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II. EXECUTIVE SUMMARY

In the present scientific report, the results of research carried out according to the guidelines of the research program for the period of May 2001 – October 2001 are presented. The research object is water and sediment, both of coastal and deep zones, of the Issyk-Kul Lake. Mineralization of Gulf water of the Issyk-Kul eastern coast depends on the sweet water influence of running rivers with low water mineralization (Tyup, Dzergalan), i.e., on their drain volume.

Sediment formation of the Gulfs is a result of sedimentation of suspended substances such as solid drain of river basins, phytoplankton production, polluted wastewaters entrance and physical and chemical processes proceeding in the lake.

III. INTRODUCTION

Protection of water resources is one of the most important problems at present. Its solution is impossible without detailed research of reservoirs, in particular, or without studying reservoir sediment formation. Sediment accumulation and composition reflect the processes proceeding in a reservoir and during water collection.

Sediments are accumulators of substances arriving at the reservoir that participate actively in its circulation system and effect on the formation of qualitative water composition. The main goal of research conducted during the reported period is the study of regularities and peculiarities of sediment formation in the coastal zone of the Issyk-Kul Lake, chemical composition of the sediment and its influence on the ecological condition of the reservoir.

IV. EXPERIMENTAL SECTION

1. Research object

For the period reported, 3 expeditions for water and sediment sampling were organized in June, July and September 2001, respectively. The research objects were the water of the coastal lake and sediment of the Dzergalan, Tyup Gulfs, Grigorievka, Kuturga, Kurmenty, Ananievo, Rogataya, Shiroki, Chisty, Nikolaevski, Lipenka, and Irdyk estuaries. The sampling was carried out on profiles and at different depths. Column sediment samples in deep zones of the lake (on depths of 100-300 m) were also taken near Cholpon-Ata town, Kajisay village, the Barskaun, Tosor and Pokrovski Gulfs. Column tubes with lengths of 60 cm, were used for sediment core sampling. They were then divided into sections with lengths of 5 cm each.

Water analyses for the determination of major ions, biogenic compounds, pollutants and heavy metal contents were conducted. Sediment analyses for the determination of granulometric and chemical composition, organic substance and heavy metal contents were carried out.

In June and July, water and sediment samples of the lake Gulfs were taken. In September, study of the transfer of fluorescently tagged tracers in eastern Bay of the Cholpon-Ata Gulf near the "Goluboi Issyk-Kul" sanatorium was commenced. Preparation and tagging of tracers was conducted using the method worked out by Prof. B. Shteinman. The tagged fluorescent sediments (blue and yellow fluorescence) were placed on the bottom at 4 points at which exact coordinates were determined using GPS eMAP apparatus. Two of these points were at depths of 5m and 15 m near the "Goluboi Issyk-Kul" sanatorium and another two at the same depths near the "Ala-Too" resting house. After a definite period of time, 5 samples of water and sediment were taken at depths of 5-43 m at distances of 500-800 m from each original sampling site. During tracer study, 20 water samples for analysis and 20 sediment samples were taken.

As column sediment samples and fluorescent-tagged tracer samples were taken at the end of September. However, their analyses have not yet been finished. The results will therefore be included in the annual report.

2. Methods of analysis

The analysis of water samples was performed in accordance with modern analytical methods as described in the appropriate State Branch Standards (SBST) and summarized in Table 1.

The determinations of dissolved oxygen, temperature, pH, permanganate and dichromate oxidation, iron, copper, zinc, cyanides and detergents were carried out in accordance with the techniques described in Manual (1977, Unified methods, 1979). Bottom sediment was analyzed with use of the spectral methods (Spectral analysis, 1961).

Table 1. State Branch Standards for used analytical methods

Item	#SBST
Selection, storage and transportation of samples	24481-80 SBST
Bicarbonates	23446.1-85 SBST
Carbonates	23446.1-85 SBST
Sulfates	4389-72 SBST
Chlorides	4245-72 SBST
Magnesium	23268.5-78 SBST
Calcium	23268.5-78 SBST
Phosphates	18309-72 SBST
Nitrites	4192-82 SBST
Nitrates	18826-73 SBST
Ammonium	4192-82 SBST
Phenols	26449.1-85 SBST
Petroleum	26449.1-85 SBST
Major ions	26449.1-85 SBST
Biogenic compounds	26449.1-85 SBST

3. Control of experimental results

The analysis quality control was conducted by using a Certified State Sample (CSS) with a known content of analyzed components as follows: dry sample of CSS was dissolved in one liter of water and analyzed for the content of major ions and heavy metals. The results obtained were compared with the CSS values. It should be noted that analyses of CSS and samples were conducted simultaneously and under the same conditions. An operative control of the analytical quality, i.e., a relative deviation between an average value of results of two parallel measurements and a certified content of a component is calculated in accordance with the following equation:

$$d_z = \frac{\overline{C} - \hat{A}}{\hat{A}} \cdot 100\% \qquad (1)$$

where $\overline{C}$ is the average value of two parallel measurements, $\hat{A}$ is the certified content of a component and d_z is a relative deviation. The value of d_z must not exceed a half of the permissible relative deviations that are regulated by SBST of this analytical method for error standards at water analysis.

