui River is a big tributary in the Amur lower reaches. It is 393 km long and has a drainage area of 12 700 km^2. Its upper reaches lie in the mountain relief of the western slopes of the northern Sikhote-Alin mountain range. The slopes of the valleys of the Anui and its tributaries (excluding the Manoma) are mostly steep and formed with volcanogenic basalts, tuffs, andesites and other rocks. Dark mountain coniferous forests of the taiga type prevail up to the Gobilli River mouth, followed down the basin with dark coniferous and dark coniferous-broad-leaved forests. Common tree species here are Ayan spruce, Khingam fir, Korean pine and birth. Mountain taiga podzols and mountain forest brown soils are typical for this area.

The Manoma, the biggest Anui tributary, flows into the Anui18 km from its mouth. The Manoma is 198 km long, its basin area is 2 450 km^2 and its stream gradient is 580 m. Its major part flows through the Sikhote-Alin mountain system and its piedmont. The studiedpart of the Manoma basin has a middle- and low-mountain relief consisting of hills and mountain chains. The south-eastern part of the basin is situated in the piedmont, characterized with low (200-400 m) gently sloping hills with rather smooth tops, as well as with not deep saddles. Most of the basin (over 80%) is covered with dark coniferous and dark coniferous-broad-leaved forests.

The Manoma Basin geologic composition consists of sandstones, clay shales and cherts, granites, granitoids, porphyrites and andesites. Quaternary deposits include alluvial pebbles, sands and clays, as well as basalts and andesites. Basin specifics are basalt plateaus along the south-western macroslope of the Sikhote-Alin, situated 500-600 m above the sea level and composed mostly of effusive rocks.

Soil diversity is caused by vertical belting. The soils, described below, did not suffer the fires. The Anui from its beginning up to the juncture with the Gobilli and Tarmasu rivers (absolute heights 1 000 – 1 500 m and higher above the sea level) drain the relief, where mountain brown taiga gley soils with rock debris prevail. They are mostly covered with larch forests. They are combined with dry-peat brown and podzol soils of the upper part of the larch and mountain pine belts. In the Gobbili River basin (absolute heights 800 – 1 400 m above the sea level) and the Manoma upper reaches mountain brown taiga illuvial humus soils are common. They were formed on the rock debris deposits under grassy larch groves with spruce and silver fir inclusions. They are accompanied with taiga gley humus soils. The soil cover in the Anui upper reaches and in the Gobilli basin is in the permafrost area, which is characterized with stable perennial temperatures of soils and rocks below 0. The Anui in its middle passage drains a relatively not high piedmont belt (300 – 700 m above the sea level) with brown forest clay and loam soils with rock debris under coniferous- broad-leaved forests. The Anui in its lower reaches and the Manoma in its middle and lower reaches drain a vast bog massif with peat soils. The peat is 0.5 – 1 m thick.

Among all Amur tributaries the Anui is the only river where there are no water quality control stations. Only one hydrological station to check water runoff has been established on its tributary Manoma.

The main factors that determined water chemical composition in the Anui and its tributaries before 1970-ies were timber felling and rafting. In recent years, when timber felling and rafting have been decreased, the other factors are becoming most evident. The first one is forest fires that became rather frequent due to the construction of the Lidoga – Vanino highway. The other one is the road net itself that increased transportation and tourist impact on this territory.

The fires noticeably changed the Anui drainage area (Fig. 4). The biggest fire happened in 1998 and damaged 165 thousand hectares of forests in the Nanai district. According to the official data this fire damaged over 2 million hectares. In 1999 – 2003 minor fires also occurred in this area. Fires of 1998 – 2001 in the area under study caused significant alteration of the vegetation cover. Forest litter and the upper humus horizon were burnt in the vast areas, successions were changed. After 6 – 9 years regeneration of sparse larch, birch, aspen and shrub, moss and grass cover was observed there.

Catastrophic fires in July – October 1998 caused long and gradual (due to windless weather) contamination of other regions with combustion products (aerosols and oxides of carbon, nitrogen and sulfur). Thus, most of these products with autumn monsoon rains could have been washed out from the smoke and precipitated on the already burnt areas as well as in other regions far distant from them.

According to satellite images of GFMC (Global Fire Monitoring Center) much contamination of the Khabarovsk Krai territory (the Anui basin including) happens due to forest fires in the neighboring regions of Russia and China

Fires in 1998 damaged a vast Priamurje territory, including basins of small rivers of Chayatynskoe narrowing in the Amur valley from Bogorodskoe village to Nickolaevsk-on- Amur (Fig. 5). That is why in 2007 the field research was undertaken in the area of small rivers on the Amur right and left sides to the north of Bogorodskoe village (Fig. 1).

Fig. 4. The Anui Upper Reaches Impacted by Fire in 1998. Gorely-2 Stream Area Near its Mouth. (November 2006).

Fig. 5. 1998 Fire Traces on the Left Bank of the Amur at the Chayatynskoe Narrowing.

2.1.2. Research Objects and Methods

The objects of study were the rivers Bolshoi Ertookooli, Manoma and Anui and streams Zabyty, Gorely-1, Gorely-2, Zavalny, Kooptoorkoo and Elman. Under the Amur-Okhotsk Project water sampling and discharge measuring were carried out in these water objects in August and October 2006 and in October 2007. Water samples were also collected from the bog near Slavyanka village. Sampling stations are shown in Fig.6. Vegetation in the Zabyty and Gorely-2 valleys was completely burnt during the 1998 fires. In the Zavalny and Gorely-1 basins 50% of the area suffered ground fires, after which in 1999 gradual forest extinction took place. In the Bolshoi Ertookooli valley 1998-2001 fires damaged 15-20% of vegetation. In the Kooptoorkoo valley some traces of fires happened in the 1960-ies are still observed.

Water discharge in mountain rivers was measured in 2007 mostly on foot (Fig. 7). Measurements were performed with a hydrometric device GP-21M, serial number 1041, tested by the Khabarovsk Meteorological Center in August 2006. In the Anui and Manoma rivers water discharge was measured from the automobile bridge.

Water samples were taken from surface water horizons in the stream middle, when water content was low. Such water physical and chemical characteristics as temperature (t ºC) and pH were recorded.

Water samples were analyzed with standard hydrochemical methods [1, 2]. To describe different water components the following methods were applied:

- a complex method for water hardness (Ca^{2+}+Mg^{2+});
- titration for Ca^{+2};
- photometry for Si in the yellow form of molibdic silicic acid;
- titration with mercury salt for chlorides (Cl^{-});

- titration with photometry to follow for sulfates (SO_4^{2-});
- a flame photometry for Na^{+}+K^{+};
- a bi-chromatic method for dissolved organic carbon (DOC);
- inductively coupled plasma mass spectrometry (ICP-MS) for bulk content of iron and manganese.

