Journal of International Scientific Publications: Ecology and Safety
Volume 8, ISSN 1314-7234 (Online), Published at: http://www.scientific-publications.net

URBANIZATION IMPACT ON THE RIVERS IN THE ALMATY CITY

Nadir Sh. Mamilov, Farkhad Kh. Khabibullin, Nailya A. Ibragimova,
Anvar Sh. Mamilov, Timofey P. Kostyuk
Institute of Biology and Biotechnology, al-Farbi av.71, 050038 Almaty, Kazakhstan

Abstract

The Almaty city was built as a stronghold in the foothills of Alatau mountains (Northern Tien Shan) in 1854. Nowadays more than 1.5 million citizens inhabit here and urbanized area rapidly increases. Hydrochemical analysis as well as analysis of fish diversity and fish population state were provided. Irregular changes in water composition and increase of microbial biomass were revealed in the urban rivers. Drastic alteration in the fish diversity, significant changes in the morphology and biology of naked osman and spotted stone loach were revealed as well as pathologies of fish gills, liver and kidneys.

Key words: *urbanization, hydrochemical, fish, diversity, pathology*

1. INTRODUCTION

Investigation and monitoring of animals at the urban territories is necessary for keeping friendly environment for human as well as for native diversity conservation. The Almaty city (Alma-Ata) was built as a stronghold in the foothills of Alatau (Northern Tien Shan) in 1854. The number of the citizens had reached 1.5 million to the end of the XX-th century. The urbanization took irreversible negative impact on the nature after exceeding 450 thousands citizens (Slaschev, 1990).

The Almaty city is encircled with mountains from south-east, south and south-west sides that bar of air circulation. Therefore the air pollution often is extremely high after automobile, industrial and household smog. The main part of pollutants came from automobiles. About 70% of all anthropogenic air pollutants remain on the territory of the city. Hence the Almaty is the source of pollution the city rivers with heavy metals and other anthropogenic pollutants (Amirbekova, 1990; Baigeldiev and Kurmankozhaev, 1993). All rivers belong to the Ili River basin and the Balkhsh Lake watershed.

Hydrological system of the watershed was geologically formed relatively recently – about several millions (up to 10,000) years ago, therefore the first fauna had been formed by fish species penetrated from mountain rivers of Tian Shan and rivers from North. Following isolation of the Balkhash watershed have formed here a stable complex from several fish species (Mitrofanov 1986), as Balkhash marinka *Schizothorax argentatus argentatus*, Ili marinka *Sch.argentatus intermedius*, scaled osman *Diptychus maculatus*, naked osman *Gymnodiptychus dybowskii*, minnow *Phoxinus phoxinus*, Seven River's minnow *Ph.brachyurus*, Balkhash minnow *Lagowskiella poljakowii*, spotted stone loach *Triplophysa strauchii*, plain stone loach *T. labiata*, Thibet stone loach *T.stoliczkai*, grey stone loach *T.dorsalis*, Severtzov's stone loach *Nemacheilus sewerzowii* and Balkhash perch *Perca schrenkii*.

The distinctive character of the indigenous fish population in the Lake Balkhash basin made it possible to distinguish it as the Balkhash district within the ichthyogeographical province of the same name contained in the Upland Asian subregion (Berg, 1962; Mitrofanov, 1986). In the second half of the 20th century, the introduction of alien species resulted in formation of new ichthyocenoses in Lake Balkhash and the Ili River and displacement of indigenous species (Mitrofanov and Dukravets, 1992).

Available data collected by I.V.Glukhovtsev et al. (1988) allow to trace changes in fish diversity of the Almaty city during last 25 years. Disastrous state of environment in the Almaty city, high endemism of the native fish fauna of Balkhash basin and problem of it conservation define actuality of such investigation.

2. MATERIALS AND METHODS

This work is based on the results of analysis of fish samples collected in 1998–2013 at the same places on the rivers Malaya Almatinka and Bolshaya Almatinka and sometimes at the rivers Esentay (Vesnovka), Terenkara and some rivers out of the city were investigated (Fig.1).

