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Ecological effects of human activity on Lake Issyk-Kul

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II. EXECUTIVE SUMMARY

The present scientific report covers the period of May 1999 – April 2000. During the reported period, the following stages of the project were carried out according to the guidelines of the research program:

1. The sampling of water, sediment and river suspended substances of the Issyk-Kul Lake and rivers flowing into it.
2. Chemical and physico-chemical analyses of the samples taken. The aim of the analyses was to determine both granulometric and salt composition of the samples and content of heavy metals and other pollutants.
3. Calculation of the anthropogenic component value for the total volume of the river drain.
4. A fluorescent tracer method to study sediment transport was checked in the conditions of the Issyk-Kul Lake.

III. INTRODUCTION

Intensive development of the Issyk-Kul Lake Basin together with the conversion of this region in the tourism and relaxation zone unavoidably results in the increase of pollutants loading in the lake. Therefore, it is very important to evaluate anthropogenic changes in the waters of the Issyk-Kul Lake Basin. It will allow one to distinguish the changes of the lake water caused by natural processes and those stimulated by the influence of anthropogenic factors. The peculiarity of the hydrochemical regime of the Issyk-Kul Lake is its direct dependence on volume and quality of river drain, which is one of the main elements controlling an ecological situation of the lake basin. The influence of anthropogenic factors on water and salt drains depends on the scales and the rate of economic activity. The hydrochemical regime of this lake is gradually changed by industrial and agricultural wastewater.

IV. EXPERIMENTAL SECTION

1. Research object (water and sediment)

During the reported period, the largest rivers flowing into the lake and main gulfs such as Rybachii, Tyup, Dzergalan, Pokrovskii, Ton, Tamga and Cholpon-Ata were investigated. The open part of Issyk-Kul Lake was also studied. The study of river water included determination of salt composition, pollutant content, composition of suspended substances and bottom sediment. Water and sediment sampling from depths of 5, 10, 15 m was carried out in the Cholpon-Ata Gulf. Water samples were analyzed for the content of major ions, pollutants and heavy metals. The bottom sediment study included determination of its granulometric composition, chemical analysis of water extracts of the sediment and spectral study for heavy metals content.

Three expeditions for water and sediment sampling were organized in June, August and November 1999, respectively. In June, 100 kg of sediment from the Cholpon-Ata River and samples of suspended substances and water of the Tyup, Dzergalan and Cholpon-Ata Rivers were taken. In August, a joint team of Israeli (Prof. B. Krumgalz, Prof. B. Shteinman and S. Kaganovsky) and from Kyrgyzstan (Dr. A.S. Karmanchuk, L.A. Kanygina and S.I. Belokon) scientists studied the possibility of applying a fluorescent tracer method for study of sediment transport in the conditions of the Issyk-Kul Lake. During this period, 26 lake water samples and 12 sediment samples were taken from the Cholpon-Ata Gulf. 16 water samples from the lake gulfs and 14 samples from the rivers were taken during November. Lake water sampling was carried out with use of a bathometer from aboard of the Gydrometeorology Management research ship. Samples of lake sediment were taken with a corer from aboard a research ship.

2. Methods of analysis

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

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

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

3. Control of experimental results

The analysis quality control was conducted by using Certified State Sample (CSS) with a known content of analyzed components as follows: dry residuum 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 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:

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

where $\overline{C}$ is an 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 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:

$$d_{max} = 0{,}0196 \cdot \frac{\hat{A}}{\sqrt{n}} \cdot x_{d_z} \tag{2}$$

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 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 or the plotting of new calibration diagrams, plus 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 following equations (Doerfel, 1969; Alekseev and Korovin, 1972):

$$\Delta S_{syst} = \frac{1}{n}\sum_{i=1}^{n}(x_i - \mu) \tag{3}$$

$$\delta S_{syst} = \frac{\Delta S_{syst}}{\mu} \tag{4}$$

where μ is the true content of a component in a standard sample, x_i is the result of an isolated measurement of a standard sample and n is the number of measurements (i=1, 2... n). An average squared error (S) was calculated on the basis of a series of repeated measurements as follows:

$$S = \sqrt{\frac{1}{n-1} \cdot \sum (x_i - \bar{x})^2} \quad (5)$$

where $\bar{x}$ is the average value of n measurements. Calculation of a relative deviation (U) was carried out with the use of the following equation:

$$U = \frac{S}{\bar{x}} \cdot 100, \ \% \quad (6)$$

The values of S and U were compared to those for the recommended method. A condition for the correct accomplishment of analyses was the absence of the systematic error. For the best quality control of the experimental data, random chemical analysis of the water samples was carried out with use of two parallel measurements and obtained results were compared. In cases where there were great differences in the results, 10-12 samples were selected randomly from the remains of the analyzed ones and investigated repeatedly by another analyst. During this procedure, the analyst did not know the nature of these samples.

V. RESULTS AND DISCUSSIONS

1. Composition of suspended substances of river water

The research objects were the composition of sediment and suspended substances of the Tyup, Dzergalan and Cholpon-Ata Rivers sampled in July 1999. Granulometric composition of river sediment is mainly characterised by fine sand with conclusions of coarse sand. The content of suspended substances in water of the Tyup River, the Dzergalan River, and the Cholpon-Ata River was found to be 4423.6 mg/l, 1811.2 mg/l and 219.7 mg/l, respectively. Granulometric composition of the suspended river substances is summarised in Table A-1. Dust and silt particles were shown to prevail in the structure of suspended substances. Dust particles dominate the composition of suspended substances of the Tyup River (45.7%) and silt particles prevail in suspended substances of the Dzergalan River (52.2%).

The results of chemical analysis show that heavy metals such as titanium, manganese, strontium, barium and zirconium prevail in river suspended substances (Table

A-2). Concentrations of these elements in suspended substances of the three rivers studied are similar to each other. The content of heavy metals in river waters is considerably less than in suspended substances (Table A-3). Concentrations of strontium, barium, lithium, titanium, vanadium and zirconium were found to be largest in river water. Presumably, concentrations of elements in suspended substances and river water are mainly dependent on their clark in lithosphere and their migration ability.

2. Composition of the lake sediment

Bottom sediment of the Issyk-Kul Lake, sampled in August 1998, is formed by suspended particles transferred by the numerous rivers flowing down from mountain ridges, temporary streams and slope processes. Fine and medium sand and silt mainly represent the sediment. In addition, sediment sampling was carried out in the region of the Cholpon-Ata biostation in August 1999. A scheme of sampling is presented in Fig. 1. Dust and silt particles were found to prevail in sediment of the southern coast in the estuary of the Barskaun, Tamga and Ton Rivers (Table A-4), however, on the northern coast near the Cholpon-Ata biostation, dust particles dominate (Table A-5). The maximum content of sand in the studied sediment is not more than 14.2% at a depth of 5 m. Water extract of bottom sediment was found to have pH=7.07÷8.14. The negative value of Ox-Red potential is the evidence of reducing processes. Moisture content changes from 10% in sand up to 63% in silt. The content of organic substance in bottom sediment is low (0.76÷7.13% calculated on dry substances). The value of C_{org} /N_{org} ratio for Cholpon-Ata Bay (Krumgalz and Karmanchuk, 1999) is 8.0:16.6, therefore the easily oxidised forms dominate in the composition of organic substances. The values of permanganate and dichromate oxidation of a water extract of sediment and that of lake water of a coastal zone reach 60 mg/l and 2.14÷19.38 mg/l, respectively.

The chemical composition of water extract of sediment is presented in Table A-6. At the same depths, salt concentration in sediment is less than in lake water. Sediment and water at a depth of 5 m contain 1.51÷2.45 g/l and 5.67 g/l of salts, respectively, at a depth of 8.5÷10 m 2.11÷2.47 g/l and 5.83 g/l, respectively, and at a depth of 13÷15 m 1.86÷2.13 g/l and 5.82÷5.96 g/l, respectively. Results related to the mineralization of lake water near the bottom equal 5.82-5.96 g/l are not shown in any table. The salt composition of sediment is chloride-sulphate-sodium which corresponds to that of the lake water. Relative

concentration of chlorides (mg-eqv/l) in sediment at a depth of 5 m is more than sulphate concentration by 1.05÷1.43 times. The chloride/sulphate ratio increases with the depth of silt deposition, and reaches a value of 1.59:2.09 at a depth of 15 m. Therefore, accumulation of chlorides and the decrease of sulphate in lake sediment grows with the increase of depth.

In order to evaluate anthropogenic pollution of the environment with heavy metals, it is necessary to investigate the ecological conditions of sediment. The evaluation of the pollution level of the Issyk-Kul Lake may be performed considering a combination of many factors such as qualitative and quantitative sets of heavy metals in sediment, their distribution on the lake bottom area, ways of penetration into the lake and lake bottom areas with highest anthropogenic pollutant loading. Investigation of all the matters was included into the work program.