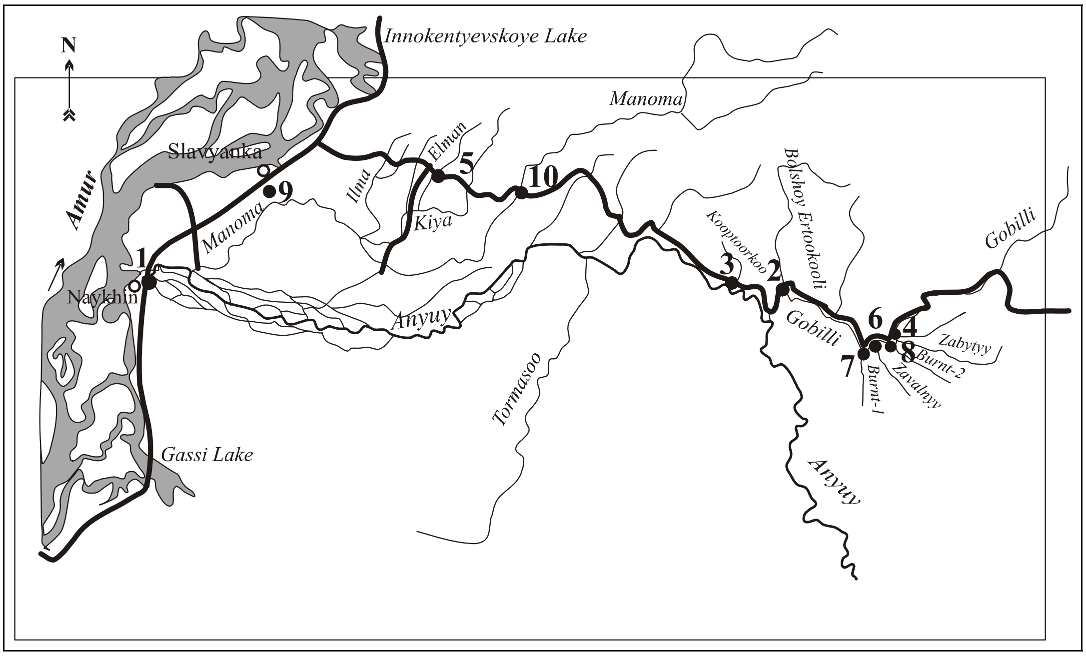

Fig. 6. Scheme of Hydrological Stations in the Anui River Basin (Numbers correspond to water sample numbers).

Fig. 7. The Anui Upper Reaches. Gorely-1 Stream mouth's reach (October 2006).

2.1.3. Results of the Anui Basin research

Hydrological Characteristics of Surface Water in July 2007

According to observation data from meteorological stations in Troitskoe and Solekool villages the background conditions in the Anui River Basin in 2007 were characterized in general with lower moisture that in 2006 (Fig. 2, 3, 8, 9; tables 2 and 11). Field works in 2006 were carried out in the period between the rainfalls and in 2007 water sampling and measurements were also done in conditions of low atmospheric moisture (September – the first half of October).

Table 11. Characteristics of Atmospheric Moistening in the Anui River Basin in 2006 and 2007 Warm Periods (Solekool meteorological station data)

Month	2006	2007	Mean in the observation period 1935-1965 [Handbook..., 2000]
	Total Precipitation, mm		
May	67	28	80
June	138	36	102
July	228	59	147
August	157	200	158
September	59	58	128
October	35	55	67
Total	685	437	682

Water discharge data for 2006 and 2007 are given in Table 12.

Table 12. Water discharge (m^3/sec) in the Anui Basin Rivers, 2006-2007

№	River - Station	August 2006	October 2006	October 2007
1	Zabyty - mouth	0.25	0.080	0.33
2	Gorely-2 - 100 m upper the bridge	0.19	0.079	0.097
3	Zavalny - 10 m lower the bridge	0.33	0.12	0.19
4	Gorely -1 - 100 m upper the bridge	0.11	0.042	0.072
5	Bolshoi Ertookooli - 30 m upper the bridge	9.19	4.52	6.05
6	Kooptoorkoo- bridge	1.14	0.40	0.76
7	Manoma - bridge	20.6	8.41	17.7
8	Elman - bridge	0.18	0.11	0.32
9	Anui - bridge	305.9	119.5	133.6

Hydrometric observations of two seasons showed that in August 2006 the total runoff of the rivers under study was 11% of the measured Anui runoff, in October 2006 – 12% and in October 2007 – 19%.

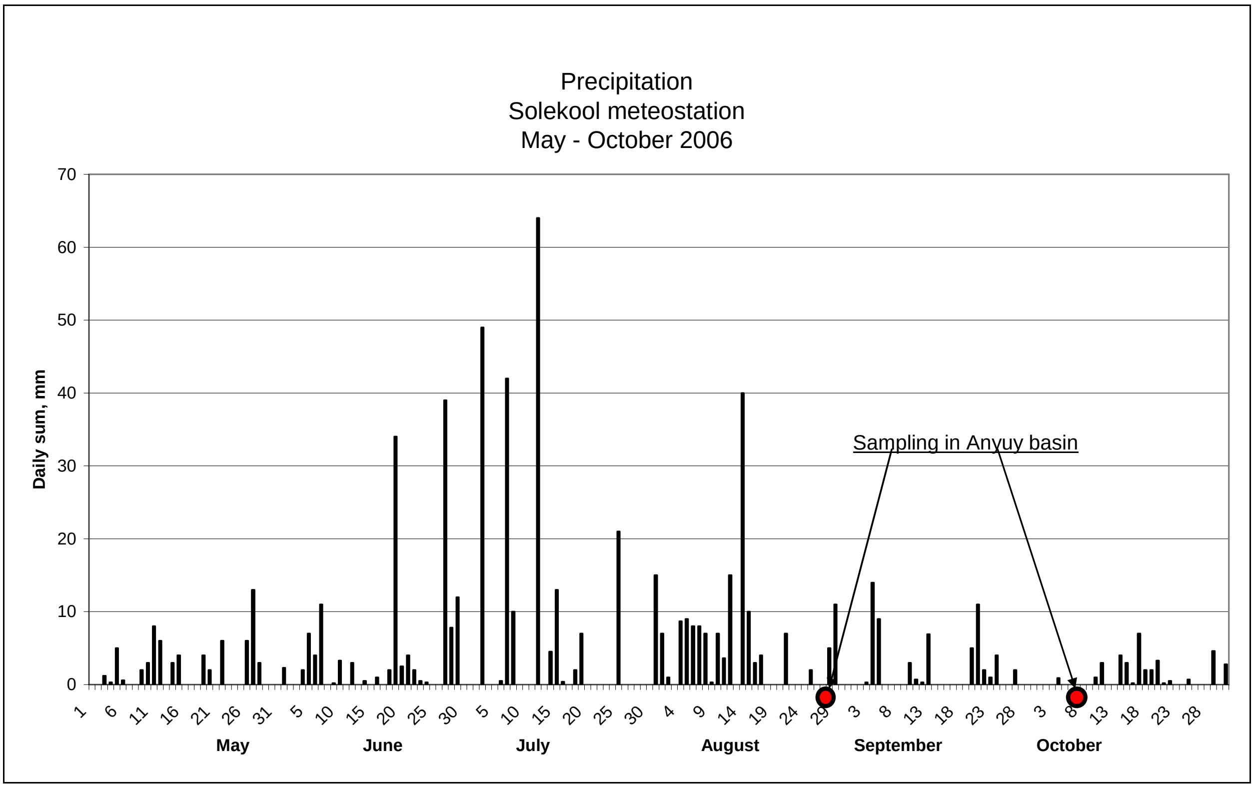

Fig. 8. Distribution of Daily Precipitation Sums within the Season at the Solekool Meteo-station in 2006.