Maximum permissible deviation (d_{max}) of the average result from the certified value may be calculated as follows:

$$d_{max} = 0{,}0196 \frac{\hat{A}}{\sqrt{n}} x_{d_z} \qquad (2)$$

where n is the number of measurements, and x_{d_z} is a permissible relative average squared deviation of the measurement result regulated with the normative document (Standards of analysis accuracy, 1987).

Quality control of the experimental results was carried out using standard sample analysis. According to this technique, distilled water with an addition of a known amount of a determined component was used as a standard sample. Six repeated determinations were carried out with each standard sample. The analyses of the standards were performed after each new preparation of fresh reagents, the plotting of new calibration diagrams or after repairing any piece of equipment. After conducting several repeated measurements, the average systematic error ΔS_{syst} and the relative systematic one δS_{syst} were calculated in accordance with the equations taken from Doerfel (1969) and Alekseev and Korovin (1972).

Relative deviation of the results of major ions determination is within 0.339% for sulfates, 1.768% for magnesium and 2.033-3.765% for heavy metals; that is within permissible errors.

V. RESULTS AND DISCUSSIONS

1. Lake Water

Chemical composition and pollutant contents in surface water layer of the coastal zone of the eastern part of the north and east shores of the lake were determined for the reported period. Water sampling was conducted in gulfs of the northern coast (Grigorievka, Ananievo, Kuturga, Kurmenty), the western part of the lake (Tyup and Dzergalan) and 7 inlets of these gulfs.

Water mineralization in the coastal zone changes in a wide range (980-5,415 mg/dm^3) what can be explained by the sweet water influence of the river drain. The Tyup and Dzergalan Gulfs have the lowest water mineralization, which considerably increases with the moving in river estuaries. An average yearly drain for the period of 1998-2000 in estuaries is 240 mln. m^3 for the Tyup River and 536 mln. m^3 for the Dzergalan River. Chemical composition of gulf waters is summarized in Tables A-1, A-2.

Gulfs of the eastern part of the northern coast are open and their water can be easily mixed with the water from the deep part of the lake. Water mineralization of the Grigorievka and Ananievo Gulfs is 5,727-5,963 mg/dm^3, Kuturga and Kurmenty – 1,095-2,853 mg/dm^3, Rogataya Bay – 2,531-2,669 mg/dm^3 and Shirokaya Bay – 1,399-4,709 mg/dm^3. This difference among mineralization values can be explained by peculiarities of morphometrical structure. The Grigorievka and Ananievo Gulfs are wide and their water can be easily mixed with the water from the deep part of the lake. The Kuturga and Kurmenty Gulfs are narrow and long, with steep banks and are flooded beds of the Kuturga and Kurmenty Rivers. River drain influences on water mineralization of the gulfs. Shirokaya and Rogataya Bays are also closed but river drain does not run into them.

Chlorides, sulfates and sodium prevail in the ion composition of the water from the Grigorievka and Ananievo Gulfs. The water type corresponds to the deep water type of the lake. The Kuturga and Kurmenty Gulfs are characterized by water of sulfate-chloride-sodium composition, peculiar to the coastal zone of the lake. The same type of water is distinctive for the Shirokaya and Rogataya Bays.

It should be mentioned that mineralization and composition of the water from the Grigorievka and Ananievo Gulfs do not change from the coast to the open part of the lake at a distance of 6-8 km. In the Kuturga Gulf, water mineralization increases from 2,695

mg/dm^3 near the coast to 2,853 mg/dm^3 at a distance of 6 km. In the Kurmenty Gulf, it rises from 1095 mg/dm^3 to 2,686 mg/dm^3 at a distance of 7 km, and in the Shirokaya and Rogataya Bays, it does not change with the increase of distance from the coast.

Gulfs of the eastern coast of the lake (Tyup and Dzergalan) stretched out representing continuations of river estuaries containing numerous inlets and bays. The sweet water influence from running river waters is easy to track. The results of the analysis are summarized in Table A-2.

In the Dzergalan Gulf, water mineralization is 2,043 mg/dm^3 near the Dzergalan River estuary; it rises with the increase of distance from the coast and reaches 4,205 mg/dm^3 at a distance of 15 km. In the Tyup Gulf, the increase of water mineralization is also observed as one get further from the Tyup river estuary: salt sum is 2206.5 mg/dm^3 at a distance of 0.1 km and 4058.5 mg/dm^3 in 6 km, respectively.

Gulfs of the eastern part of the lake in contrast to the other lake gulfs have numerous inlets and bays that, in a geomorphologist' opinion, were formed as a result of flooding at the estuaries of river valleys. Some of them are stretched and deep and cut deep inland. The others are rather shallow and widely open into the lake. They were formed owing to the change of coastal line. Morphological peculiarities caused their original hydrologic and hydrochemical regime, different from the open part of the lake.