According to the classification by Zaikov (1946) most of the rivers studied belong to the rivers of the so-called Tien-Shan type with a spring–summer flood caused by snow and glacier melting and rainfalls. Underground waters also contribute appreciably to the river feed. The Malaya Almatinka and Bolshaya Almatinka rivers flow through the city of Almaty and differ greatly from the other rivers in the basin by a high concentration of pollutants (Olin and Baishev, 2001). The fish were caught with a fine-meshed dragnet 15 m long with a 3 mm mesh, a rectangular landing net 500 × 700 mm with a 3 mm mesh.

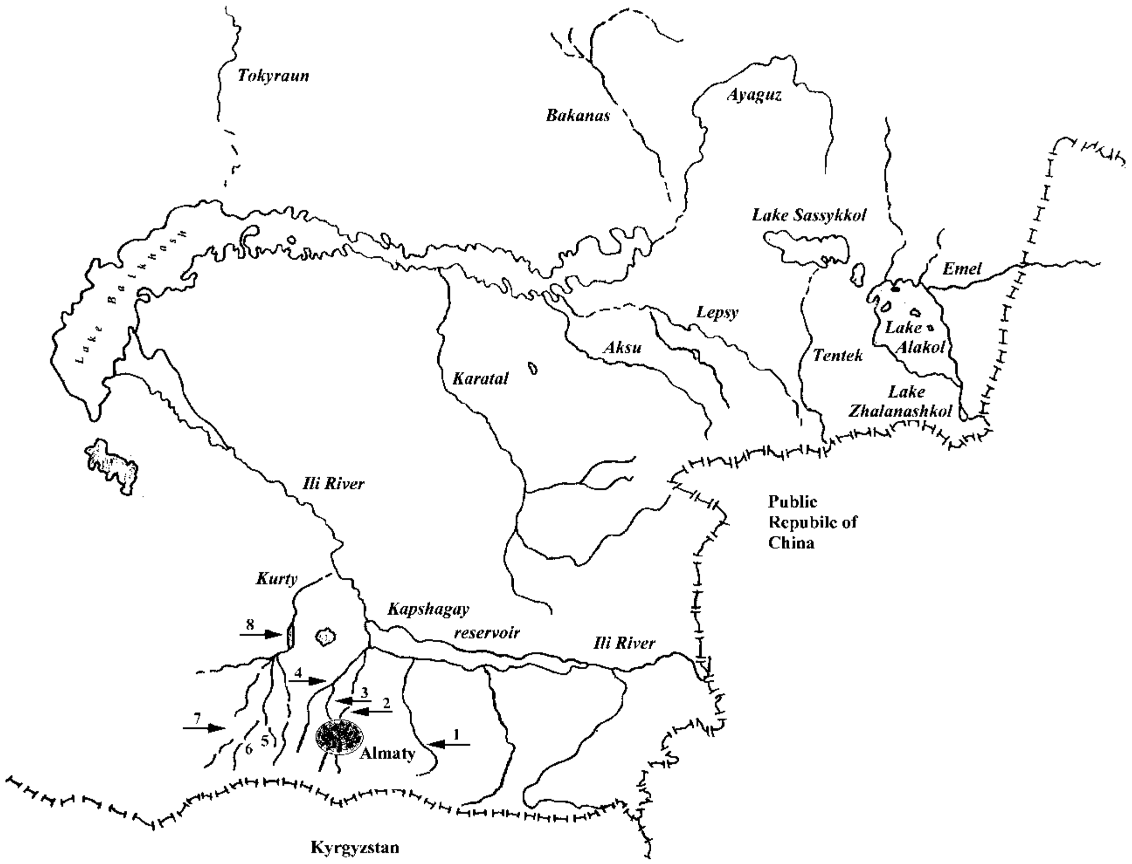

Fig. 1 – Investigated area. Rivers numbered as: 1 – Turgen, 2 – Malaya Almatinka, 3 – Bolshaya Almatinka (Esenaty and Terenkara between them), 4 – Kaskelen, 5 – Kargayly, 6 – Karasu, 7- Samsy, 8 - Kurty

Concentrations of some heavy metals (HM) in water samples were measured by inductively coupled plasma spectroscopy-mass spectrometry method (Thomas, 2003; Dean, 2005).

Analysis of microbiological and biochemical properties was conducted in sediments of the following small rivers in Almaty district: Samsy, Kaskelen, Karasu and Kargaly. A number of randomized set of sub-samples were used to obtain few composite samples for analyses in laboratory.