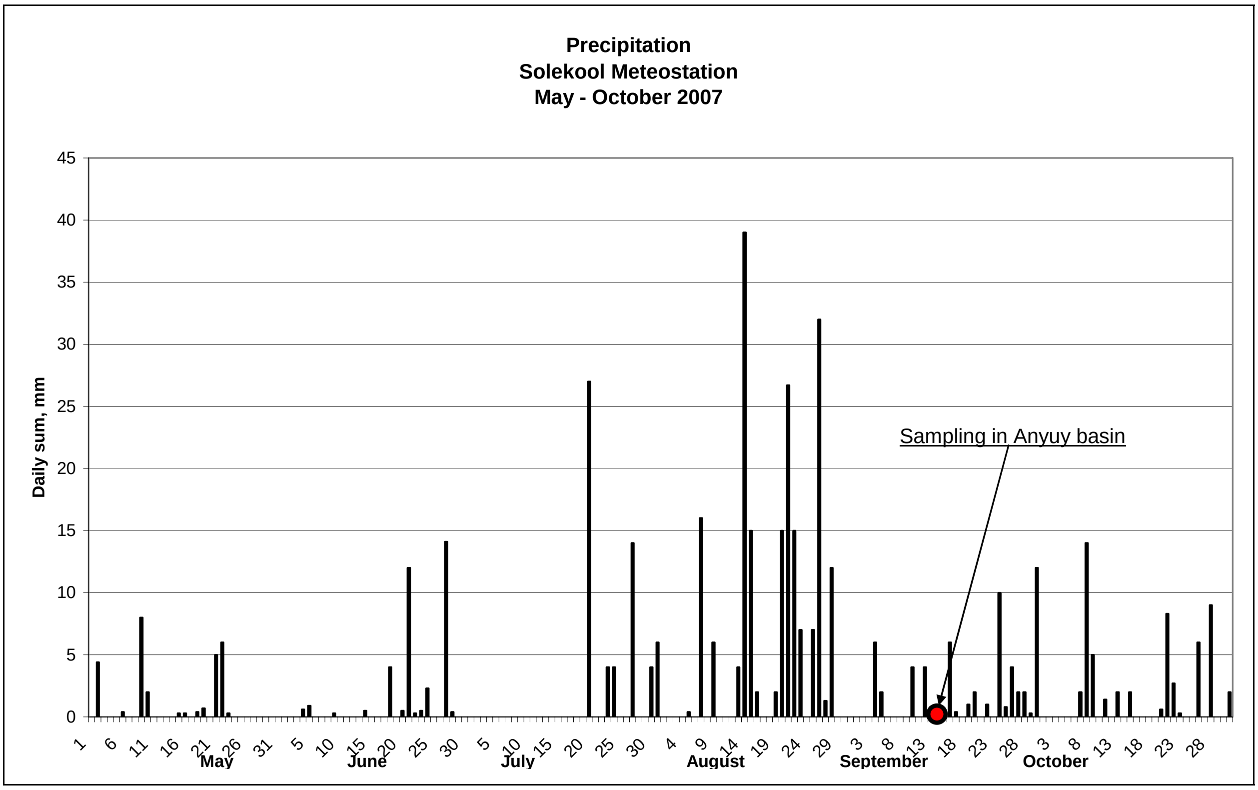

Fig. 9. Distribution of Daily Precipitation Sums within the Season at the Solekool meteo-station in 2007.

Hydrochemical Characteristics of Surface Water

Hydrochemical characteristics of surface water includes such parameters as pH values, main ion concentrations (Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}), silicon and iron compounds that belong to biogenic substances and values of main cation (Na^+/ K^+, Ca^{2+}/ Mg^{2+}) ratios in mg-equiv./dm^3. Table 13 presents these results.

Hydrogen indicator (pH) is an important characteristic of water quality. Its value in the rivers under study varies within the range 6.79-7.85 (August 2006), 6.34-7.59 (October 2006), 7.07-7.48 (October 2007).

The permissible concentration value of pH for water in the water objects with fishing capacity is determined as 6.5 – 8.5. The observed pH values did not exceed the permissible level. In three places (Bolshoi Ertookooli, Manoma, Anui) pH is as low as 6.34. Values of pH in waters of the Lower Amur fluctuate within 6.4 – 6.9 (these waters are ranked as pH neutral).

Cations mostly have the following succession Ca^{2+}>Mg^{2+}>Na^+>K^+ and seldom Mg^{2+}>Ca^{2+}>Na^+>K^+ (2 cases observed) (excluding Elman River, 2006).

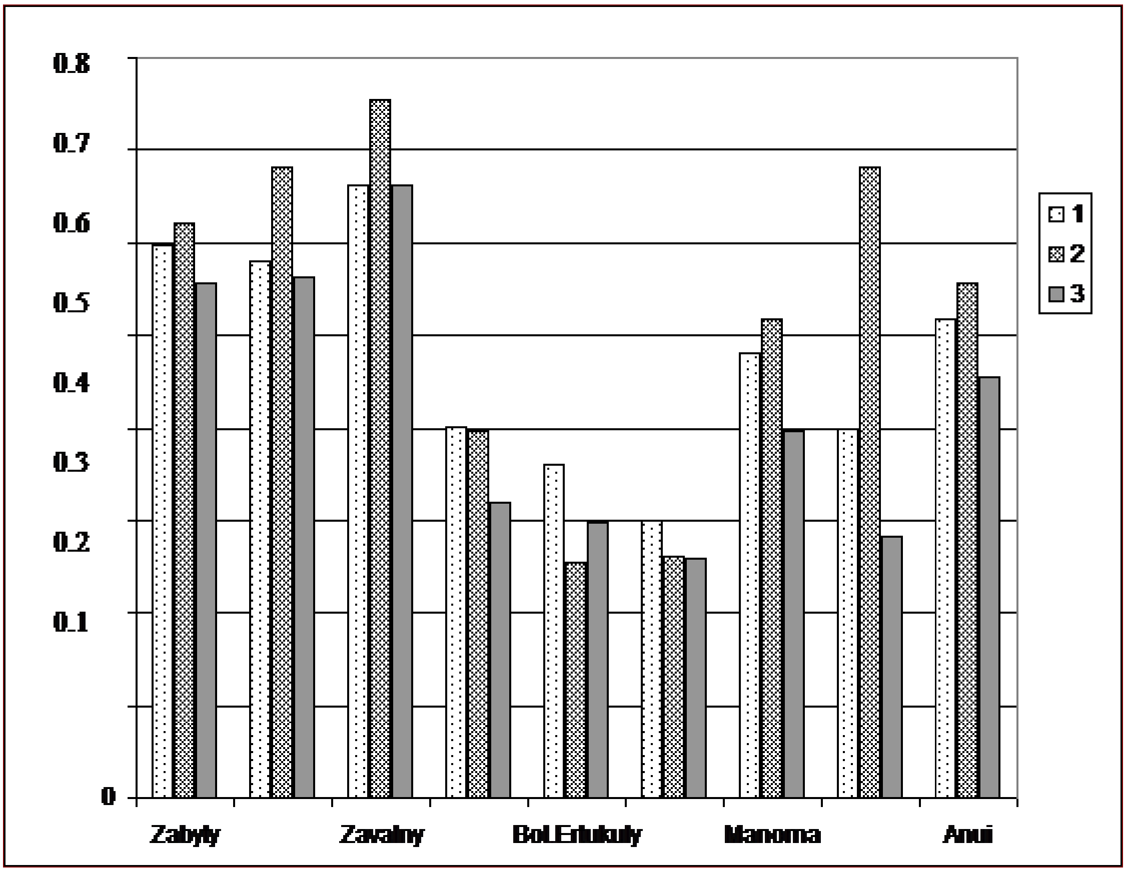

Fig.10. Water Hardness Data (mmol dm^{-3}) in August 2006 (1), October 2006 (2) and October 2007 (3).