The Lipenka Bay has the lowest water mineralization (2,740-3,427 mg/dm^3) since this bay is flooded valley of the Lipenka River. Water from the Nikolaevski, Chisty and Shiroki inlet contains 4,652-5,415 mg/dm^3 of dissolved salts. These inlets are open and their water can be easily mixed with lake water.

Influence of rivers running into the Gulfs is diffused on definite distances and depths, therefore, water composition of the gulfs in river estuaries corresponds to ratios of major ions of river water. Thus, water composition of the Dzergalan and Tyup Gulfs in the estuaries of the Dzergalan and Tyup Rivers is sulfate-sodium-magnesium as a composition of river water. The chloride content in the Gulf waters is higher with the increase the distance from the coast, and water composition then becomes sulfate-chloride-sodium.

The highest content of biogenic elements in water was detected near the coast, while their concentrations decrease with the raise of distance from the coast (Tables A-3, A-4). The concentration of nitrite nitrogen is within 0.00-0.42 mg/dm^3. Its maximum values were found in the Rogataya Bay and Ananievo Gulf. The concentration of nitrate nitrogen is 0.00-0.20 mg/dm^3. The highest values are typical for the Kurmenty and Ananievo Gulfs. Ammonium presents in the concentrations of 0.00-0.10 mg/dm^3. Its maximum value was determined in the Kurmenty Gulf. MPC norms of nitrogen compounds are exceeded by 1.8-2.1 times in waters of the Ananievo and Kurmenty Gulfs. Contents of ammonium, nitrogen and phosphorus do not exceed MPC levels. Among the pollutants, the content of detergents in the coastal zone water is 0.00-0.024 mg/dm^3 and petroleum – 0.000-0.008 mg/dm^3 that do not exceed MPC values. Phenol concentration is 0.000-0.008 mg/dm^3 (MPC norm is 0.001 mg/dm^3). In the Grigorievka Gulf, phenol content exceeds MPC level by 8 times, in the Ananievo Gulf - 5 times, in the Shirokaya and Rogataya - 4 times and in the Kurmenty Gulf - 3 times.

Content of heavy metals in the coastal zone water is presented in Tables A-5, A-6.

In gulf waters, iron concentration is within 0.000-0.220 mg/dm^3. MPC level is exceeded 4.4 times in the Dzergalan Gulf, 3.2 times – in the Tyup Gulf and 1.2-1.6 times in the other gulfs and inlets. High copper concentration was found in the Grigorievka Gulf (0.001-0.007 mg/dm^3) that exceeds MPC values 7 times. In the other sampling locations, copper is absent in most cases.

Zinc concentration in the gulf waters is 0.000-0.011 mg/dm^3 which is lower than MPC norms. Cadmium presence is found in isolated samples; its concentrations are lower than MPC level.

Concentration of tin in water is 0.000-0.035 mg/dm^3. MPC value is exceeded by 2-35 times. Arsenic concentration in the gulf waters is 0.000-0.060 mg/dm^3; its maximum value exceeds MPC level by 6 times and was discovered in the Grigorievka Gulf. In the Ananievo Gulf water, arsenic content is higher than MPC norms by 1.3-2.6, in the Kuturga Gulf – 1.1-1.6 times.

High tin concentrations should be mentioned in Gulf waters of the eastern coast: in the Dzergalan Gulf, MPC level is exceeded by 34 times, in the Irdyk inlet – by 35 times, in the Shiroki and Nikolaevski inlets – by 21 times. In the northern gulfs: in the Kurmenty Gulf – 30 times, in the Grigorievka Gulf – 13 times, in the Ananievo Gulf – 26 times, in the Kuturga Gulf – 17 times, in the Shirokaya Bay – 17 times, and the Rogataya Bay – 20 times. But tin was not discovered in the Dzergalan Gulf at a distance of 0.01 km from the coast. Therefore, the littoral zone of the eastern part of the northern coast and eastern coast of the lake is found to be influenced by large anthropogenic loading. This is confirmed by the presence of high concentrations of nitrate nitrogen, phenol and heavy metals, especially tin and arsenic.

The most polluted gulfs are the Grigorievka, Kurmenty, Tyup and Dzergalan ones.

2. Composition of lake sediment

Suspended substances and particles of mountainous rocks of water collecting basins that arrive in the lake with river drain and temporary streams are exposed to the influence of in-reservoir processes. They are exposed to hydraulic grading according to size, settle and form plots with different types of sediment characterized by definite water-physical properties, granulometric and chemical composition (Palamarchuk, 1972).

A peculiar role of sediment in the reservoir is determined by its composition and the following properties:

- to deliver organic substances and ions of phosphate, ammonium, iron and silica into the water;
- to purify water from phenols and naphtoles by physico-chemical and biological binding;
- to absorb many detergents;
- to absorb ions of heavy metals.

Knowledge of the modern condition of sediment gives us an opportunity to evaluate its influence on the water sphere.