Microelement distribution in sediment of the Issyk-Kul Lake has never been studied. Current research is based on the results of the analyses of 17 sediment samples. 13 samples were taken from the Cholpon-Ata Gulf and 4 at the southern coast near the estuaries of the Barskaun, Ton and Tamga Rivers. The results obtained are given in Table A-7. It is known that microelements arrive at the reservoir together with suspended substances of rivers flowing into the lake or with particles of nondecomposed rock minerals.

Lead. The average and maximum content of lead in sediment are $1 \cdot 10^{-3}$ % and $2.0 \cdot 10^{-3}$ %, respectively, and its changing range is from $2.0 \cdot 10^{-3}$ to $5 \cdot 10^{-3}$ %. The tendency of lead content growth at increasing sediment deposition depth is observed. Maximum content of lead at a depth of 13 m ($2.0 \cdot 10^{-3}$%) was found to exceed its clark in lithosphere, nevertheless, the value is less than 3 times the lead content in river suspended substances arriving at the lake.

Copper. This element migrates together with suspended substances of mountain rivers and its average contents in river suspended substances and in the sediment are $2.3 \cdot 10^{-3}$ % and $2.5 \cdot 10^{-3}$ %, respectively. Dependency of copper concentration on sediment deposition depth has not been observed. The comparison of an average copper content in lake sediment and its clark in lithosphere demonstrates lower content in the sediment. Presumably, such reduced concentration in the sediment is caused by intensive copper consumption by plankton.

Zinc. The average zinc content in the sediment was found to be $3.0 \cdot 10^{-3}$ %, whereas its maximum content is $5.0 \cdot 10^{-3}$ %. Zinc concentration in suspended substances of river drain is $7.7 \cdot 10^{-3}$ % which is lower than its clark in lithosphere ($8.3 \cdot 10^{-3}$ %). Reduced content in sediment as compared to that in suspended substances is due to zinc consumption by phytoplankton. According to the available literature data, zinc co-precipitates with calcium carbonate and accumulates in the structure of chemogenic calcium carbonate at the coastal zone.

Nickel. The nickel content in silt was shown to change from $0.5 \cdot 10^{-3}$ % to $4.0 \cdot 10^{-3}$ % and to be close to its concentration in river suspended substances. The greater part of nickel migrates together with suspended substances and also accumulates at the coastal zone.

Cobalt. The cobalt distribution in the lake sediment was found similar to that of nickel. Its average concentration ($0.8 \cdot 10^{-3}$ %) is higher than that of cobalt in river suspended substances, and less than 2 times its clark in lithosphere. Maximal concentration was observed at a depth of 5 m at the coastal zone. Cobalt concentration does not exceed the level of its concentration in the rocks of the basin.

Chromium. An average content of chromium in lake sediment is $2.9 \cdot 10^{-3}$ % and it is less than its content in river suspended substances. Clark of chromium in lithosphere is more than 2.5 times its content in sediment. Similar to cobalt, maximum concentration of chromium was observed at a depth of 6 m at the coastal zone.

Molybdenum. Average and maximum concentrations of molybdenum in sediment are $1.1 \cdot 10^{-3}$ % and $2.0 \cdot 10^{-3}$ %, respectively. Its concentration in river suspended substances is $4.0 \cdot 10^{-4}$ %. Molybdenum accumulates in sediment, where its concentration is higher by 2-5 times than its content in suspended substances and 10 times higher in than in lithosphere and precipitate rocks.

Manganese. The main part of manganese arrives to the lake with suspended substances; this is evidence of its approximate equal concentrations in sediment ($7.0 \cdot 10^{-2}$ %) and suspended substances ($7.7 \cdot 10^{-2}$ %). Manganese content in precipitate rocks and lithosphere is within the same limits.

Titanium. This element is one of the most widespread elements in the nature and the value of its clark is $6.0 \cdot 10^{-1}$ %. Average titanium concentrations in sediment and suspended substances are $2.75 \cdot 10^{-1}$ % and $3.7 \cdot 10^{-1}$ %, respectively. Its lower concentration in comparison with lithosphere is caused by weak migration ability.

Zirconium. Zirconium content in sediment corresponds to its concentration in suspended substances ($1.5 \cdot 10^{-2}$%). Zirconium concentration in precipitate rocks and lithosphere is approximately twice as high ($2.9 \cdot 10^{-2}$%). This can be explained by the low migration ability of the element.

Strontium. The highest concentration of strontium in sediment ($1.5 \cdot 10^{-1}$ %) in comparison with that of river suspended substances ($0.27 \cdot 10^{-1}$ %) points to its active migration ability. Maximum content of strontium in sediment exceeds both that of precipitate rock and the value of its clark in lithosphere.

Barium. Maximum and average contents of barium in sediment are $4.0 \cdot 10^{-2}$ % and $2.7 \cdot 10^{-2}$ %, respectively, whereas its concentration in river suspended substances is $3.3 \cdot 10^{-2}$ %. Like titanium, barium is one of the widespread elements. Its clark in lithosphere ($5.0 \cdot 10^{-1}$ %) is less than that of titanium only but its content in precipitate rocks is smaller ($8.5 \cdot 10^{-2}$ %). This difference points out that barium has weaker migration ability than titanium.

The results found regarding microelement content in sediment of the Cholpon-Ata Gulf are evidence of higher concentrations of molybdenum and strontium in sediment than in lithosphere and soil. Accumulation of molybdenum and strontium in silt is caused by their increased migration ability. Contents of lead, copper, zinc, nickel, cobalt, chromium, manganese, zirconium and barium in sediment are less than in lithosphere and in rocks of the Issyk-Kul Lake basin. Their low concentrations are caused by low migration ability. Titanium and barium that have the highest clarks both in lithosphere and rocks but do not accumulate in sediment due to their low migration mobility. Accumulation of heavy metals in the sediment of the Issyk-Kul Lake is due to the outflow of suspended substances by rivers of the Issyk-Kul Lake basin.

The main factors explaining low microelements concentrations of the Cholpon-Ata Gulf are:

- absence of the river drain and suspended substances of the Cholpon-Ata River during the warm periods of the year;
- decrease of lake level which led to a reduction of river basis of erosion and was expressed in increasing of large fractions of sand particles in river suspended substances. Consequently, the entrance of fine-aleurite components of the river drainage is relatively decreased.

In order to clarify the connection between concentrations of heavy metals in sediment and bottom layer of water, a comparison of two these mediums was conducted. The results obtained are given in Table A-8. Concentrations of metals in sediment are higher than those in the bottom layer of water: titanium by 12.5 times, lead - 10 times and zirconium - by 5 times. The contents of nickel, cobalt, chromium and manganese in sediment are in 2.2÷3.2 times higher than those in the bottom layer of water. For the above-mentioned elements, migration from water to sediment occurs actively. On the contrary, concentrations of molybdenum and strontium in water are higher than those in sediment by 4.2 and 2.4 times, respectively. It is evidence that these ions are mainly in dissolved state in bottom layer of water and there is weak migration into sediment.

3. Research of sediment transport in the region of the Issyk-Kul Lake [a]

During the period of 18 August to 28 August 1999, a joint team of Israeli and Kyrgyzstan scientists carried out the study of sediment transport in the region of the Issyk-Kul Lake. The Israel team was made up of Prof. B.S. Krumgalz, Prof. B. Shteinman and Mr. S. Kaganovsky while Dr. A.S. Karmanchuk, L.A. Kanygina and S.I. Belokon are from Kyrgyzstan. The main task was to teach the Kyrgyzstan members of the scientific team to use the fluorescent tracer method developed at the Israel Oceanographic & Limnological Research, Tel-Shikmona. A certain amount of fluorescent tracers was left in Kyrgyzstan to enable Dr. A.S. Karmanchuk to conduct a similar study in other areas of the Issyk-Kul Lake in the future with her scientific team.

A. Tracer methods

Determinations of sediment dynamics with various radioactive, magnetic or fluorescent tracers have been used for many years (Kilpatrick and Taylor, 1966; Harris and Sanderson, 1968; Scott et al., 1969; Rathbun and Nordin, 1971; Blackley and Heathershaw, 1982;). In this approach, labeled particles are placed in the stream where their movement is followed, enabling qualitative and quantitative assessments of the direction and velocity of the sediment transport. Natural radioactive tracers can also be used (Shteinman et al., 1992; 1994), but have the disadvantage of having a weak and

[a] This section was written by Prof. B. Shteinman.

unselective signal while placing strong, "artificial" radioactive tracers into natural waterways is usually prohibited by law. In view of the drawbacks of the above methods, we developed the application of tagged fluorescent tracers to measure sediment transport (Shteinman and Inbar, 1995; Shteinman et al., 1997). Fluorescent tracers have the advantage of being ecologically harmless; moreover, they can be detected with extremely high sensitivity. This method becomes increasingly versatile when particles are tagged with fluorescent dyes of different colors which can also be "programmed' to remain unchangeable for varying periods of time.

In the current report, we give details of the modifications made by our team in the fluorescent tracer (FT) method in order to prepare tracer particles of different colors and with specified lifetimes. We show results obtained with this approach to determine sediment transport at the littoral zone of Lake Issyk Kul (Fig.1).