Water hardness (Ca^{2+}+Mg^{2+}) 0.262-0.755 mmol dm^{-3} of equivalent (Fig. 10). Water in the studied water objects is ranked as soft. Minimal water hardness values were observed in the Bolshoi Ertookooli (09.10.2006) and its maximum values were found in Zavalny water. Calcium ion concentration fluctuated within the range 2.8 – 9.7 mg dm^{-3}.

The Ca^{2+} concentrations reveal noticeable seasonal fluctuations. When mineralization decreases (spring) calcium ions dominate. It can be explained with easy alkalization of soluble calcium salts from the surface soils and rocks. Magnesium ion content in the studied rivers was 1.0 – 4.9 mg dm^{-3}. Maximum Mg^{2+} values were registered in the Elman and minimum – in the

Kurtupku (09.10.2006). In the surface waters magnesium ion content noticeably varies and as a rule maximum values are observed in low water periods and minimum values – in time of floods.

The ratio Ca^{2+}/Mg^{2+} is the chief indicator of a metamorphosed water composition. In weakly mineralized natural waters the calcium ion is the chief component of the chemical composition, whereas the magnesium ion appears with metamorphization. The value of Ca^{2+}/Mg^{2+} ratio in waters under research was mostly 1-2 and agrees with the interval specific to weakly mineralized surface waters. Samples from Zabyty and Gorely-2 streams are the exclusion as the Ca^{2+}/Mg^{2+} ratio there was 3-4.

Natrium ion concentrations were 1.4 – 2.7 mg dm^{-3}. Physical and geographic conditions and geological specifics of the water object basins impact natrium ion concentrations in surface water.

Compared to natrium potassium is less mobile and has the tendency to be sorbed on the high-dispersed particles of soil, rocks, bottom sediments and caught by plants in the growth and nutrition processes. Its concentrations in surface waters are smaller than that of natrium. The content of K^+ in the studied rivers was 0.4 – 1.0 mg dm^{-3}. Na^+/K^+ ratio was 3-10.

Maximal levels of main ions in water most often occur in the period of summer low water and just before the river freezing, when rivers change their recharge for the ground-water type. Maximal levels of main ions in water are observed in spring, when rivers are recharged mostly from melting water [3]. In the 7-year period of observation main ion concentrations in river water varied in small ranges, sulfate ion being exclusion. Due to the atmospheric transport of sulfur dioxide from other Priamurje regions under fire and its further accumulation in the surface soil horizons sulfate ion content varied significantly. Two years after the fires (2000 and 2001) sulfate ion content exceeded 3.6 mg dm^{-3}, and in the recent two years it increased up to 4.1 mg/dm^3. Maximal sulfate ion content level (6.1 mg dm^{-3}) was observed in late autumn 2003 associated with heavy smoke in the Anui upper reaches and in river water in 2004 [3,4].

Sulfate ion content in the solution is limited by the comparatively low solubility of calcium sulfate. SO_4^{2-} content in surface waters has seasonal fluctuations. The most important factor to determine sulfate regime is the changing correlation between surface run-off and subsurface drainage. Economic activities in the water object significantly impact sulfate regime (in this case it is a pyrogenic factor). SO_4^{2-} concentrations in the studied rivers were 1.3 – 9.9 mg dm^{-3} (Fig.3). Usually SO_4^{2-} concentrations in the Amur River are within the range 1.3 – 7.7 mg dm^{-3}.

Chloride ion content in the studied rivers varied 0.1 – 1.0 mg dm^{-3}. Maximum values were observed in the Elman River (16.10.2007) and minimum values were registered in the streams Zabyty and Gorely-2 and the Manoma River (09.10.2006). In 2007 chloride ion content in water was higher than in 2006.

Silicon concentrations in slightly contaminated waters undergo seasonal fluctuations. The chief factors that determine silicon regime are the changing correlation between surface runoff and subsurface drainage, intensity of biological consumption of silicon by water organisms, development peculiarities of diatoms and their decomposition. Dissolved silicon concentrations in the surface waters of the Anui Basin varied 5.0 – 8.9 dm^{-3}. In the Amur River silicon concentrations fluctuate in the range of 0.1 – 7.0 mg dm^{-3} with the mean value 5.3 mg dm^{-3}.

Table 13 presents estimated data on the dissolved substance discharge in the Anui Basin. The input of Anui tributaries is not significant. Only the Manoma and Bolshoi Ertookooli contributed totally 2-4% (2006) and 6-12% (2007) of the Anui mineral substance discharge.

Seasonal dynamics of these components was not revealed.

Table 13. Chemical Composition of River Water in the Anui Basin (mg dm^{-3}) and Dissolved Matter Discharge (t day^{-1})