Research results (Tables A-7, A-8) show sediment of the coastal zone of the Issyk-Kul Lake is mainly presented by dust and silt particles with a diameter of 0.25-0.01 mm and 0.01-0.001 mm, respectively. The content of dust particles is 5.1-83.3%. The highest dust content is typical for the Irdyk and Lipenka Bays and the lowest dust content is found in the Grigorievka Gulf. The thickness of the dust layer at the Issyk-Kul bottom varies due to the bottom relief of the lake bowl, quantity and granulometric composition of sediment material.

Coarse sand particles are prevalent in sediment of the Irdyk inlet (88.2%) and Ananievo Gulf (79.2%). Silt particles are concentrated in sediment of the Kurmenty Gulf (66.7%) and Tyup Gulf (54.2%). The highest clay content is found in the Tyup Gulf sediment (23.2%).

Sediment taken at different depths has various granulometric compositions within the same gulf. Thus, in the Dzergalan Gulf, sand content increases from 0.2 to 3.6 % with the increase of deposition depth, and dust particle contents also rise from 60.3 to 83.2% at a depth of 30 m and 82.5% at a depth of 35 m. Silt particles accumulate to 43.2% at a depth of 27 m and their content then decreases. For clay, a tendency of content decrease is typical with the decrease of deposition depth of the sediment. Although in the Tyup Gulf, clay content in sediment abruptly increases from 2.4 to 23.2 % with the increase of deposition depth.

Narrow, stretched on flooded river beds, the Tyup and Kurmenty Gulfs and Nikolaevski inlet have the highest content of clay particles in their sediment than the Grigorievka, Ananievo, Kuturga and Dzergalan Gulfs which are open into the lake. On the contrary, sand and silt sand prevail in the sediment of open gulfs. This difference is caused by the decrease of stream rates in closed gulfs that promotes the sedimentation process. General regularities of formation and distribution of sediment of the coastal zone of the Issyk-Kul Lake are the following ones:

- process of silt accumulation is observed on the prevalent part of the lake bottom (depths of no more than 60 m);
- silt with predomination of sand are formed in the shallow parts of the gulfs which are open to the lake;
- grey silt with predomination of clay is mainly formed in gulfs that appeared after the flooding of river estuaries.

Sediment as a heterogeneous system consists of particles with different sizes whose presence is a result of sedimentation of substances arriving from various sources. Density and water capacity of sediment influencing the rate of chemical reactions and processes of physico-chemical exchange depend on their granulometric composition (Kudrin V.P., 1960).

Chemical properties of sediment (the capacity for chemical binding, destruction and other transformations of substances arriving with the sediment) are caused by the chemical composition of its mineral part and the qualitative composition of organic substances.

Chemical composition of sediment from the lake Gulfs is presented in Tables A-9, A-10. Sediment mineralization of the gulfs along the northern coast is: the Grigorievka Gulf – 29.4-175.3 g/kg, Ananievo Gulf – 98.9-205.0 g/kg, Kuturga Gulf – 90.4-140.2 g/kg, Kurmenty Gulf – 96.3-219.7 g/kg, Shirokaya Bay – 122.2-199.0 g/kg, Rogataya Bay – 132.7-186.0 g/kg. Sediment of the shallow zone (with a depth less than 3 m) contains 29.4-98.9 g/kg dissolved salts. Sediment mineralization increases from 121.4 till 219.7 g/kg with the increase of deposition depth. Sediment composition in the shallow part of the Grigorievka Gulf is sulfate-chloride-magnesium-calcium. Sediment of other gulfs has a sulfate-chloride-sodium-magnesium composition that corresponds to the ratio of major ions in the lake water.

Gulfs of the eastern coast that are greatly influenced by the river drain are characterized by a low content of salts in sediment. Sediment mineralization of the Dzergalan Gulf is 64.7-127.5 g/kg, Tyup Gulf – 109.9-165.6 g/kg, Irdyk Bay – 32.6-43.5 g/kg, Lipenka Bay – 70.6-93.1 g/kg, Shiroki inlet – 133.9-175.4 g/kg, Nikolaevski inlet – 144.6-194.5 g/kg, Chisty inlet – 128.9-178.9 g/kg.

Sediment of the Dzergalan Gulf has the lowest content of salts and is characterized by sulfate-chloride-magnesium-calcium-sodium composition. Sediment of other gulfs has a sulfate-chloride-sodium-magnesium composition. The tendency of salt content increase is observed with the increase of the sediment deposition depth.

Concentrations of organic substances in sediment of the Issyk-Kul coastal zone are summarized in Tables A-11, A-12. The content of organic matter in sediment that was determined as a weight loss after calcification changes from 0.2% (the Irdyk Bay) to 27.7% (the Chisty inlet). Its average meaning in the coastal zone is 12%, in the eastern coast 10.8% and in the eastern part of northern coast – 13.2%. The highest values were discovered in the Ananievo Gulf and Nikolaevski inlet. Regions with high contents of organic substances (26.6-27.2%) are situated in areas where the highest water flora is spread. Sediment that is situated near the shore at a depth of 1-2 m has a lower value of organic substance content (0.2-3.1%).