B. Preparation of fluorescently tagged particles

Sediment was taken from the bottom of the Issyk Kul Lake in the area of the Cholpon-Ata River. After thorough air-drying, they were mixed with one of the following dyes to obtain particles with colored fluorescence: rhodamine (red fluorescence), auramine (yellow), and eosine (orange). Depending on the specific dye solutions, a special fixative was added. The "lifetime" of these particles was depended on the kind of fixative and could be varied from 10 days to 6-7 months. The tagged fluorescent sediment was placed at their original sites on the bottom of the lake (**Fig. 2**). After 2-3 days, bottom samples from the lake bed were taken at appropriate distances from the original placement site (**Figs. 3-5**) and analyzed for their content of tagged fluorescent particles. All sampling sites were precisely marked for subsequent mapping (**Fig. 6**). The discussion of the obtained results is presented below.

C. Analytical Methods

Before analysis, the collected material was carefully air-dried by forced ventilation and thoroughly mixed in a revolving drum to give a uniform distribution of FTs within the bulk of non-fluorescing particles. For initial, visual evaluation, the dried material was

examined under UV lamp and the presence of colored particles was observed. On this basis alone, maps could be prepared showing the distribution of differently colored particles far from the original site of marked sediment inclusion (**Fig. 6.**).

Earlier, the team of Prof. Shteinman developed three methods of obtaining a quantitative analysis of the concentrations of colored FTs based either on their fluorescence emission or on their specific spectral absorption. In the first technique, a thin layer of dried sediment sample was placed 20 cm from an excitation monochromator (150 W Xenon lamp with 90° geometry) which showed an excitation range of 275 to 400 nm. The fluorescence emitted from FTs in the sample was collected by a focusing lens and passed through a second monochromator set for a wide spectral range of 400-500 nm. The monochromator slits (16 and 4 mm) and photomultiplier voltage (900 V) were held constant throughout the measurements. Variations of the amplifier gain of 1 to 100 permitted the detection of fluorescence intensities over a range of three orders of magnitude. Calibration was carried out by placing measured amounts of FTs under the excitation beam and recording the peak heights of the fluorescence emitted (for example, see **Fig.** 7). The collected samples were air-dried and sent to Israel. The quantitative analysis of colored fluorescent tracers was carried out by Prof. B. Shteinman together with his scientific team.

As an alternative to this approach, quantitative determinations of FT concentrations were also made by analysis of acetone or ethanol extracts of weighed dry sediment samples. These extracts were placed in a 3-ml cuvette in a Kontran UV KON 930 spectrophotometer in order to obtain spectral scans of optical density from 300 to 600 mm. The optical density at specific wavelengths was maximum for differently colored FTs. For calibration, known quantities of the various tracer dyes were dissolved in acetone or ethanol and their fluorescent spectrum was determined. Concentrations of FTs measured in experiments were then quantified by comparison with the calibrated samples. The effects of overlapping absorption were taken into account when determining the concentrations of a mixture of differently colored FTs (**Fig. 8**).

Batches of dried material were placed in a thin layer over a 400 cm^2 board. This surface area was then entirely scanned with a Sony video camera which detected the labeled particles in color and recorded on a PC equipped with a Targa + frame grabber. The total number of differently colored FTs in each scan was evaluated using Image-Pro software for image analysis. In this manner, an exact count could be made of the total FTs within a weighed, dry sample of sediment.

Earlier, we checked that the labeling process with fluorescent dyes did not change the hydrodynamic properties of the original particles. Laboratory tests indicated that labeled fluorescent particles had settling velocities identical to those of untreated particles from the same sample.

D. Results

The main purpose of this study was to demonstrate the possibility of using the fluorescent tracer method developed at the Israel Oceanographic & Limnological Research for sediment transport investigations under various conditions at the Issyk-Kul Lake. The results obtained during this cruise are presented in Table 2. The analysis of the results led us to the following conclusions:

1. Sediment transport from east to west was dominant at cruise conditions in the Cholpon-Ata Gulf. This direction corresponds to that of a water stream.
2. Sediment transport near the shore at a depth of 5 m swerved to the bay and continued its movement along the shore. The sediment flow gradually decreased apparently due to sediment accumulation on shore and under the water sandbank. Question marks show the places of the apparent sediment accumulation. It should be emphasized that "red" labeled sediment was not found in Station #11.
3. The zone of the movement of underwater sediment reaches depths of 15 m.

Table 2. The number of tracer particles in bottom sediment (per 100 g of dry sediment weight).

Station	Tracer color		
	red	yellow	orange
1	22	0	0
2	0	0	0
3	0	0	0
4	35	0	0
5	29	0	0
6	0	0	0
7	0	9	0
8	11	0	0
9	9	0	0
10	3	0	0
11	0	5	19
12	0	0	0
13	0	0	0

VI. POLLUTANT LOADING IN THE ISSYK-KUL LAKE BASIN

The influence of human activity on natural waters results not only in the appearance of components, which are not characteristic to the environment, such as phenols, detergents, petroleum and heavy metals, but also in changing of major ion contents. The economic activity led to metamorphization of river water from hydrocarbonate-calcium type to sulphate-sodium type. The development of irrigation has a great influence on changes of ion composition of the river drain. One method of evaluating pollution of river water is the consideration of an anthropogenic component which is separated from the total river drain. The value of the anthropogenic component was calculated as follows:

$$R_{an} = R_i - R_{back} \tag{7}$$

where R_{an} is an anthropogenic component, R_i is an ion drain for the calculated period and R_{back} is a background one. The calculation was conducted on the basis of the ion composition data of the Tyup, Dzergalan, Karakol and Chon-Kyzylsu Rivers's water during 1998. In accordance with the data of the Gydrometeorology Service, water drain of these rivers for the mentioned period was 49.53 m^3/s. Natural background composition was determined as an average one from the chemical composition of river headwater. The results are given in Table A-9. An anthropogenic component of the ion drain for the Issyk-Kul hollow reaches $80.14 \cdot 10^3$ tons per year and its greatest part falls to sodium and sulfates. The modern scales of human activity in the Issyk-Kul Lake basin led to the increase of river ion drain by 33%.

An anthropogenic component in river drain reaches 72-100%. Pollution with copper and zinc is absent as their contents in river water correspond to background concentrations (Table A-10). The content of pollutants in river water is not constant and changes occasionally, therefore, it corresponds to the particular period only. Concentrations of hydrocarbonates and calcium are least subjected to anthropogenic influence, as their content in natural waters is determined by the mobile hydrocarbonate-calcium equilibrium and limited by low solubility of calcium carbonate.

Due to anthropogenic influence, the salt drain of the main rivers flowing into the Issyl-Kul Lake changed both quantitatively and qualitatively.

Analysis of the main rivers of the Issyk-Kul Lake basin show that the chemical composition of water and the content of pollutants (petroleum, phenols and detergents in 1999 (Table A-11) were within the same limits as in 1998 (Krumgalz and Karmanchuk, 1999).

The chemical composition of water in the coastal lake zone (Table A-12) is characterized by the salt content equal to 2805.6-6164.3 mg/l. The inflow of fresh rivers into the coastal zone results in the decrease of salt concentration in the lake water.

VII. RECREATION CAPACITY OF THE ISSYK-KUL LAKE

Under conditions of full natural isolation of the Issyk-Kul Lake, its ecological state is also aggravated by that lake level has a general tendency to decrease for the last century. For the use of the lake as a recreation zone, it is important to determine a recreation capacity of the area. An attempt was made to determine a value of recreation capacity of the beach zone of the Issyk-Kul Lake, which is permitted for conservation of its satisfactory state. Optimal loading of resting people on the beach zone under the modern conditions was calculated as follows:

$$H_p = \left(\frac{S_b}{d} + \frac{S_s}{N}\right) \cdot \eta \qquad (8)$$

where H_p is permissible number of resting people on the beaches of the Issyk-Kul Lake, S_b is an area of the 1st and 2nd categories beaches, S_s is an area of the shallow zone, d is a specific loading of the beach territory (7 m^2), N is a permissible area of the water surface per one bather needed for the natural self-cleaning (100 m^2) and η is a decreasing coefficient of recreation territory use (η=0.7). Calculations conducted in accordance with this method show that at the modern state of the Issyk-Kul Lake coast, permissible loading should not exceed 220,000 people at the same time. Unfortunately, this value has been already exceeded. Probably, only the creation of water-protection zones might solve this problem.

VIII. CONCLUSIONS

1. Heavy metals such as titanium, manganese, strontium, barium and zirconium, being widespread elements in the composition of precipitate rocks of the research region, prevail in the suspended substances of river drain. Concentrations of chemical elements both in river sediment and river water mainly depend on their clarks in lithosphere and their migration abilities.
2. The bottom lake sediment is mostly sand and silt sand by nature. Salt content in the sediment is less by 2.5-3 times than that in the lake water at the same depths. Chloride content in the sediment rises and sulphate content decreases with a depth increase. Accumulation of heavy metals in the sediment is due to their coming together with suspended substances of river drain.
3. The sediment transport from east to west dominates in the Cholpon-Ata Gulf and is according to the current water direction during the summer period. The zone of underwater sediment movement reaches a depth of 15 m.
4. The anthropogenic activity in the Issyk-Kul Lake basin led to the change of river water types from hydrocarbonate-calcium type to sulphate-sodium type. An anthropogenic component of the ion river drain reaches $80.14 \cdot 10^3$ tons of salts per year, i.e., 33% of all river drain pollutants. The pollution of both flowing rivers and the coastal zone is within the same limits as in 1998. Permissible loading on the recreation zone of the lake coast should be not exceeding 220,000 people in a year, although to date, this number is much higher.