Total microbial respiration rate in the sediments was measured on the base of CO_2 production rate. Samples of sediments equivalent to 5 g dry weight were incubated for 24 hours hermetically sealed in 15 ml glass flasks. The amount of CO_2 produced during this time was measured by gas-chromatography (Heilman and Beese, 1992). Total microbial biomass was measured by substrate-induced respiration (SID) (Anderson and Domsch, 1978) modified according to (West and Sparling, 1986; Mamilov et al., 2000). Concentration of total organic matter in sediments was determined by dichromate digestion method (Greenberg et al., 1992). Standard deviations of the difference of the mean were calculated for all data. The difference was considered as significant at $P < 0.01$. Analyses were performed using build-in features of 'STATISTICA 5.0' and 'EXCELL 2003' software.

All measurements were made on materials fixed in 4% neutral formalin as it was described by I.F.Pravdin (1966) and J.Holcik (1989). Abnormalities in external and internal constitution were assessed by Yu.S.Reshetnikov et al. (1999) and Yu.V.Chebotareva et al (1999). The age of fish in the samples was determined from analysis of vertebrae scales. In order to confirm these data, additional analysis of operculum was conducted (Tchoughounova 1952; Le Louarn 1992). Index of fluctuating asymmetry (As) was assessed by V.M.Zakharov et al. (2000). Expert assessment of fish state was provided using index of unfavorable state (IUS) according Yu.S.Reshetnikov et al. (1999).

Aquatic pollution impacts first of all on the target organs responsible of the organism detoxication like liver, kidney and gills (Mumford et al., 2007). Hence, control at the tissues and cellular levels is necessary for monitoring of fish state and fish diversity conservation. Gills, livers and kidneys of the spotted stone loach *Triplophysa strauchii* from the Malaya Almatinka river had been collected and prepared according the recommendations of J.D. Bancroft and M.Gamble (2002) and and S.Mumford et al. (2007).

3. RESULTS AND DISCUSSION

Among all analyzed the cleanest water was detected in Turgen river and its upper flow (Table 1). Elevated concentrations of some elements in the river Bolshaya Almatinka from its source to the southern border of the Almaty city clearly suggests anthropogenic contamination. There was observed fast increase in concentration of the analysed elements on the sort distance of the rapidly flowing water that cannot be explained by natural factors. Table 1 shows significant inter-seasonal and inter-annual variations in concentration of metals. The most apparent variations were detected in rivers flowing through the city or suburban areas - rivers Bolshaya Almatinka, Malaya Almatinka, Kaskelen. The lowest concentrations of heavy metals were found in underpopulated remote areas with non-modified landscape (Turgen river) and also in upper flows of the rivers adjacent to the city.

Table 1 – Concentrations of heavy metals in water samples 2006-2012 (10^{-6} g/L)

River	Date	Metal				
		Fe	Cu	Zn	Cd	Pb
Kaskelen (plain part)	July 2006	48,7	1,05	2,20	2,32	0,086
	October 2006	327,5	3,55	8,81	3,10	0,035
	May 2008	140,0	0,82	0,75	<0,01	0,077
	August 2009	140,0	2,31	1,50	3,32	1,300
	May 2010	710,0	7,43	0,66	<0,01	0,047
	May2011	270,0	2,10	0,98	0,02	0,047
	August 2012	18,0	1,10	<0.07	<0.01	0.095
Turgen (upper flow)	September 2006	29,0	1,10	2,10	0,02	<0.010
	October 2006	28,2	0,70	1,50	0,02	0,086
	July 2007	67,0	0,58	6,80	<0,01	0,640
	April 2008	54,0	0,53	0,50	<0,01	0,024
	October 2008	22,0	0,04	0,02	<0,01	0,500
Malaya Almatinka (lower flow in the city)	April 2006	73,0	2,90	5,70	1,90	1,700
	October 2006	47,5	1,05	2,20	1,60	1,730
	May 2007	240,0	1,50	0,93	<0.01	0.210
	September 2007	210,0	1,10	1,00	<0.01	0,220
	April 2008	160,0	0,63	0,66	<0.01	0,014
	September 2008	3,4	0,02	0,03	<0.01	0,730
	July 2011	290,0	3,02	1,70	<0.01	0,024