Date	pH	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}	Si	Fe	dis-charge*
Zabyty Stream										
27.08.2006	7.32	2.3	0.6	8.0	2.4	0.4	9.2	6.1	0.03	0.628
09.10.2006	7.29	2.6	0.6	8.8	2.2	0.1	8.3	6.0	0.02	0.197
16.10.2007	7.12	2.2	0.4	8.0	1.9	0.6	9.3	6.0	0.02	0.809
Gorely – 2 Stream										
27.08.2006	7.05	2.2	0.6	8.0	2.2	0.5	9.2	5.9	0.03	0.469
09.10.2006	7.02	2.5	0.5	9.2	2.7	0.1	9.9	6.0	0.02	0.211
16.10.2007	7.27	2.3	0.4	8.8	1.5	0.7	7.7	6.0	0.02	0.230
Zavalny Stream										
27.08.2006	7.19	1.5	1.0	8.0	3.2	0.3	9.0	5.2	0.03	0.805
09.10.2006	7.11	1.8	0.9	9.7	3.3	0.7	6.8	6.4	0.05	0.307
16.10.2007	7.35	1.4	0.6	8.8	2.7	0.6	7.1	5.5	0.03	0.438
Gorely – 1 Stream										
27.08.2006	6.79	1.7	0.8	4.4	2.2	0.4	6.1	5.7	0.04	0.203
09.10.2006	6.91	1.8	0.6	4.8	1.9	0.3	5.5	5.6	0.02	0.074
16.10.2007	7.27	1.6	0.5	4.4	1.2	0.7	6.2	5.7	0.02	0.125
Bolshoi Ertookooli – bridge										
27.08.2006	7.15	1.4	0.6	4.4	1.7	0.5	4.6	5.5	0.04	14.848
09.10.2006	6.44	1.7	0.7	2.8	1.4	0.3	3.1	5.3	0.06	5.975
16.10.2007	7.17	1.4	0.5	4.0	1.2	0.6	5.4	5.5	0.02	9.723
KooptoorkooRiver – bridge										
27.08.2006	6.93	1.4	0.6	3.2	1.7	0.4	5.0	5.6	0.04	1.762
09.10.2006	6.92	1.7	0.6	3.6	1.0	0.3	3.5	5.6	0.05	0.564
16.10.2007	7.08	1.7	0.6	3.2	1.2	0.6	3.0	5.7	0.02	1.050
Manoma River – bridge										
27.08.2006	6.93	1.4	0.6	3.2	1.7	0.4	5.0	5.6	0.04	37.377
09.10.2006	6.92	1.7	0.6	3.6	1.0	0.3	3.5	5.6	0.05	16.203
16.10.2007	7.08	1.7	0.6	3.2	1.2	0.6	3.0	5.7	0.02	29.122
Elman River - bridge										
27.08.2006	7.85	2.1	0.5	3.2	2.9	0.6	2.2	8.9	0.49	0.317
09.10.2006	7.59	2.7	0.8	5.6	4.9	0.6	1.3	8.7	0.46	0.235
16.10.2007	7.48	1.7	0.4	3.2	1.5	1.0	3.6	7.8	0.28	0.531
Anui River – bridge										
27.08.2006	7.15	1.8	0.6	6.4	2.4	0.5	5.9	5.7	0.42	615.814
09.10.2006	6.34	2.0	0.6	7.2	2.4	0.3	3.1	5.0	0.16	212.692
16.10.2007	7.07	1.4	0.5	6.0	1.9	0.7	6.0	5.4	0.18	252.792

Note: * – discharge is calculated without iron

Organic Matter

Landscape structure of the Anui Basin, dynamics and amount of precipitation, character of soils and anthropogenic factor impacts determine certain regularities of geochemical migration of organic matter (OM) and chemical elements (especially such hydrogenic elements as iron, manganese, etc.) in the area under studies.

The research undertaken in 2006 and 2007 showed that the studied rivers, which drain this area, had a high DOC content (Table 14).

Minimal DOC was found in water of the Bolshoi Ertookooli River and all the studied streams except for Gorely-1 and did not exceed 2.0 mg C dm^{-3} at average. It may be explained with a slow decomposition of the organic part of soil in close-to-permafrost conditions. The other reason might be the decrease of carbon discharge from the burnt areas, widely spread in the Anui Basin. High OM concentrations were registered in Manoma river (twice higher), Gorely-1 stream water and especially in the Elman stream, where DOC reached 9.0 mg C dm^{-3} and water colority was 145 degrees, which is typical for a bog river. Most high DOC values were registered in bog water (about 40.0 mg C dm^{-3} in 2006). In the rather dry autumn of 2007 DOC values were three times lower. In Anui OM concentrations were comparatively not high, i.e. 5.5 mg C dm^{-3} in 2006 and twice lower in 2007.

Table 14. Some Water Quality Indicators for the Anui Basin Rivers (2006 and 2007).

№	Sampling station	Colority, degrees			pH		DOC, mg C dm^{-3}		
		2006		2007	2006		2006		2007
		August	October	October	August	October	August	October	October
1	Anui R.	55	60	50	7.36	7.65	5.5	5.3	3.8
2	Bol. Ertookooli R.	15	5	22	7.30	6.50	2.0	2.0	2.2
3	KooptoorkooS.	10	<5	17	7.05	7.18	0.7	2.3	2.1
4	Zabyty S.	10	5	10	7.39	7.48	2.0	3.0	2.0
5	Elman S.	145	65	145	7.15	7.55	8.8	7.5	8.6
6	Zavalny S.	10	10	15	7.31	6.50	0.8	1.8	1.5
7	Gorely 1 S.	25	5	20	7.09	6.72	4.0	0.8	2.1
8	Gorely 2 S.	10	10	10	7.08	7.30	2.0	2.1	1.4
9	Bog (2 km south of Slavyanka)	430	156	185	5.82	6.50	39.5	12.0	12.6
10	Manoma R.	55	45	85	7.18	6.55	5.3	3.7	4.8

Iron and Manganese

Iron concentrations in the Anui Basin river waters in August 2006 varied in a wide range from scores to thousands of microgram per litre (Table 15).

Table 15. Manganese and Total Iron Concentrations in Water Samples from the Anui Basin Rivers in August 2006 and October 2007 (mcg dm^{-3})

№	Sampling station	Fe		Mn	
		August 2006	October 2007	August 2006	October 2007
1	Anui R.	443.16	294.93	14.77	0.04
2	Bolshoi Ertookooli R.	43.83	68.93	1.05	5.93
3	Kooptoorkoo S.	22.70	89.73	0.38	1.07
4	Zabyty S.	35.65	100.03	0.10	8.81
5	Elman S.	1291.30	592.09	18.36	8.92
6	Zavalny S.	100.52	104.20	2.74	9.58
7	Gorely 1 S.	64.20	53.97	1.32	1.20
8	Gorely 2 S.	59.27	98.23	0.57	1.83
9	Bog (Slavyanka)	4428.91	898.17	167.98	5.39
10	Manoma R.	165.09	187.29	4.77	0.62

Significant DOC values, exceeding the permissible concentration levels (PCL) for the fishing waters, were registered in the Elman River (12.9 PCL). It may be explained with a high content of organo-mineral complexes in its water. In the Anui water DOC were 4.4 PCL in summer 2006 and 1.5 times less in autumn 2007.

Maximal ion concentrations of 44.3 PCL were registered in bog water in summer 2006. In autumn 2007 iron concentrations in most rivers and streams (Zabyty, Kupturku, etc.) increased 2-4 times but did not exceed the permissible concentration level.

Dissolved manganese concentrations in the collected water samples were within the first dozen, rarely in scores of microgram per litre. Maximal concentrations were observed in summer 2006 in bog water (167.98 mcg md^{-3}) and in the Elman River (18.36 mcg md^{-3}).

2.2. Small Rivers of the Chayatynskoe Narrowing of the Amur Valley

2.2.1. Landscape Characteristics and Objects of Study

Field research in 2007 was also undertaken in the Chayatynskoe Narrowing, where the Amur Valley is pressed with mountain systems from the right and left sides. Left-side mountains are the Puer Mountain Ridge system with the maximal height of 887 m above the sea level. The rivers Ukhta, Flugovo, Bolshaya Tuchka, Bykova Pad drain Peur eastern end, covered with light-coniferous larch and secondary larch (birch, aspen) forests. In the upper mountain belt mountain pine is common. Amur right-bank area has minor mountain systems and single mountains (Kana mount) about 700 m above the sea level. Their slopes are covered with larch and deciduous forests, followed with dark-coniferous spruce and fir forests towards the mountain tops.

Fires in 1998 resulted in obvious alteration of the soil and vegetation cover. Forest letter and the upper humus horizon were burnt over vast areas. Big talus patches with sparse grown trees (birch, aspen) and dead wood appeared.