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X. MANAGEMENT

During the second year, small equipment (electronic balances, portable pH-meter, photocolorimeter) were purchased for the Scientific and Research Institute of Irrigation (Bishkek, Kyrgyzstan). Three scientific expeditions for the sampling of water and sediment in the area under study were carried out and all collected samples were analyzed. Thus, all the work planned by the research program for this period has been completely fulfilled.

XI. COLLABORATION

Due to collaborations between the Israel Oceanographic & Limnological Research Institute and the Kyrgyzstan Institute of Irrigation, the training of Dr. A. Karmanchuk, S. Belokon and L. Kanygina on the new method of sediment transport determination by use of fluorescent tracers was conducted by Prof. B. Krumgalz, Prof. B. Shteinman and S. Kaganovsky.

XII. ACKNOWLEDGEMENT

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We would like specifically to acknowledge the assistance that we constantly receive from Mr. Boaz Ayalon from the American Embassy, Tel Aviv (Israel). We are also very appreciative of the participation of the following persons in the experimental part of the project: S. Belokon, V. Mitrophanov, V. Karmanchuk, L. Kanygina, N. Rachmanov and J. Titova from Kyrgyzstan side and Prof. B. Shteinman and S. Kaganovsky from the Israels side.

XIII. APPENDIX.

Table A-1. Granulometric composition of suspended substances of river water

Sampling location	Particle composition (% wt.) with diameter (mm)											
	1-0.5	0.5-0.2	0.2-0.1	0.1-0.05	0.05-0.01	0.01-0.005	0.005-0.001	<0.001	sand [a]	dust [a]	silt [a]	clay [a]
Tyup River estuary	0.4	0.4	2.1	9.0	36.7	22.6	13.3	15.5	2.9	45.7	35.9	15.5
Dzergalan River estuary	0.5	0.5	0.6	3.5	25.4	26.1	26.1	17.3	1.6	28.9	52.2	17.3

[a] The size of sand, dust, silt and clay are the follow: 0.25-1.0 mm, 0.01-0.25 mm, 0.001-0.01 mm and <0.001 mm, respectively.

Table A-2. Results of chemical analysis of river suspended substances (June 1999)

Sampling location	Content, % wt.											
	Mn	Ni	Ti	Cr	Mo	Zr	Cu	Pb	Zn	Y	Sr	Ba
Cholpon-Ata River estuary	$9\cdot10^{-2}$	$3\cdot10^{-3}$	$3\cdot10^{-1}$	$3\cdot10^{-3}$	$0.5\cdot10^{-3}$	$1.5\cdot10^{-2}$	$3\cdot10^{-3}$	$0.5\cdot10^{-3}$	$1.5\cdot10^{-2}$	$3\cdot10^{-3}$	$3\cdot10^{-2}$	$3\cdot10^{-2}$
Tyup River estuary	$7\cdot10^{-2}$	$4\cdot10^{-3}$	$4\cdot10^{-1}$	$4\cdot10^{-3}$	$0.5\cdot10^{-3}$	$1.5\cdot10^{-2}$	$3\cdot10^{-3}$	$0.5\cdot10^{-3}$	$0.4\cdot10^{-2}$	$4\cdot10^{-3}$	$2\cdot10^{-2}$	$3\cdot10^{-2}$
Dzergalan River estuary	$7\cdot10^{-2}$	$4\cdot10^{-3}$	$4\cdot10^{-1}$	$4\cdot10^{-3}$	$0.4\cdot10^{-3}$	$1.5\cdot10^{-2}$	$2\cdot10^{-3}$	$0.7\cdot10^{-3}$	$0.4\cdot10^{-2}$	$4\cdot10^{-3}$	$3\cdot10^{-2}$	$4\cdot10^{-2}$

Table A-3. Results of chemical analysis of dry remainder of river water (June 1999)

Sampling location	Content, % wt.											
	Ni	Ti	V	Cr	Mo	Zr	Cu	Pb	Y	Sr	Ba	Li
Tyup River estuary	$0.4 \cdot 10^{-3}$	$0.12 \cdot 10^{-1}$	$0.7 \cdot 10^{-2}$	$3 \cdot 10^{-3}$	$1.5 \cdot 10^{-3}$	$0.2 \cdot 10^{-2}$	$1.5 \cdot 10^{-3}$	$0.3 \cdot 10^{-3}$	$1.5 \cdot 10^{-3}$	$15 \cdot 10^{-2}$	$3 \cdot 10^{-2}$	$3 \cdot 10^{-3}$
Dzergalan River estuary	$0.4 \cdot 10^{-3}$	$0.12 \cdot 10^{-1}$	$0.15 \cdot 10^{-2}$	$1.5 \cdot 10^{-3}$	$1.5 \cdot 10^{-3}$	$0.2 \cdot 10^{-2}$	$1.5 \cdot 10^{-3}$	$0.3 \cdot 10^{-3}$	$1.5 \cdot 10^{-3}$	$7 \cdot 10^{-2}$	$3 \cdot 10^{-2}$	$3 \cdot 10^{-3}$
Cholpon-Ata River estuary	$2 \cdot 10^{-3}$	$0.07 \cdot 10^{-1}$	$0.3 \cdot 10^{-2}$	$4 \cdot 10^{-3}$	$2 \cdot 10^{-3}$	$0.2 \cdot 10^{-2}$	$5 \cdot 10^{-3}$	$0.3 \cdot 10^{-3}$	$1.5 \cdot 10^{-3}$	$7 \cdot 10^{-2}$	$3 \cdot 10^{-2}$	$3 \cdot 10^{-3}$

Table A-4. Granulometric composition of sediment of the Issyk-Kul Lake (August 1998)

Sampling location	Particle composition (% wt.) with diameter (mm)											
	1-0.5	0.5-0.2	0.2-0.1	0.1-0.05	0.05-0.01	0.01-0.005	0.005-0.001	<0.001	sand	dust	silt	clay
0.1 km from the Barskaun river estuary, depth of 10m	0.6	16.2	15.3	12.2	31.2	6.5	5.8	12.2	32.1	43.4	12.3	12.2
0.5 km from the Barskaun river estuary, depth of 50 m	0.4	0.4	0.2	5.3	28.7	29.9	18.3	16.8	1.0	34.0	48.2	16.8
0.5 km from the Tamga river estuary, depth of 25 m	0.7	0.8	8.9	12.8	51.7	9.2	9.2	6.7	10.4	64.5	18.4	6.7
0.5 km from the Ton river estuary, depth of 45 m	0.5	0.7	17.0	29.4	36.9	6.2	5.8	3.5	18.2	66.3	12.0	3.5
2 km from the coast, region of the sanatorium "Goluboy Issyk-Kul", depth of 28 m	1.0	34.9	16.0	12.1	21.9	2.6	4.5	7.0	51.9	34.0	7.1	7.0

Table A-5. Granule composition of sediment of the Issyk-Kul Lake, near the biostation of Cholpon-Ata town, August 1999

Sampling location	Particle composition (% wt.) with diameter (mm)									
	1-0.25	0.25-0.05	0.05-0.01	0.01-0.005	0.005-0.001	<0.001	sand	dust	silt	clay
Profile 1, depth of 5 m	13.2	31.7	26.9	13.5	11.9	2.8	13.2	58.6	25.4	2.8
Profile 1, depth of 10 m	8.2	26.7	37.8	9.5	13.2	4.6	8.2	64.5	22.7	4.6
Profile 1, depth of 15 m	5.9	23.8	47.1	10.9	9.2	3.1	5.9	70.9	20.1	3.1
Profile 2, depth of 5 m	2.7	29.1	43.2	11.0	10.5	3.5	2.7	72.3	21.5	3.5
Profile 2, depth 8.5 m	12.7	33.6	30.5	10.6	8.6	4.0	12.7	64.1	19.2	4.0
Profile 2, depth of 13 m	0.8	24.0	51.4	12.2	9.1	2.5	0.8	75.4	21.3	2.5
Profile 3, depth of 5 m	14.2	37.6	25.2	6.0	13.0	4.0	14.2	62.8	19.0	4.0
Profile 3, depth of 9.5 m	8.2	23.0	34.4	12.9	15.4	6.1	8.2	57.4	28.3	6.1
Profile 3, depth of 15 m	3.9	32.4	34.2	12.1	12.5	4.9	3.9	66.6	24.6	4.9
Profile 4, depth of 6 m	3.6	36.2	41.6	9.2	4.3	5.1	3.6	77.8	13.5	5.1
Profile 4, depth of 10 m	3.0	56.7	16.4	10.3	0.3	3.1	3.0	73.1	10.6	3.1
Profile 5, depth of 16 m	3.4	32.8	29.9	11.5	21.1	1.3	3.4	62.7	32.6	1.3