Bolshaya Almatinka (plain part)	September 2006	19,0	2,10	3,60	1,60	<0.010
	September 2007	480,0	5,40	1,90	<0.01	0,370
	June 2011	200,0	160,0	1,00	<0.01	0,032
Bolshaya Almatinka (upper flow)	September 2007	78,0	0,76	4,20	<0.01	0,610
	September 2008	17,0	0,02	0,01	<0.01	0,490
	December 2009	120,0	2,20	0,36	0,02	0,380
	September 2010	98,0	0,91	0,28	0,03	0,059
	September 2012	11,0	0,78	<0.01	<0.01	0,011
Samsy	June 2011	260,0	3,80	0,87	<0.01	0,028
	July 2012	370,0	4,00	0,70	0,05	0,018

The main sources of heavy metals in mountain and foothill areas are soil erosion and direct contamination due to aerosol transfer and intensive construction of private and public buildings as it was detected in other countries (Alabaster, J.S. and Lloyd, R., Water Quality Criteria for Freshwater Fish . FAO and Butterworths. London, 1980). In contrast, decreasing concentrations of Zn and Pb after the out-flow of the rivers from the urban area can be explained by the precipitation and bioaccumulation of these metals in the urban spots.

Copper and cadmium are toxic heavy metals for fishes, causing heavy poisoning. Iron, lead and zinc are less toxic. Lead is similar to the calcium in the processes of elements precipitation in fish skeleton, while zinc exerts particularly strong impact on the state of gills. Toxicity of iron is determined to the great extent by its forms in fresh waters (Alabaster and Lloyd, 1980).

Ions of Cu, Zn, Hg, and Cd enter in the fish organism predominantly with food (Brown et al., 1990; Bury et al., 2003). However, uptake from water also plays an important role (Sastry and Gupta, 1979), especially if micronutrients are deficient in food while concentrations of waterborn HM are high (Kamunde et al., 2002).

HM accumulate in many intern organs. Supporting structures and gill mostly accumulate waterborn HM, while stomach, pyloric appendages and intestine accumulate food-associated elements (Chowdhury et al., 2005). Most often highest concentrations of HM are found in fish liver, kidney, gills (Farkas et al., 2003), and in some cases in the gut (Chowdhury et al., 2005). Abiotic and biotic factors may considerably change toxicity and bioavailability of HM for aquatic organisms (Mason et al., 2000; Taylor et al., 2000; Straus, 2003). Resistance to metal effects depends on the fish species and usually increases with age (Kuroshima et al., 1993). As a rule HM toxicity for aquatic organisms increases if water hardness and pH drop down, and water temperature rises (Clearwater et al., 2000; Straus, 2003).

The rate of microbial colonization was significantly different in sediments from analysed rivers. The highest values of microbial biomass were detected in sediments of the lower flow of the Kaskelen river. In general, there were substantially lower values in the upper flows of the following small rivers: Kargaily, Karasu, Samsy and Kaskelen. Notably, the total microbial biomass was more than 3 times lower in the Samsy river. In the upper flow of the considered rivers the highest values were detected in the Kaskelen river, apparently suggesting strong eutrophication of this ecosystem. There were no significant differences among other rivers Kargaily, Karasu and Samsy.

The rate of CO_2 production by sediments was almost twice lower in the upper flows of the considered rivers than in the middle flow of the Kaskelen river. The fact is most probably related to the higher content of dissolved organic matter in sediments of the middle flows (Fig. 2).