Field research, carried out on September 21-22, 2007, was focused on the following water objects: the rivers Bykova Pad, Bolshaya Tuchka, Melnitsa, Malaya Melnitsa, Ukhta and streams Dyugau, Flugovo and Korotky. The river net scheme is presented in Fig. 11 and a more precise image with fire sites can be found:
<http://maps.google.com/maps?t=h&hl=ru&ie=UTF8&ll=52.503668,140.3013&spn=0.340223,0.925598&z=10&om=0>

Water was sampled in natural and fire-impacted mountain streams (Table 16) from surface water horizons in the river middle in the low-water period. Based on landscape and hydrologic specifics the following correlation pairs can be selected for the further systematic observations: Ukhta and Bolshaya Tuchka, Flugovo and Bykova Pad, Dyugau and Korotky. These pairs of river basins have similar soil and geology structures, valley exposition, drainage area and stream gradient.

Water samples were collected and analyzed according to standard hydrochemical methods [1, 2]. To describe different water components the following methods were applied:

- a complex method for water hardness (Ca^{2+}+Mg^{2+});
- titration for Ca^{+2};
- photometry for Si in the yellow form of molibdic silicic acid;
- titration with mercury salt for chlorides (Cl^{-});
- titration with photometry to follow for sulfates (SO_4^{2-});
- a flame photometry for Na^{+}+K^{+};
- a bi-chromatic method for dissolved organic carbon (DOC);
- inductively coupled plasma mass spectrometry (ICP-MS) for bulk content of iron and manganese.

Besides, samples from three soil profiles were collected and now a being analyzed.

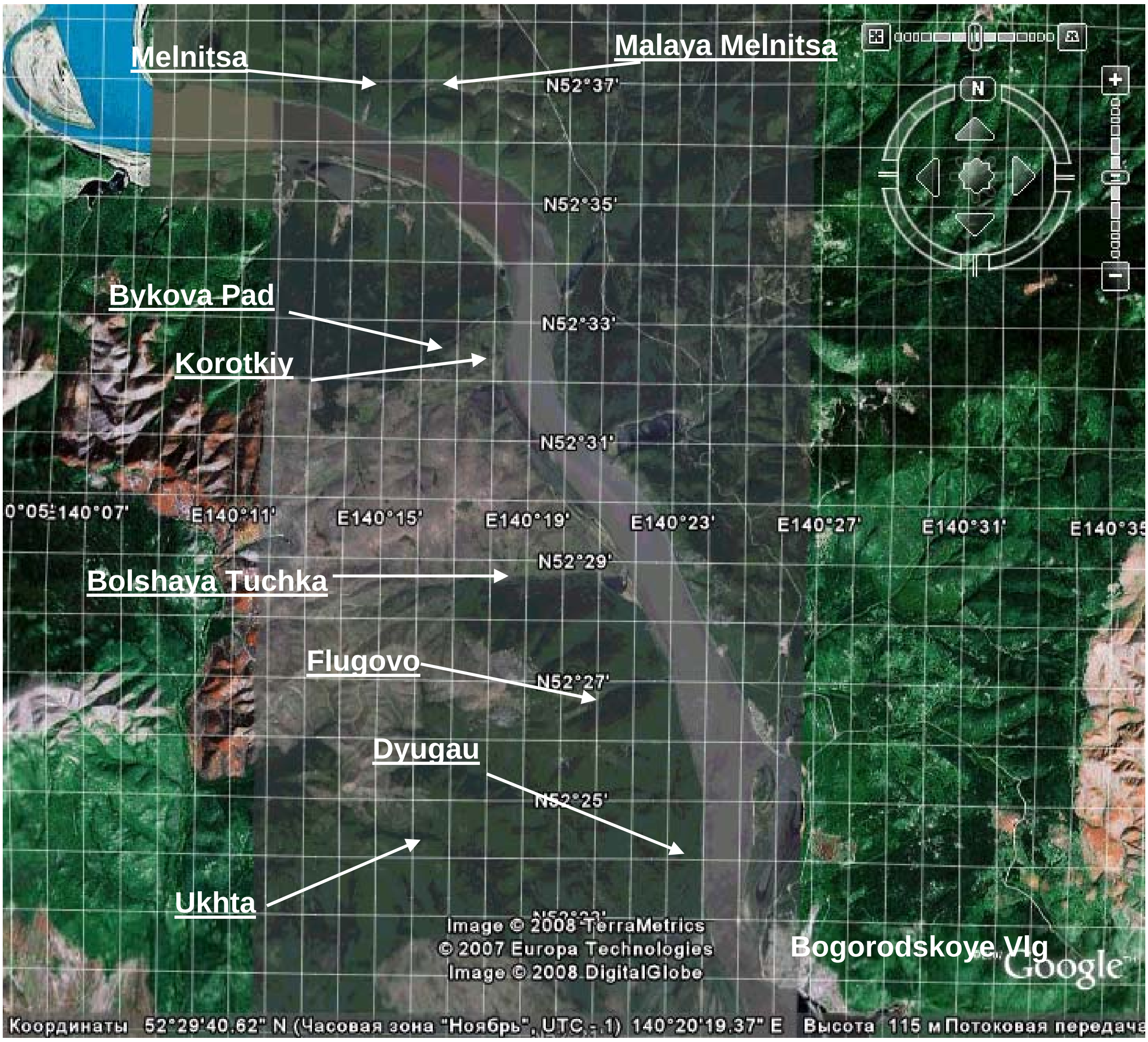

Fig. 11. Satellite image of the studied area in the Chayatynskoye Narrowing of the Amur.

2.2.2. Results of the Study of Small Rivers in the Chayatynskoe Narrowing of the Amur Valley

Hydrological and Hydrochemical Characteristics

Hydrometric data of small rivers in the Chayatynskoe Narrowing are given in Table 16.

Table 16. Hydrometric Characteristics of Small Rivers in the Chayatynskoe Narrowing, September 21-22, 2007.

№	River - Station	1998 fire damaged area, %	Valley exposition	Discharge, м^3/sec
1	Ukhta – 200 m upper the mouth	10	SE	0.23
2	Flugovo stream – mouth	0	E	0.035
3	Dyugau stream – mouth	10	E	0.002
4	Bolshaya Tuchka – mouth	60	E	0.37
5	Bykova Pad – 100 m upper the mouth	90	E	0.062
6	Korotky stream – 50 m upper the mouth	95	N	0.003
7	Melnitsa – mouth	0	SW	0.089
8	Malaya Melnitsa – 50 m upper the mouth	0	SW	0.048

Hydrochemical characteristics of surface water includes such parameters as pH values, main ion concentrations (Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}), silicon compounds that belong to biogenic substances and values of main cation (Na^+/ K^+, Ca^{2+}/ Mg^{2+}) ratios in mg-equiv dm^{-3}. These results are presented in Table 17.

Table 17. Water Chemical Composition in Rivers in the Chayatynskoe Narrowing (mg dm^{-3}), September 2007.