Moisture content of sediment changes in wide range from 29.1 to 75.1%. The highest values of moisture content are typical for sediment along the eastern coast: 62.2-79.3% in the Irdyk Bay and 74.5-85.1% in the Tyup Gulf. Moisture content of the northern coast sediment is lower (34.2-70.5%). In the Kurmenty Gulf, Shirokaya and Rogataya Bays, moisture content of sediment is 36.1-49.9% (Tables A-11 and A-12).

Sediment is the main accumulator of pollutants in the lake. It is conductive to water self-refining, accumulates different chemical elements arriving in the reservoir from the water-collected surface of the hollow and with wastewaters of industrial plants, rest houses and arable lands. Results of spectral analysis of sediment show that metal concentrations in sediment can be put in regression order: Si > Ca > Al > Fe > Ti > Mn > Sr > Ba > Zr > Zn > Li > Ni > Cu > Pb > Co > Sn (Reports for 1999-2000). Sediment is characterized by high concentrations of alkaline elements (calcium, strontium and barium) that show evidence of carbonate formation processes typical to the lake. Prevalence of silica, aluminium and iron in sediment compositions confirms the terrigenic character of the lake sediment.

Zinc and copper have the largest index of metal concentration in sediment (2.74 and 2.70, respectively). Lead, calcium, zirconium, cobalt and barium have a value of $K_c>1$. $K_c=1$ which is typical for chromium, lithium and tin. Nickel, titanium, aluminium, silica and iron have a value of $K_c<1$. They are weakly accumulated by sediment owing to their low chemical activity in natural conditions of the Issyk-Kul Lake and are partly assimilated by phytoplankton.

In addition to spectral analysis, heavy metal concentrations were determined using AA-2 apparatus (Tables A-13, A-14). Lead, cadmium, copper and zinc contents were determined in the samples studied. Cadmium is absent in all samples of sediment of the northern coast gulfs. Lead content is 1.15-10.40 mg/kg. Its highest concentrations are typical for the Grigorievka Gulf (4.70-10.40 mg/kg) and the lowest – for the Kurmenty Gulf (2.42-6.48 mg/kg). Lead concentrations in the Ananievo Gulf sediment is 1.15-6.35 mg/kg, Kuturga Gulf – 2.37-5.15 mg/kg, Shirokaya Bay – 3.61-9.88 mg/kg, Rogataya Bay – 3.00-7.10 mg/kg. Lead concentration in the sediment of the eastern coast gulfs is between 7.20-26.40 mg/kg; maximum concentrations are found in the sediment of the Dzergalan Gulf (9.50-26.40 mg/kg). Lead content is 7.20-16.20 mg/kg in the sediment of the Tyup Gulf, 7.40-17.80 mg/kg of the Irdyk Bay, 17.20-18.10 mg/kg for the Lipenka Bay, 20.20-23.10 mg/kg for the Shiroki inlet, 16.10-18.70 mg/kg for the Nikolaevski inlet, and 16.60-19.10 mg/kg for the Chisty inlet. Sediment of the eastern coast contains lead in 2.3 times more than sediment of the northern one.

Copper content is 0.73-7.00 mg/kg in sediment of the northern coast. Copper concentration is within 0.79-6.20 mg/kg in the Grigorievka Gulf sediment, 0.73-6.58 mg/kg in the Ananievo Gulf, 4.81-6.21 mg/kg in the Kuturga Gulf, 2.16-7.00 mg/kg in the Kurmenty Gulf, 0.73-2.08 mg/kg in the Shirokaya Bay, and 3.95-6.22 mg/kg in the Rogataya Bay. Maximum copper concentration was discovered in the Kurmenty Gulf, while minimum copper concentration was found as in the Shirokaya Bay. Copper content is 2.20-26.80 mg/kg in the eastern coast gulf sediment. Maximum value was found in the

Dzergalan Gulf sediment (8.90-26.80 mg/kg). Copper concentration is 2.20-11.40 mg/kg in the Tyup Gulf sediment, 3.51-12.20 mg/kg in the Irdyk Bay, 11.97-16.20 mg/kg in the Lipenka Bay, 8.60-12.10 mg/kg in the Shiroki inlet, 11.90-15.10 mg/kg in the Nikolaevski inlet and 12.00-19.96 mg/kg in the Chisty inlet. Copper concentration in sediment of the eastern coast exceeds the copper content of the northern coast sediment by 2 times. Definite regularity in copper distribution according to the sediment deposition depth was not observed.

Zinc concentration in the sediment of the northern coast is 0.00-13.95 mg/kg. Zinc is absent in the sediment of the Rogataya Bay. Its maximum value was discovered in the Kurmenty Gulf: 1.50 mg/kg at a depth of 6 m and 13.95 mg/kg at a depth of 27 m. Zinc content is 0.49-4.34 mg/kg in the Grigorievka Gulf sediment, 1.50-2.14 mg/kg in the Ananievo Gulf, 0.65-4.15 mg/kg in the Kuturga Gulf and 1.05-5.19 mg/kg in the Shirokaya Bay. Zinc is absent in sediment of the eastern coast.

Cadmium was not discovered in sediment samples of the northern and eastert coasts.