Table A-6. Chemical composition of water extract of the Issyk-Kul Lake sediment, sampled near the biostation of Cholpon-Ata town (August 1999)

Sampling location	Concentration, (in numerator - mg/l, in denominator - mg-eqv/l)							
	Ca^{2+}	Mg^{2+}	$Na^{+}+K^{+}$	HCO_3^{-}	CO_3^{2-}	SO_4^{2-}	Cl^{-}	Mineralization, mg/l
Profile 1, depth of 5 m	104.2 5.20	51.1 4.20	336.7 14.65	109.8 1.80	-	441.9 9.19	462.8 13.06	1506.5
Profile 1, depth of 10m	104.2 5.20	55.9 4.60	607.20 26.40	97.6 1.60	-	730.4 15.19	689.0 19.41	2284.3
Profile 1, depth of 15m	108.2 5.40	43.8 3.60	483.9 21.04	109.8 1.80	12.0 0.40	432.1 8.99	668.4 18.85	1858.2
Profile 2, depth of 5 m	164.3 8.20	51.1 4.20	543.0 23.62	122.0 2.00	-	673.2 14.00	709.6 20.02	2263.2
Profile 2, depth of 8.5 m	100.2 5.00	60.8 5.00	542.1 23.59	109.8 1.80	-	649.3 13.51	647.9 18.28	2110.1
Profile 2, depth of 13m	84.2 4.20	34.0 2.80	536.8 23.36	97.6 1.60	24.0 0.80	451.0 9.38	658.4 18.58	1886.0
Profile 3, depth of 5 m	108.2 5.40	53.5 4.40	659.0 28.67	97.6 1.60	-	865.8 18.01	668.4 18.86	2452.5
Profile 3, depth of 15m	100.2 5.00	55.9 4.60	567.4 24.68	109.8 1.80	24.0 0.80	588.4 12.24	689.0 19.44	2134.7
Profile 4, depth of 10m	104.2 5.20	55.9 4.60	672.5 29.15	109.8 1.80	30.0 1.00	822.2 17.10	678.7 19.15	2473.3

Table A-7. Content of heavy metals in the Issyk-Kul Lake sediment sampled near biostation of Cholpon-Ata town, August 1999, %

Element	Concentration, % wt.						
	Sediment		Rivers	Rocks			
	Maximum content	Average content	Average content in suspended substances	major	average	precipitate	lithosphere
Lead	0.0020	0.0010	0.0060	0.0008	0.0015	0.0020	0.0016
Copper	0.0040	0.0025	0.0023	0.0100	0.0035	0.0057	0.0047
Zinc	0.0050	0.0030	0.0077	0.0130	0.0070	0.0080	0.0083
Nickel	0.0040	0.0024	0.0037	0.0160	0.0055	0.0095	0.0058
Cobalt	0.0020	0.0008	0.0007	0.0045	0.0010	0.0020	0.0018
Chromium	0.0040	0.0029	0.0037	0.0200	0.0050	0.0100	0.0080
Molybdenum	0.0020	0.0011	0.0004	0.0001	0.0001	0.0002	0.0001
Manganese	0.0700	0.0575	0.0770	0.2000	0.1200	0.0670	0.1000
Titanium	0.3000	0.2750	0.3700			0.5870	0.6000
Zirconium	0.0150	0.0118	0.0150			0.0280	0.0292
Strontium	0.1500	0.0600	0.0270			0.1230	0.0980
Barium	0.0400	0.0270	0.0330			0.0850	0.5000

Table A-8. An average content of heavy metals in sediment and water bottom layer of the Issyk-Kul Lake, %

Element	Concentration, % wt.	
	Sediment	Water bottom layer
Lead	$2.9 \cdot 10^{-3}$	$0.3 \cdot 10^{-3}$
Copper	$3.7 \cdot 10^{-3}$	$2.2 \cdot 10^{-3}$
Zinc	$0.4 \cdot 10^{-2}$	-
Nickel	$1.7 \cdot 10^{-3}$	$0.7 \cdot 10^{-3}$
Cobalt	$1.3 \cdot 10^{-3}$	$0.4 \cdot 10^{-3}$
Chromium	$2.8 \cdot 10^{-3}$	$1.2 \cdot 10^{-3}$
Molybdenum	$1.8 \cdot 10^{-3}$	$7.6 \cdot 10^{-3}$
Manganese	$6.6 \cdot 10^{-2}$	$2.1 \cdot 10^{-2}$
Titanium	$2.5 \cdot 10^{-1}$	$0.2 \cdot 10^{-1}$
Zirconium	$1.5 \cdot 10^{-2}$	$0.3 \cdot 10^{-2}$
Strontium	$4.4 \cdot 10^{-2}$	$10.4 \cdot 10^{-2}$
Barium	$3.8 \cdot 10^{-2}$	-

Table A-9. Anthropogenic component of ion river drain of the Issyk-Kul hollow

Ions	Background content, mg/l	Composition of river water, mg/l	Water drain, m^3/s	Ion background drain, thousand ton	Ion river drain, thousand ton	Anthropogenic component, thousand ton	Anthropogenic component, %
Ca^{2+}	26.3	26.6	49.53	41.08	41.55	0.47	1.1
Mg^{2+}	4.7	7.7	49.53	7.34	12.03	4.69	63.9
$Na^{+}+K^{+}$	3.7	19.0	49.53	5.78	29.68	23.90	413.5
HCO_3^{-}	91.5	91.9	49.53	142.92	143.55	0.63	0.4
SO_4^{2-}	22.4	51.2	49.53	34.99	79.97	44.98	128.6
Cl^{-}	6.0	9.5	49.53	9.37	14.84	5.47	58.4
Ion sum	154.6	205.9	49.53	241.48	321.62	80.14	33.2

Table A-10. Anthropogenic component of pollutant river drain of the Issyk-Kul hollow

Pollutants	Background content, mg/l	Content in river water, mg/l	Water drain, m^3/s	Background drain, thousand tons	Pollutants drain, thousand tons	Anthropogenic component, thousand tons
BOC_5 [a]	1.35	2.32	49.53	2.11	3.62	1.51
COC [b]	8.61	15.48	49.53	13.45	24.18	10.73
Copper	0.002	0.002	49.53	0.003	0.003	0.00
Zinc	0.002	0.002	49.53	0.003	0.003	0.00
Detergents	0.001	0.011	49.53	0.001	0.017	0.016
Phenols	0.00	0.002	49.53	0.00	0.003	0.003
Petroleum	0.001	0.050	49.53	0.001	0.078	0.077
Pesticides	0.00	0.001	49.53	0.00	0.001	0.001
Pollutant sum	9.964	17.866	49.53	15.568	27.905	12.337

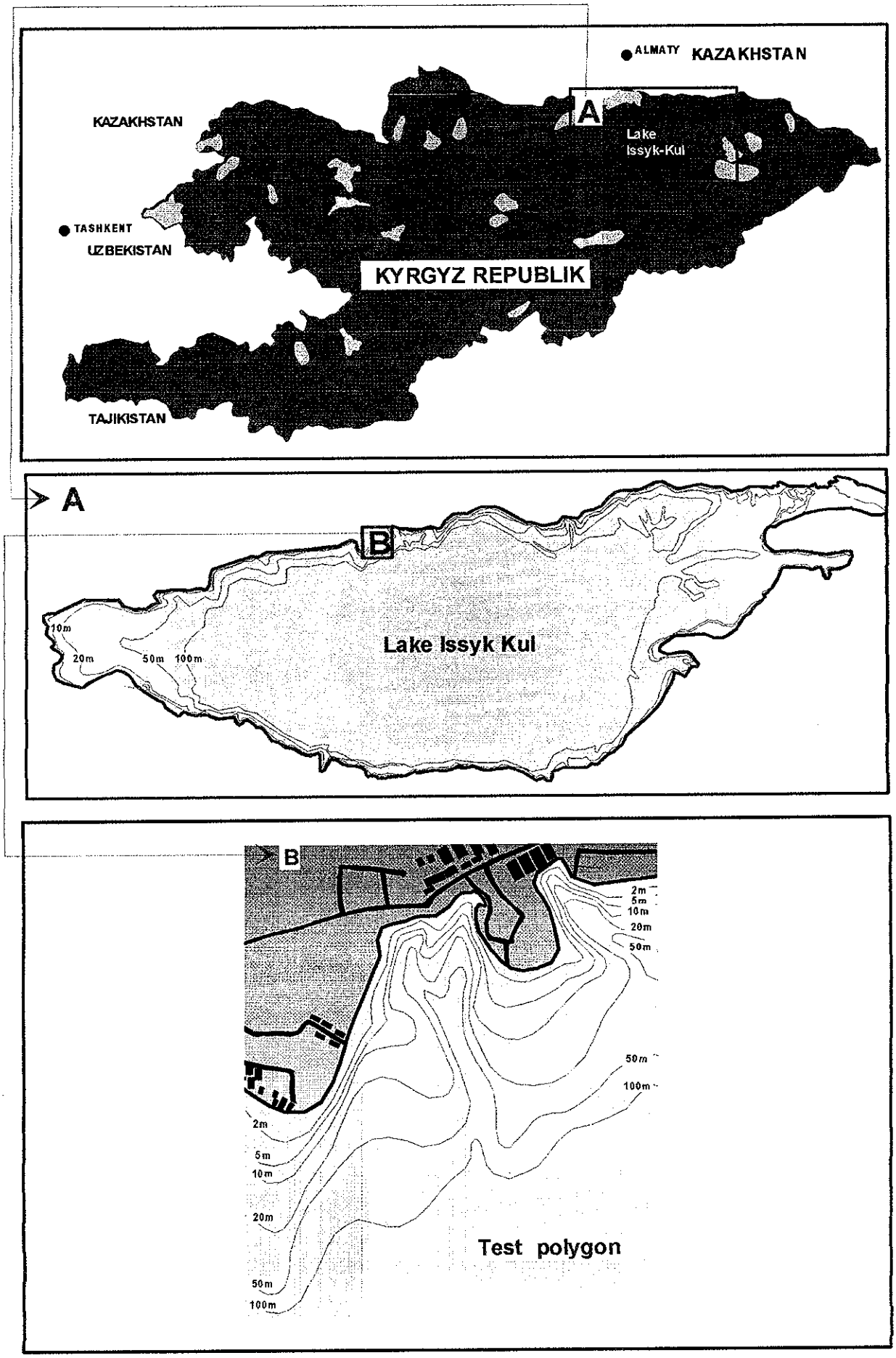
[a] BOC_5 is the biochemical oxygen consumption for 5 days in anaerobic conditions.
[b] COC is the chemical oxygen consumption for the complete oxidation of organic substances.