Sample №	River - Station	pH	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}	Si	M
1	Ukhta – 200 m upper the mouth	6.91	1.43	0.52	3.5	2.6	0.8	1.59	6.45	26.2
2	Flugovo stream – mouth	7.11	1.58	0.47	2.8	1.5	0.8	0.30	7.58	25.9
3	Dyugau stream – mouth	7.06	1.30	0.47	2.8	1.1	0.8	0.99	5.26	19.3
4	Bolshaya Tuchka – mouth	6.89	1.39	0.41	1.8	0.9	0.7	0.99	6.12	16.5
5	Bykova Pad – 100 m upper the mouth	6.95	1.45	0.45	1.5	1.0	0.8	1.12	6.29	17.8
6	Korotky stream – 50 m upper the mouth	6.86	1.70	0.52	1.9	1.5	0.9	0.13	7.90	22.4
7	Melnitsa – mouth	7.22	1.65	0.53	5.3	1.6	0.8	1.85	5.97	31.1
8	Malaya Melnitsa – 50 m upper the mouth	6.95	1.52	0.58	2.4	1.2	0.8	1.42	5.81	21.5

Note: M – mineralization was calculated as a sum of main ions (Na^+, K^+, Ca^{2+}, Mg^{2+}, HCO_3^-, Cl^-, SO_4^{2-}) and biogenic substances (Si, NH_4^+, NO_3^-, NO_2^-).

Hydrogen indicator (pH) is an important characteristic of water quality. Its value in the rivers varied within the range 6.91 – 7.22.

The permissible concentration value of pH for water in the water objects with fishing capacity is determined as 6.5 – 8.5. The observed pH values did not exceed the permissible level. Values of pH in waters of the Lower Amur fluctuate within 6.4 – 6.9. These waters are ranked as pH neutral.

Cations mostly have the following successions $Ca^{2+}>Mg^{2+}>Na^+>K^+$ and $Mg^{2+}>Ca^{2+}>Na^+>K^+$ (in three cases observed: Ukhta River, Bykova Pad and Korotky streams).

Water hardness ($Ca^{2+}+Mg^{2+}$) was 0.157-0.396 mmol $dm^{-3}$of equivalent. This water is characterized as soft.

Minimal water hardness values were observed in the Bykova Pad and Bolshaya Tuchka and its maximum values were found in the Ukhta River and Melnitsa Stream. Calcium ion concentration in the rivers fluctuated within the range 1.5 – 5.3 mg dm^{-3}. Magnesium ion concentrations were 0.9 – 2.6 mg dm^{-3}.

The ratio Ca^{2+}/Mg^{2+} is the chief indicator of a metamorphosed water composition. In weakly mineralized natural waters the calcium ion is the chief component of the chemical composition, whereas the magnesium ion appears with metamorphization. The value of Ca^{2+}/Mg^{2+} ratio in waters under research was 1-2 (agrees with the interval specific to weakly mineralized surface waters).

Natrium ion concentrations varied in a small range 1.30 – 1.7 mg dm^{-3}. K^+ concentrations were 0.41 – 0.58 mg dm^{-3}. Potassium is less mobile compared to natrium and can be sorbed on the fine particles of soil, rocks, and bottom sediments and caught by plants in the growth and nutrition processes. Na^+/K^+ ratio was 4-6.

Sulfate ion content in the solution is limited by the comparatively low solubility of calcium sulfate. SO_4^{2-} concentrations in the studied rivers were 0.13 – 1.85 mg dm^{-3}. Usually SO_4^{2-} concentrations in the Amur River are within the range 1.3 – 7.7 mg dm^{-3}.

Chloride ion content in the studied rivers varied 0.7 – 0.9 mg dm^{-3}.

Dissolved silicon concentrations ware 5.26 – 7.90 mg dm^{-3}. In the Amur River silicon concentrations fluctuate in the range of 0.1 – 7.0 mg/dm^3 with the mean value 5.3 mg dm^{-3}.

Table 18 and Fig. 12 present data on the discharge of dissolved mineral substances. Maximal volumes are discharged from the rivers Bolshaya Tuchka and Ukhta, and minimal volumes come from Dyugau and Korotky streams.

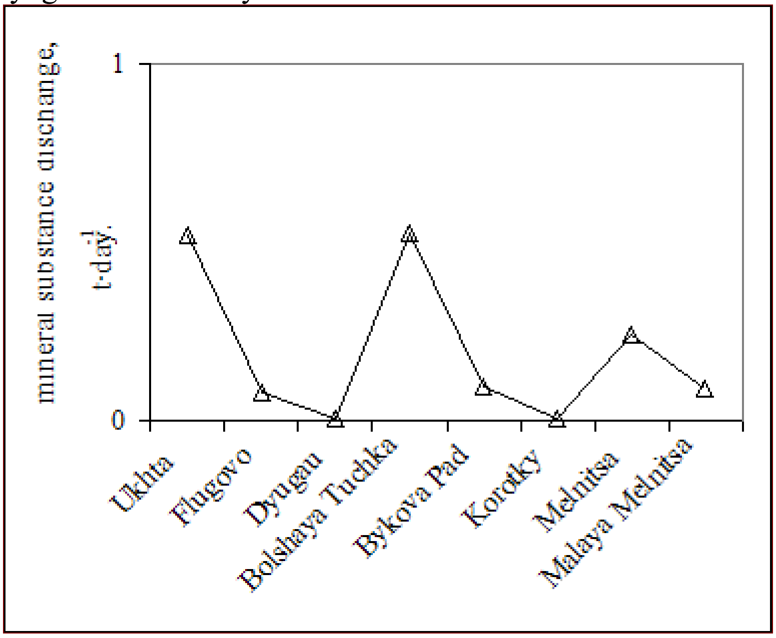

Fig. 12. Dissolved Mineral Substance Discharge in Small Rivers in the Chayatynskoe Narrowing, September 2007.

Table 18. Dissolved Mineral Substance Discharge in Small Rivers in the Chayatynskoe Narrowing (t day^{-1}), September 2007.

Sample №	River - Station	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}	Si	M
1	Ukhta – 200 m upper the mouth	0.028	0.010	0.070	0.052	0.016	0.032	0.128	0.521
2	Flugovo stream – mouth	0.005	0.001	0.008	0.005	0.002	0.001	0.023	0.078
3	Dyugau stream – mouth	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.003
4	Bolshaya Tuchka – mouth	0.044	0.013	0.058	0.029	0.022	0.032	0.196	0.527
5	Bykova Pad – 100 m upper the mouth	0.008	0.002	0.008	0.005	0.004	0.006	0.034	0.096
6	Korotky stream – 50 m upper the mouth	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.006
7	Melnitsa – mouth	0.013	0.004	0.041	0.012	0.006	0.014	0.046	0.239
8	Malaya Melnitsa – 50 m upper the mouth	0.006	0.002	0.010	0.005	0.003	0.006	0.024	0.089

Note: M – total discharge of mineral substances was calculated as a sum of discharge of main ions (Na^+, K^+, Ca^{2+}, Mg^{2+}, HCO_3^-, Cl^-, SO_4^{2-}) and biogenic substances (Si, NH_4^+, NO_3^-, NO_2^-).

Organic Matter

Dynamics and amount of precipitation, character of soils and anthropogenic factor impacts determine certain regularities of geochemical migration of organic matter (OM) and chemical elements (especially such hydrogenic elements as iron, manganese, etc.) in the area under studies.