The research of the pollution level of the Issyk-Kul sediment by heavy metals deals with importance of this reservoir as a rest and tourism zone and the anthropogenic load connected with this activity.

The uneven distribution of heavy metals in sediment is typical for the coastal zone of the lake. The highest content of microelements is typical for lake parts where wastewaters are discharged into them: gulfs of the southern coast and estuary zones of gulfs formed after the flood of rivers (Dzergalan and Tyup Rivers). The character of vertical distribution of heavy metals according to sediment deposition depth deals with their concentrations but exact regularity was not observed. The most polluted sediments by heavy metals are in the Dzergalan Gulf, Lipenka Bay and Chisty inlet.

VI. POLLUTANT LOADING ON THE LAKE

Human activity strongly affects the formation of the composition of the Issyk-Kul lake sediment. Different substances of anthropogenic origin arrive at the lake with wastewaters, accumulate in sediment and influence the qualitative composition of water.

Formation, accumulation character and composition of sediment reflect the totality of the processes proceeding in the reservoir and water-collected surface of the Issyk-Kul basin. Sediment accumulates arriving pollutants and participates in their circulation. For determination of the level of lake water pollution, the maximum permissible concentration (MPC) for separate types of pollutants and heavy metals are used. MPC values are absent for reservoir sediments, therefore, background contents of heavy metals in suspended substances arriving in the lake with river water are determined.

For evaluation of anthropogenic components in sediment, the ratio of heavy metal contents in coastal zone sediment C_i at the background value C_b was used. Pollution level is evaluated as the sum index of pollution (SIP) as follows:

$$PI = \sum K_c \cdot n \tag{3}$$

$$K_c = C_i / C_b \tag{4}$$

where C_i and C_b are concentration of the "i" element in sediment and its background value and "n" is the number of summing elements.

For the pollution index of the sediment, the following gradations were determined (Brekhovskikh V.F., 2001):

minimum pollution	0-10,
medium	11-15,
high	>15.

Background values of heavy metals were determined by their contents in suspended substances arriving in the lake with river drainage. Heavy metal concentrations were determined by the spectral method in suspended substances of the Toruaigyr, Cholpon-Ata, Tyup, Dzergalan and Ton Rivers (Table A-15).

Values of background concentrations of toxic metals are: 3.0 mg/kg for copper, 7.7 mg/kg for zinc, 5.6 mg/kg for lead, 0.3 mg/kg for cadmium, 0.2 mg/kg for tin and 0.00 mg/kg for arsenic. According to this data, K_c and PI were calculated (Table A-16).

Pollution level for sediment along the coastal zone of the lake was determined for 6 important elements: Cu, Zn, Pb, Sn, Cd, As and is 2.10 (the Ananievo Gulf) – 11.49 (the Akchiya Gulf). The Issyk-Kul sediment has a minimum pollution in accordance with the gradation mentioned above. The exception is sediment of the Akchiya Gulf which has PI=11.49 that corresponds to the medium pollution level.

The purest regions of the coastal zone are gulfs of the northern coast (Ananievo and Kuturga Gulfs and Rogataya and Shirokaya Bays). The most polluted ones are gulfs of the southern coast (Akchiya and Koltsovka) and eastern coast (Dzergalan and Shiroki). Average values of heavy metal (Cd, Zn, Pb) concentrations in sediment of single gulfs of the northern coast are lower than the background concentrations. Background excess was discovered for Pb, Cu and Zn in the southern (Akchiya, Koltsovka, Ton, Akterek) and eastern (Dzergalan, Chisty, Shiroki, Lipenka) gulfs of the lake. Low concentrations of heavy metals in the Issyk-Kul sediment show evidence that the sediment cannot be considered as a source of secondary pollution of the lake at present.

Literature on the geology of rock precipitation of the Issyk-Kul hollow was used for clarifying the geochemistry of heavy metals in the Issyk-Kul sediment (Osmonbetov K.O., 1999, Tursungaziev B.T., 1998). The geological structure of the hollow is very complicated. Complexes of rocks from before the Paleozoic era until the Quaternary era were developed here. Protherozoic and Paleozoic eras are presented by metamorphosis and precipitation of the rocks. Mezokainozoic era is presented by the Jura sediment and Quaternary deposits.

Molybdenum and tungsten are widespread in the precipitation rocks of the Kungei Ala-Too (the northern coast of the lake) and lead – in the region of the Tyup-Dzergalan zone. Precipitation rocks of the Terskei Ala-Too (the southern coast of the lake) contain zinc, lead and tin, in rocks of the Barskaun River upper course – lead and zinc and of the Chon-Kyzyl-Su River – tin.

Lead is widespread in composed rocks of the western part of the lake.