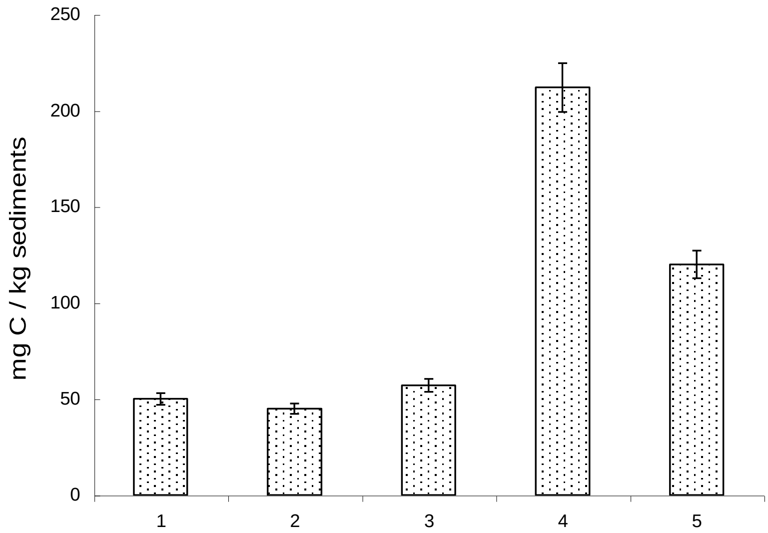

Fig. 2. – Dissolved organic matter in sediments of small rivers in Almaty district: 1 – Kargaily, 2-Karasu, 3-Kaskelen (upper flow), 4-Kaskelen (middle flow), 5-Samsy. Bars represent the values of standard deviations, n=3.

Relatively low values in the upper flows of the Kargaily, Karasu and Kaskelen rivers suggest that these ecosystems are quite oligotrophic. The values increasing towards the lower flow are most probably related to the accumulation of organic matter along the river.

Data on the fish diversity and it changes in the investigated rivers are presented in the table 2. Comparison with the data 1985-1987 (Glukhovtsev et al., 1988) revealed such reorganizations in the fish communities in the Bolshaya Almatinka and Malaya Almatinka rivers:

1. Fish diversity grew in the Bolshaya Almatinka at the section of river situated in the low part of the city. Naked osman, minnow, abbottina and loaches had been revealed there.

2. Balkhash minnow disappeared and beautiful sleeper revealed in the fish fauna of the Malaya Almatinka river.

Table 2 - Changes of fish diversity in the Bolshaya Almatinka and Malaya Almatinka rivers during 1988-2013

Fish species	1988 (Glukhovtsev et al., 1988)		1998-2001		2002-2013	
	BA	MA	BA	MA	BA	MA
Indigenous fish species:						
Seven River's minnow - *Phoxinus brachyurus* Berg, 1912	+	+	0	+	0	+
Balkhash minnow - *Rhynchocypris poljakowii* (Kessler, 1879)	+	+	+	0	+	+
Gray stone loach - *Triplophysa dorsalis* (Kessler, 1872)	0	0	+++	+++	++	++
Tibetan stone loach - *Triplophysa stoliczkai* (Steindachner, 1866)	0	0	+	+	+	+
Spotted gubach - *Triplophysa strauchii* (Kessler, 1874)	++	++	++	+++	+++	+++
Plain thicklip loach - *Triplophysa labiata* (Kessler, 1874)	++	++	+	0	+	+

Severtsov's stone loach - *Nemacheilus sewerzowii* G. Nikolsky, 1938	0	0	+	0	0	+
Scaleless (naked) osman - *Gymnodiptychus dybowskii* (Kessler, 1874)	+	+	++	++	++	+++
Balkhash marinka - *Schizothorax argentatus* Kessler, 1874	0	+	0	+	0	+
Balkhash perch - *Perca schrenkii* Kessler, 1874	0	0	0	+	+	+

Key: BA - Bolshaya Almatinka, MA - Malaya Almatinka, +++ numerous species, ++ usual but not numerous species, + rare species, 0 species was not found

Continuation of the table 2

Fish species	1988 (Glukhovtsev et al., 1988)		1998-2001		2002-2013	
	BA	MA	BA	MA	BA	MA
Alien fish species:						
White amur (grass carp) - *Stenopharyngodon idella* (Valenciennes, 1844)	0	+	0	+	0	+
Stone moroco - *Psedorasbora parva* (Temmincket Schlegel, 1846)	+++	+++	++	++	+++	++
Abbottina - *Abbottina rivularis* (Basilewsky, 1855)	++	+	+	+	++	++
Amur bitterling – *Rhodeus sericeus* (Pallas, 1776)	0	0	0	0	+	+
Sawbelly - *Hemiculter leucisculus* (Basilewsky, 1835)	0	0	0	0	+	+
Silver carp - *Hypophthalmichthys molitrix* (Valenciennes, 1844	0	+	0	+	0	+
Crucian carp - *Carassius gibelio* (Bloch, 1782)	+	+	0	+	+	+
Carp - *Cyprinus carpio* Linnaeus, 1758	0	+	0	+	+	+
Chinese medaka - *Orizias sinensis* Chen, Uwa et Chu, 1989	0	0	0	0	+	+
Sander - *Sander lucioperca* (Linnaeus, 1758)	0	0	0	0	0	+
Beautiful sleeper - *Micropercops* (*Hypseleotris*) *cinctus* (Dabry et Thiersant, 1872)	+	0	+	++	+	++
Amur goby - *Rhinogobius* (*Ctenogobius*) *similes* Gill, 1859	+	+++	+	+	++	++
Amur snakehead - *Channa argus warpachowskii* (Berg, 1909)	0	0	0	0	0	++