The research revealed that DOC the rivers, which drain the area under study, varied in a noticeable range (Table 19).

Minimal DOC values were registered about 2.0 mg C dm^{-3} in the rivers Dyugau and Bykova Pad and the Korotky Stream (left Amur tributaries). These rivers, running through the foothills of the Puer Mountain Ridge, are short, have narrow valleys and small drainage area.

The highest OM concentrations between 7.0 and 8.5 mg C dm^{-3} were found in Ukhta, Flugovo and Bolshaya Tuchka river waters. Water colority there did not exceed 40 degrees. These rivers have a common divine (absolute height is over 800 m above the sea level), where dead wood and sparse growth of trees are widely spread due to the former fires. Podzol illuvial humus soils prevail here. These soils accumulate weakly decomposed OM. The transport of water-soluble organic carbon from these soils is seemed to be slowed down by the frost penetration into the soil. Soil cover specifics, significantly different from the right bank area of the Amur, could also determine OM discharge with these rivers. In the upper parts of the Puer mountain slopes (upper reaches of the rivers Ukhta, Flugovo and Bolshaya Tuchka and their tributaries) soils of the mountain taiga range, such as dry-peat podzols and podburs (especially under the mountain pine).

Table 19. Organic Matter Content in Small Streams in the Chayatynskoe Narrowing, September 2007.

Sampling №	Sampling station	Colority, degrees	pH	DOC mg C dm^{-3}
1.	Ukhta	40	6.91	6.7
2.	Flugovo stream	25	7.11	8.4
3.	Dyugau stream	30	7.06	2.1
4.	Bolshaya Tuchka	35	6.89	5.9
5.	Bykova Pad	25	6.95	1.8
6.	Korotky stream	40	6.84	2.2
7.	Melnitsa	65	7.22	7.5
8.	Malaya Melnitsa	35	6.95	8.2

In the right bank area of the Amur organic carbon concentrations are rather high. Maximal DOC values, 8 mg C dm^{-3} at average, were registered in the rivers Metlitsa and Malaya Metlitsa. Metlitsa waters have a high water colority of 65 degrees. Common soils within drainage area of these rivers are brown taiga soils with lots of rock debris. In the river upper reaches dry-peat podburs are widely spread. The accumulation of humus substance is also high in these soils as in the Amur left-bank area. Still, we suppose that the formation of water-soluble forms of organic carbon is more intensive here than in the left-bank area, owing to remoteness from the permafrost area and closeness to the sea.

OM content increase might be also caused by the decomposition products of fish, coming upstream for spawning.

Fig. 13 presents our estimates of organic matter discharge in the area of studies.

Maximal OM volumes, i.e. 0.378 tons of OM per day^{-1} were discharged into the Amur with Bolshaya Tuchka waters. Minimal values of 0.0011 tons of OM per day^{-1} were found in the Korotky Stream.

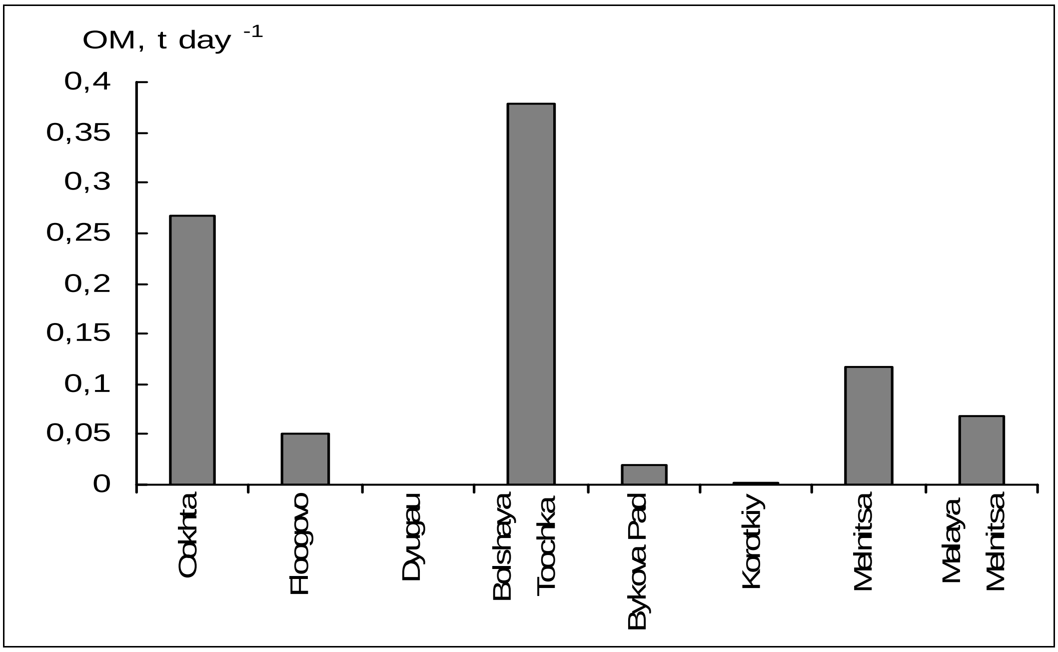

Fig. 13. Changes in Organic matter Discharge in Small Rivers in the Chayatynskoe Narrowing

Iron and Manganese

Iron concentrations in the studied rivers varied in the range from one to two hundred of microgram per litre (Table 20). Maximal ion concentrations exceeding the permissible concentration level were observed water of the Flugovo and Melnitsa rivers (2.1 PCL). Such concentration levels are characteristic for the Lower Amur waters.

Dissolved manganese concentrations in water samples were within the first dozen, rarely in scores of microgram per litre. Maximal concentrations were observed in Melnitsa River water (14.27 mcg md^{-3}).

Table 20. Manganese and Total Iron Concentrations in Samples of Water from Burnt and Non-burnt Rivers of the Lower Amur (mcg dm^{-3}).

Sample №	Sampling Station	Fe	Mn
1	Ukhta	119.38	2.71
2	Flugovo stream	213.57	10.20
3	Dyugau stream	98.30	3.19
4	Bolshaya Tuchka	99.51	2.69
5	Bykova Pad	110.82	2.63
6	Korotky stream	94.79	2.52
7	Melnitsa	206.14	14.27
8	Mal.Melnitsa	110.53	8.81

Conclusions

The chemical composition of waters in the Anui Basin rivers is formed under both natural and anthropogenic impacts, such as climate conditions, basin soil and geology specifics, correlation of surface run-off and subsurface drainage, economic activities in the given region. Even now 1998 catastrophic fire impact on soil chemical composition can be observed as causing increase of sulfate ion concentrations in the water objects

In spite of the fact that Anui Basin soils have a rather high reserve of organic carbon, the migration of water-soluble carbon forms into soils solutions and ground waters is much slowed down due to slow melting of permafrost (especially in the basins of rivers Gobbili, Tormasu and upper Anui). That is why DOC in the river mouth is relatively small. Low OM concentrations in fire-burnt areas seem to be associated with complete mineralization of organic matter in water, as well as incomplete recovery of the area after the fires (7-8 years). Thus, on carbon migration in water the assessment of fire impact needs more detailed (including other areas) and prolonged observations.

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