Heavy metal contents in the Issyk-Kul precipitation rocks are (g/m^3):

cadmium -	0.020-0.090
tin -	0.004-0.070
lead -	0.007-0.080
tungsten -	0.144-0.360
thorium -	0.090-0.250
bismuth -	0.007-0.015

Heavy metal concentrations are the same for lead, cadmium and tin (0.002-0.003 mg/kg) in the composition of the precipitation rocks, running river water and the coastal zone of the lake. The lead content is higher by 2-5 times in products of rock erosion than in the initial rock itself (Lubchenko M.J., 1987). As a result, lead concentration reaches 5.6

mg/kg in suspended substances of river drainage and 0.002 mg/kg – in the precipitation rocks (see Table A-16).

Copper and zinc concentrations in the lake sediment do not exceed the contents of these elements in the precipitation rocks, and we discovered that the contents of lead, cadmium and tin are higher by hundreds of times in sediment than in complicated rocks. Accumulation of these metals in sediment is caused by their high migration ability and by sorption from water by clay particles of sediment (Tarnovski, 1980).

The causes of high concentrations of copper, zinc, lead and tin in the sediment of the southern coast of the lake have not been clarified yet. Vertical column samples of the southern coast sediment are being analyzed. This material will be included in the annual report after sample analysis completion and result processing.

VII. CONCLUSIONS

1. Water mineralization in the coastal zone changes from 980 to 5,415 mg/dm^3 that can be explained by the sweeting influence of the river drain. The lowest water mineralization is typical for the Tyup and Dzergalan Gulfs. It considerably increases toward river estuaries. Gulfs of the northern coast (Grigorievka, Ananievo, Kuturga) are open and their water can be easily mixed with waters from the deep zone of the lake, therefore, salt content in this water is higher in comparison to the gulfs of the eastern coast. The ratio of major ions of gulf waters along the northern coast corresponds to water composition of the deep zone of the lake, while the gulfs of the eastern coast correspond to the coastal zone that has sulfate-chloride-sodium composition.
2. Among the pollutants, the concentration of nitrate nitrogen exceeds MPC values by 1.8-2.1 times in the Ananievo and Kurmenty Gulfs. Phenol content is 8 MPC in the Grigorievka Gulf water, 5 MPC in the Ananievo and 3 MPC in the Kurmenty gulfs.

   Among heavy metals, copper concentration exceeds MPC level by 7 times in the Grigorievka Gulf water, tin content by 34 times in the Dzergalan Gulf, 23 times in the Tyup Gulf and 21 times in the Shiroki and Nikolaevski inlets.

   High arsenic concentrations were discovered in the Grigorievka Gulf water (6 MPC), Ananievo Gulf (1.3-2.6 MPC) and Kuturga Gulf (1.1-1.6 MPC).

   Zinc and cadmium contents in water are lower than MPC values.

   The littoral zone of the northern and eastern coasts of the lake experienced a large anthropogenic load that is confirmed by high concentrations of nitrate nitrogen, phenols and heavy metals in water. The most polluted regions are the Grigorievka, Kurmenty, Tyup and Dzergalan Gulfs.
3. Sediments of the gulfs studied are mainly dust and silt particles. Dust particle content is 5.1-83.3%. Coarse sand particles are typical for the Irdyk Bay and Ananievo Gulf sediments (79.2-88.2%); silt particles are widespread in the Kurmenty (66.7%) and Tyup Gulfs (54.2%). The highest clay content was discovered in the Tyup Gulf sediment (23.2%).
4. Littoral zone sediments along the northern coast contains 29.4-205.3 g/kg of salts and have sulfate-chloride-sodium-magnesium composition. Gulfs of the eastern coast, which are largely influenced by river drainage, have a sediment mineralization of 64.7-165.6 g/kg. With the increase of sediment deposition depth, the tendency of salt content increase was observed.

   The concentration of organic matter in sediment is 0.2-27.7%. An average content of organic substances in the eastern gulf sediments is 10.8% and in the northern ones

13.2%. Regions with the highest content of organic substances in sediment correspond to the places where the highest water flora is widespread.

Moisture content of the sediments is between 29.1-85.1%. The largest moisture content is typical for the Tyup Gulf sediment (74.5-85.1%), and it is 32.4-70.5% in the northern gulf sediments.

5. Sediment is the main accumulator of pollutants in the lake. Alkaline elements (calcium, strontium and barium) have been accumulated in sediment that is connected with carbonate formation processes, which are typical for the lake. The prevalence of silica, aluminium and iron in sediment composition confirms the terrigenic character of the lake sediment. In the northern coast sediment, lead content is 1.15-10.40 mg/kg, copper – 0.73-7.00 mg/kg, zinc – 0.00-13.95 mg/kg and cadmium is absent. In sediment of the littoral zone of the eastern coast, zinc content is 7.20-26.40 mg/kg, copper – 2.20-26.80 mg/kg and lead and cadmium are absent. The most polluted sediment by heavy metals is in the Dzergalan Gulf, Lipenka Bay and Chisty inlet.
6. For evaluation of human the load of heavy metals in sediment, the sum pollution index (PI) was used which is ratio of toxic metal concentrations in sediment (C_i) to their background value (C_b). The pollution level of littoral zone sediment was evaluated as minimum. The exception is the Akchiya Gulf, which has a medium level of pollution. At present, lake sediments cannot be considered as the secondary source of lake pollution.