Table A-11. Comparative characteristics of pollution state of river water in the Issyk-Kul Lake basin, mg/l

Component	1998			1999	
	Spring	Summer	Autumn	Summer	Autumn
Nitrate nitrogen	1.10	0.27	0.34	0.11	0.06
Nitrite nitrogen	0.02	0.01	0.00	0.02	0.01
Ammonium nitrogen	0.00	0.01	0.00	0.03	0.07
Total phosphorus	0.00	0.04	0.01	0.03	0.03
Total iron	0.23	0.14	0.04	0.02	0.06
Detergents	0.010	0.010	0.006	0.010	0.004
Phenols	0.001	0.001	traces	0.002	0.001
Petroleum	0.22	0.40	0.31	0.20	0.25
Copper	0.010	0.008	0.003		
Zinc	0.001	0.001	0.001		
Mineralization	262.5	189.7	222.1	204.7	288.7

Table A-12. Chemical composition of coastal zone water of the Issyk-Kul Lake (November 1999)

Sampling location	Concentration, mg/l							
	Ca^{2+}	Mg^{2+}	$Na^{+}+K^{+}$	HCO_3^{-}	CO_3^{2-}	SO_4^{2-}	Cl^{-}	Mineralization
Rybachii Gulf, ship repairing plant	150.3	97.3	900.7	280.6	9.0	1022.2	1010.2	3470.3
Rybachii Gulf, oil-base	152.3	70.5	712.3	280.6	-	686.0	903.9	2805.6
Rybachii Gulf, meat plant	128.3	149.6	1788.3	280.6	18.0	2151.3	1648.2	6164.3
Rybachii Gulf, after flowing of collector	134.3	141.1	1285.7	231.8	15.0	1630.0	1276.0	4713.9
Rybachii Gulf, shipping company	144.3	141.1	1596.7	262.3	27.0	1899.9	1541.9	5613.2
Cholpon-Ata town, sanatorium "Goluboy Issyk-Kul"	118.2	154.4	1610.9	280.6	18.0	1848.1	1595.0	5625.2
Cholpon-Ata town, the East Bay	150.3	125.3	1347.8	250.1	15.0	1648.9	1329.2	4866.6
Cholpon-Ata town beach	140.3	138.6	1748.5	280.6	15.0	1986.3	1701.4	6010.7
Cholpon-Ata town, biostantion	158.3	127.7	1563.1	256.2	27.0	1815.5	1541.9	5489.7
Ananievo village, dock	150.3	120.4	1636.5	268.4	12.0	1934.9	1541.9	5664.4
Dzergalan Gulf, town beach	138.3	110.7	1184.7	396.5	-	1370.7	1152.0	4352.9
Kurmenty village, dock	134.3	133.8	1716.3	262.3	21.0	2034.5	1595.0	5897.2
Tyup Gulf	130.1	135.3	705.9	283.5	-	649.0	910.1	2983.9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Test polygon

Fig.1

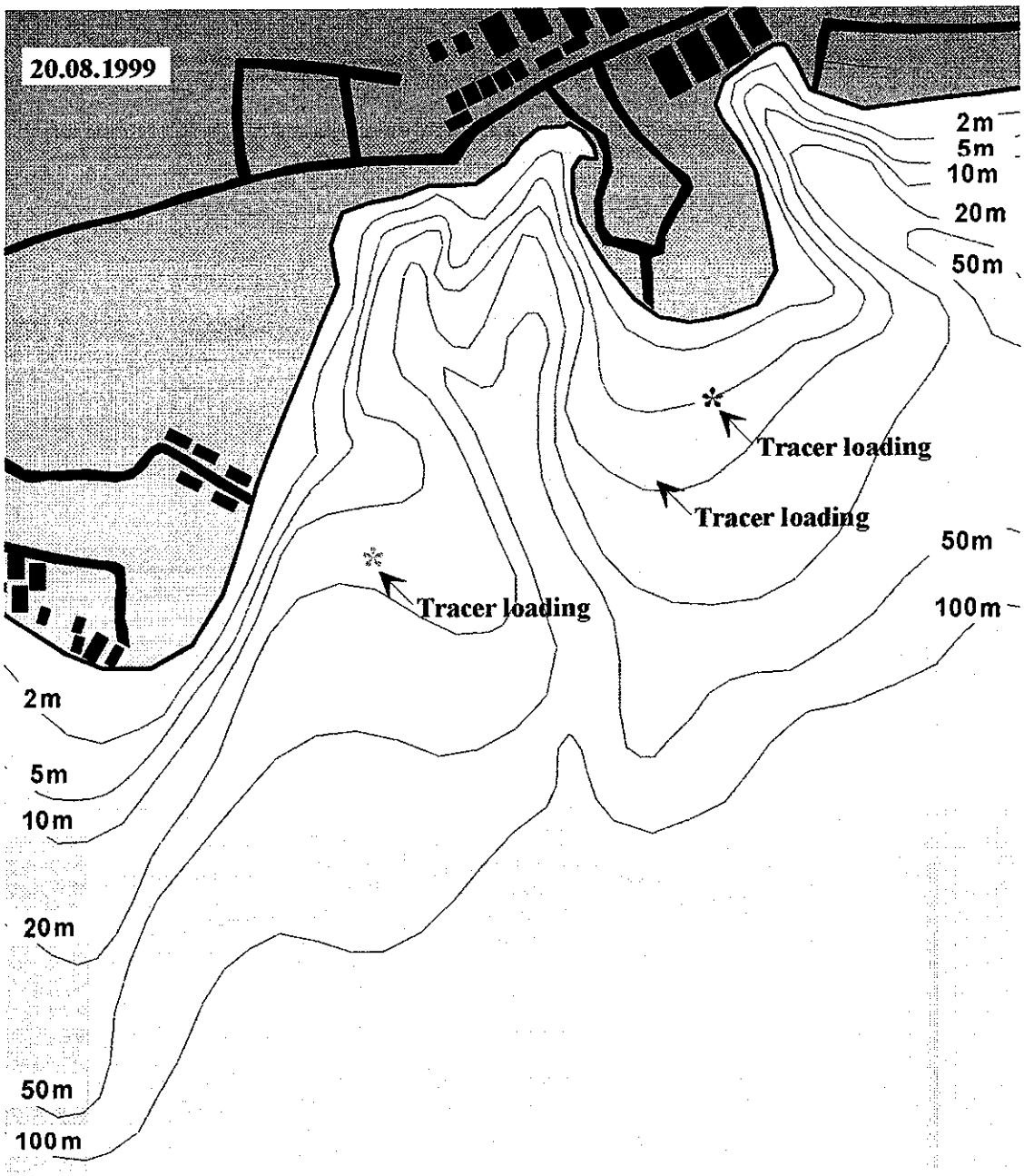
20.08.1999
2m
5m
10m
20m
50m
Tracer loading
Tracer loading
50m
Tracer loading
100m
2m
5m
10m
20m
50m
100m

Fig.2.

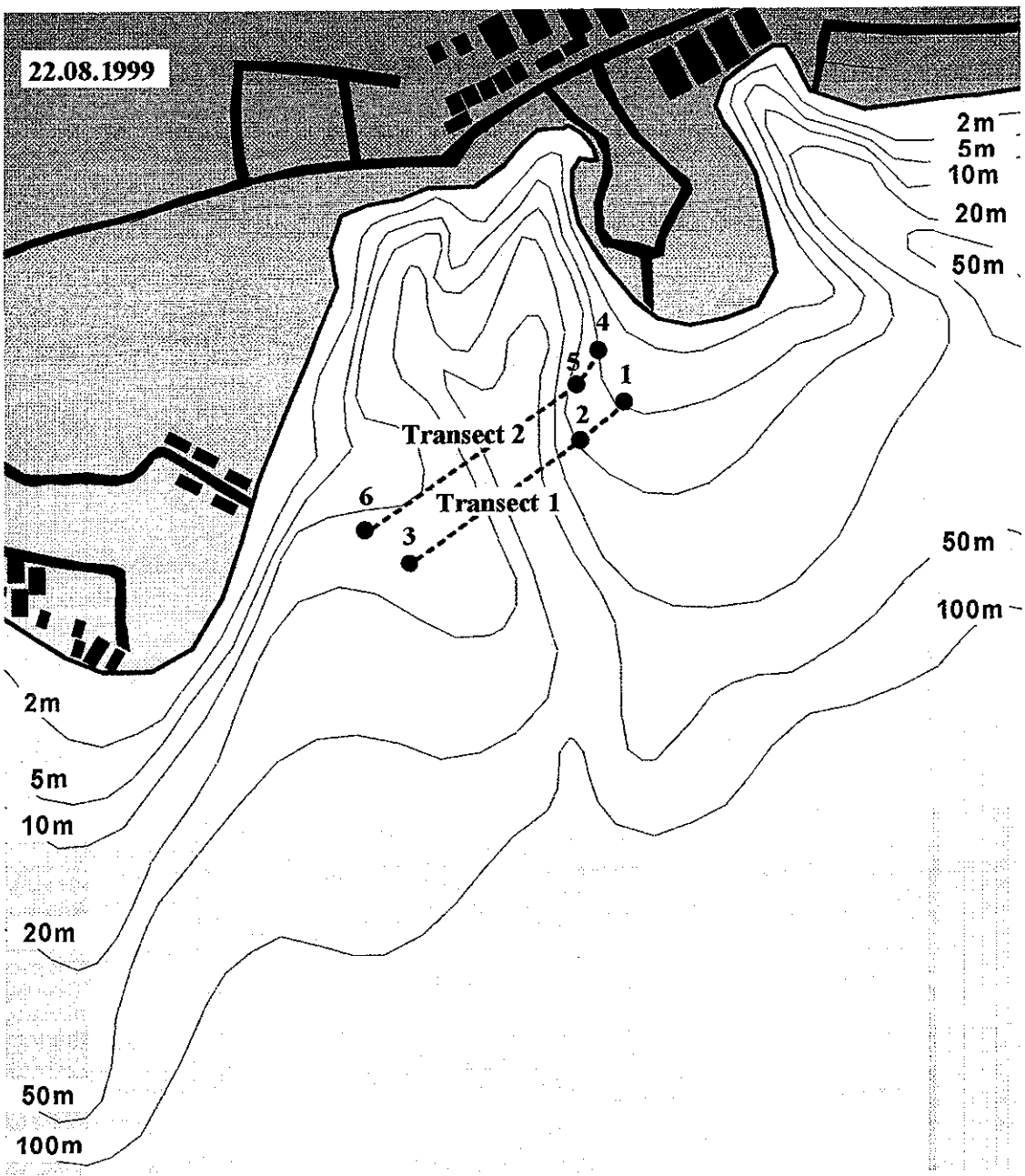
22.08.1999
2m
5m
10m
20m
50m
4
5
1
2
Transect 2
6
Transect 1
3
50m
100m
2m
5m
10m
20m
50m
100m

Fig.3.

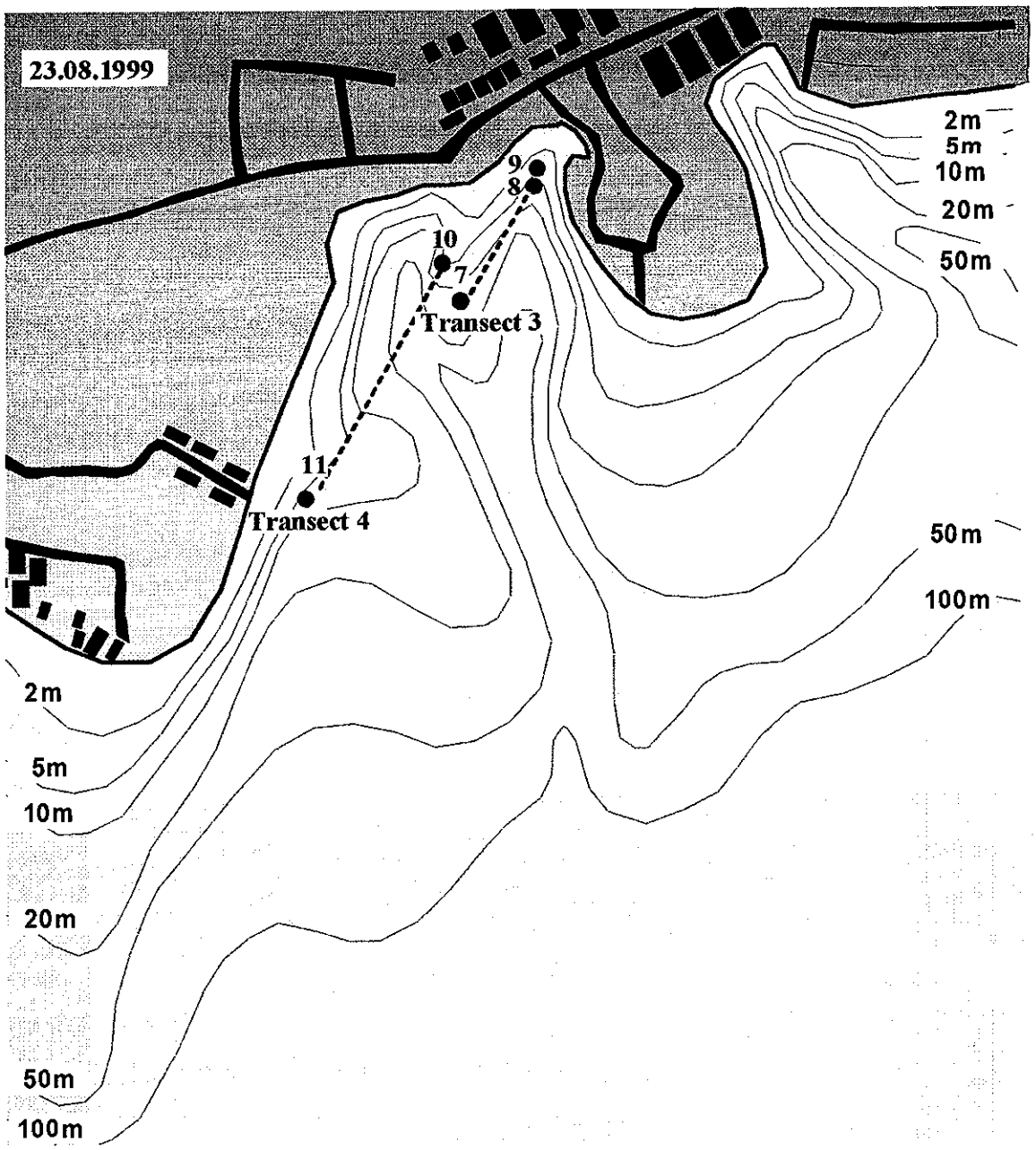
23.08.1999
2m
5m
10m
20m
50m
9
8
10
7
Transect 3
11
Transect 4
50m
100m
2m
5m
10m
20m
50m
100m

Fig.4.