VIII. REFERENCES

Accuracy standards for water analysis and the classification of analytical methods in accordance with preciseness of results. 1987. M. "VPMS", pp. 127. (in Russ).

Alekseev R.I. and Korovin Yu.I. 1972. *Manual for calculation and processing of the quantitative analysis results*. M. "Nauka", pp. 72. (in Russ).

Brekhovskikh V.F., Volkova Z.V., Kocharyan A.G. *Heavy metals in sediment and their role in water quality formation*. M., Mir, 2001, pp. 87 (in Russ).

Doerfel K. 1969. *Statistics in analytical chemistry*. M. "Mir", pp. 248. (in Russ).

GOST 17.4.1.02.82. *Nature protection. Classification of chemical substances for pollution control.*

GOST 26449.1-85. *Methods of chemical analysis of saline waters.* (in Russ).

Karmanchuk A.S. *Hydrochemistry and ecological condition of Lake Issyk-Kul.* "Soros-Kyrgyzstan" fund Publishing house, 2001, 58-69 (in Russ).

Krumgalz B.S. and Karmanchuk A.S. 2000. Ecological effects of human activity on Lake Issyk-Kul. Annual report (1.05.2000-30.04.2001) to CDR-CAR. IOLR Rep. H-14/99, Nat. Inst. Oceanogr., Haifa, Israel, 27 pp.

B.S. Krumgalz & G. Fainshtein. *Trace Metals and Organic Matter in Nearshore Sediment Cores from the Eastern Mediterranean (Haifa Bay of Israel)*. 1991 Elsevier Science Publishers Ltd, England, 15 p.

B.S. Krumgalz, G. Fainshtein and A. Cohen. *Grain size effect on anthropogenic trace metal and organic matter distribution in marine sediments*. The Science of the Total Environment? 116 (1992) 15-30

B. Krumgalz. *The use of heavy metal distribution "fingerprints" for tracing heavy metal contamination sources*. 3rd International Conference – Venice. September 1998.

Kudrin V.P. *About classification and origin of reservoir sediments*. Bul. of reservoir biology, 1960, #819, 57-61 (in Russ).

Linnik P.N., Nabivanets B.I. *Form of metal migrations in surface waters.* L."Gydrometeoizdat", 1986, pp. 270. (in Russ).

Manual for the chemical analysis of the surface waters. 1977. Edited by A.D. Semyonov. L. "Gydrometeoizdat", pp. 534. (in Russ)

Norms and criteria of pollution evaluation of sediment in water objects. Region normative, SPb, 1996, pp. 20 (in Russ).

Novikov J.V., Lastochkina K.O. *Research methods of reservoir water quality.* M., Medicine, 1990, pp. 400 (in Russ).

Osmonbetov K.O. *Geology and metallogeny of Kyrgyzstan.* Bishkek, 1999, pp. 136 (in Russ).

Palamarchuk I.K. Sediment and its role in reservoir. Gydrobiological magazine, 1972, vol. 8, #1, 118-127 (in Russ)

Prytkova M.J. *Geografical regularities of sediment accumulation in reservoirs.* L., "Nauka", 1986, pp. 88

Saet J.E., Revich B.A., Yanin E.P. Geochemistry of the environment. M., "Mir", 1964, pp. 902. (in Russ)

Spectral analysis of microcomponents. 1961. Edited by I.Yu. Sokolov. M. "Literature on geology and protection of the earth bowels – Publishing House", pp. 287. (in Russ).

Tarnovski A.A. *Geochemistry of sediment of modern lakes.* L., LGU Publishing house, 1980, pp. 165 (in Russ)

Tursungaziev B.T. *Mineral base of Kyrgyzstan on a boundary of the passage to the market economics.* Bishkek, 1998, pp. 213 (in Russ)

Unified methods of water analysis. 1979. Edited by Yu.Yu. Lurye. M. "Khimiya", pp. 367. (in Russ).

IX. MANAGEMENT

During the period of May 1, 2001-October 31, 2001, eMap DX receiver for the determination of sampling location coordinates on the Issyk-Kul Lake was purchased for the Kyrgyz side.

Three scientific expeditions for the sampling of lake water and sediment in the Grigorievka, Ananievo, Kuturga, Kurmenty, Tyup and Dzergalan Gulfs and the Shiroki, Rogaty, Chisty, Irdyk, Lipenka and Nikolaevsky inlets were carried out in June, July and September.

All samples of water and sediment collected were analyzed for salt and granulometric composition. Biogenic elements, organic pollutants and heavy metals (Fe, Cu, Zn, Cd, Sn, As, Pb) were also determined. Thus, all the work planned by the research program for this period has been completely fulfilled.

X. COLLABORATION

Due to collaboration between the Israel Oceanographic & Limnological Research Institute and the Kyrgyzstan Institute of Irrigation, Kyrgyz scientists have mastered the tracer method developed by Prof. B. Shteinman, and determined sediment transfer in the Cholpon-Ata Gulf.

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XII. APPENDIX

All Tables can be supplied upon request.