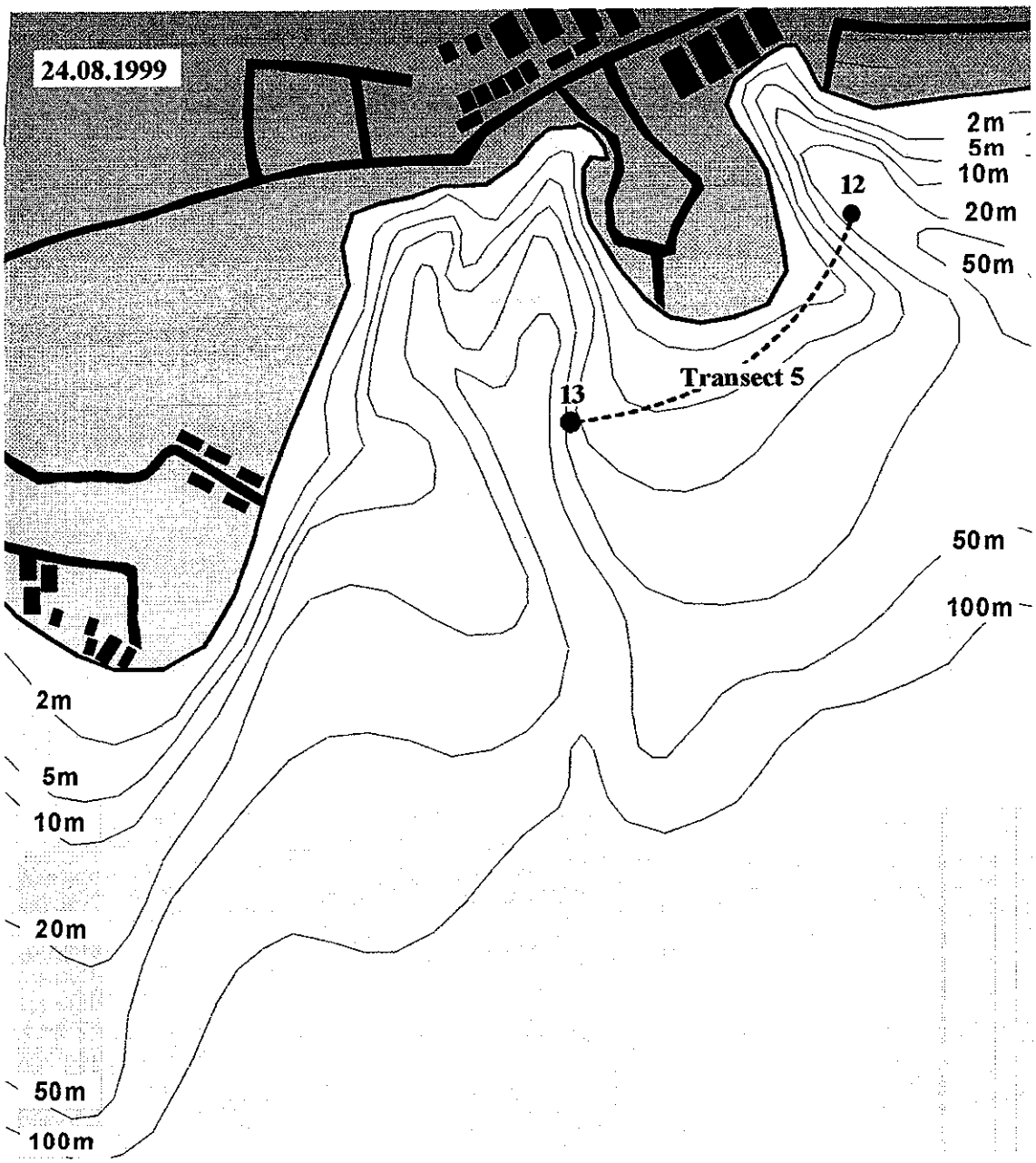
24.08.1999
2m
5m
10m
20m
50m
12
Transect 5
13
50m
100m
2m
5m
10m
20m
50m
100m

Fig.5.

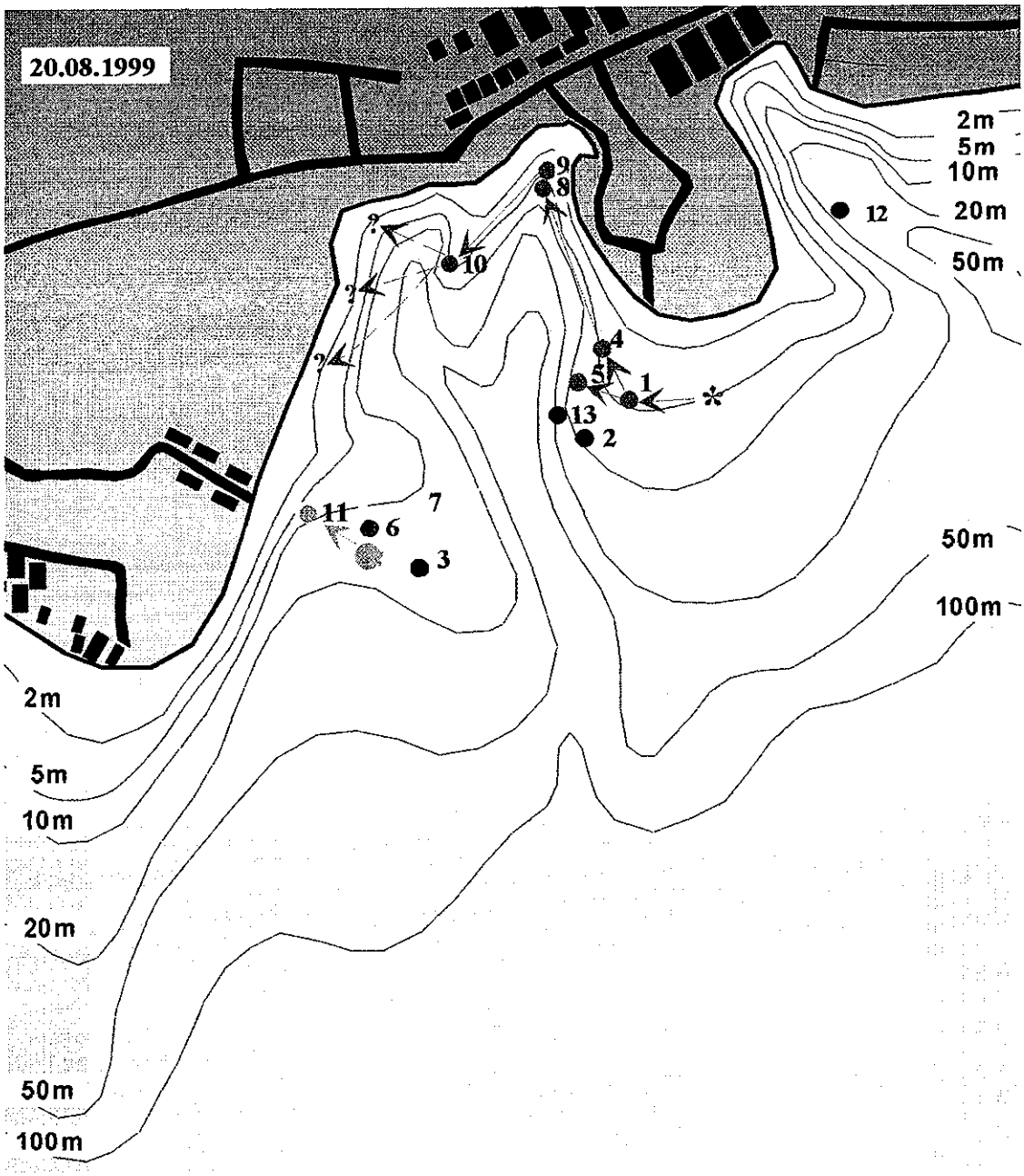

Fig.6.

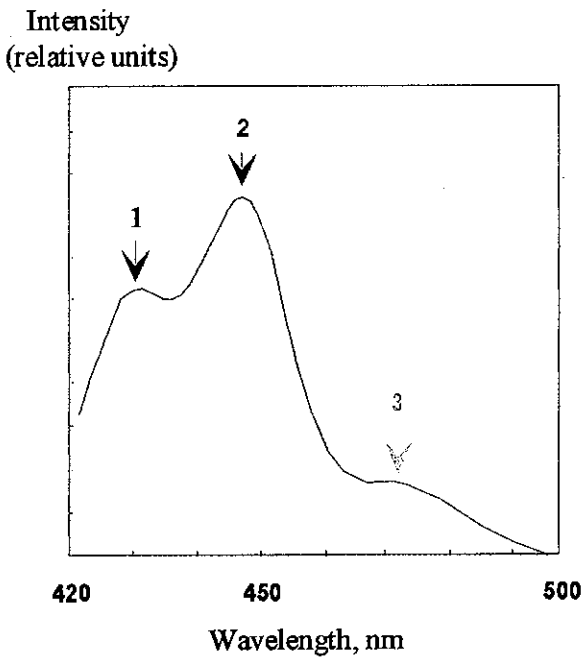

Fig. 7. Emission spectrum of three differently tagged FT particles.
Peak heights of 1-rhodamine, 2-anthracene, 3-eosine.

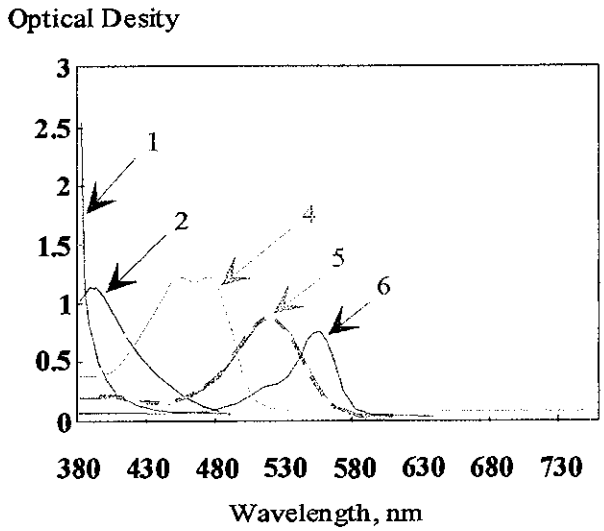

Fig. 8. Absorbtion spectra of different dyes used for tagging sediment particles.
1-anthracene, 2-primulin, 3-auramine, 4-fluorescine, 5-eosin, 6-rhodamine