In whole, results of our investigation revealed shortage of distribution area for many of indigenous fish species. Data on the last findings of some indigenous fish species in the investigated area are presented in the table 3. Shortage of distribution area occurs relatively slow for naked osman, spotted stone loach, grey stone loach. But living area drastic decreases for marinka, Severtsov's stone loach, Seven River's minnow and Balkhash minnow, Balkhash perch.

Table 3 - Years of the last findings of rare indigenous fishes in the investigated area

Виды рыб	Water bodies			
	The Kurty water reservoir and Kurty river after it	Kaskelen River	Bolshaya Almatinka River	Malaya Almatinka River
Seven River's minnow	Was not found	2006	2008	2012
Balkhash minnow	Was not found	2006	2006	2007
Balkhash marinka	1994	2013	2003	2006
Ili marinka	1988*	2006	Was not found	2001
Tibetan stone loach	2003	2010	2006	2005
Plain thicklip loach	2010	2008	2007	2003
Severtsov's stone loach	Was not found	2007	2001	2006
Balkhash perch	1996	2007	2006	2006
*After Baimbetov et al., 1988				

Negative human impact on the rivers of the city increased during last 25 years after the first well-grounded investigation provided by I.Glukhovtsev and al. (1988). Nowadays, not the Vesnovka (Esentay) River only but all of the rivers in the city and near of it were turned in dumps. During investigation period we could never investigate number and diversity of baby fishes in the city rivers because the nets with small mesh size were clogged up with different litter during a too short time.

Pollution of the City Rivers had negative impact on the fish state. The maximal lifespan of the naked osman in our samples was 6 years that significantly less than the known maximal lifespan for this species (Sidorova and Timirkhanov, 1988). Young fishes were dominants in the samples of loaches and maximal lifespan 6 years was less that known for these species too (Martekhov, 1963). Therefore negative human impact conducted to shortage of lifespan of indigenous fishes.

The results of morpho-pathological analysis confirmed unfavorable fish state from the Bolshaya Almatinka and Malaya Almatinka Rivers (table 4). Adult health exemplars were not found in both the rivers. There are differences in as and level of pathologies between osaman and loaches from the same river. That can reflect differences of their life-styles because loaches are typical bottom dwellers and naked osman is a pelagic fish species. Increase of pathologies according to age was observed in the both groups that indicated to chronic intoxication after water pollution.

Histological analysis of gill, liver and kidney of spotted stone loach (*Triplophysa strauchii*) form the Malaya Almatinka River was done. Revealed gill pathologies are presented at the figure 3. Types of cells were not possible to differentiate in the primary gill epithelium because of marked hypertrophy and hyperplasia of cells; mucous cells were observed in almost all layers. The edema was observed. Over the entire lamella length marked expansion of the intracellular space between the layers of respiratory cells. Mucous cells were found along the entire length. Hyperemia of the supporting cells, focal adhesions of adjacent lamellae were found too.

Table 4 - The results of morpho-pathological analysis of some fishes

River	Fish species	IUS		As	% of pathologies in		
		lim	M		heart	liver	kidney
Bolshaya Almatinka	Naked osman (n=19)	3-5	2.4	0.1	63	21	63
	Spotted stone loach (n=30)	1-5	2.8	0.4	96	66	20
Malaya Almatinka	Naked osman (n=31)	1-4	1.9	0.1	77	19	32
	Spotted stone loach (n=14)	1-4	2.3	0.5	85	64	7
	Grey stone loach (n=11)	1-5	1.8	0.4	72	36	18
lim – limits, M – mean							

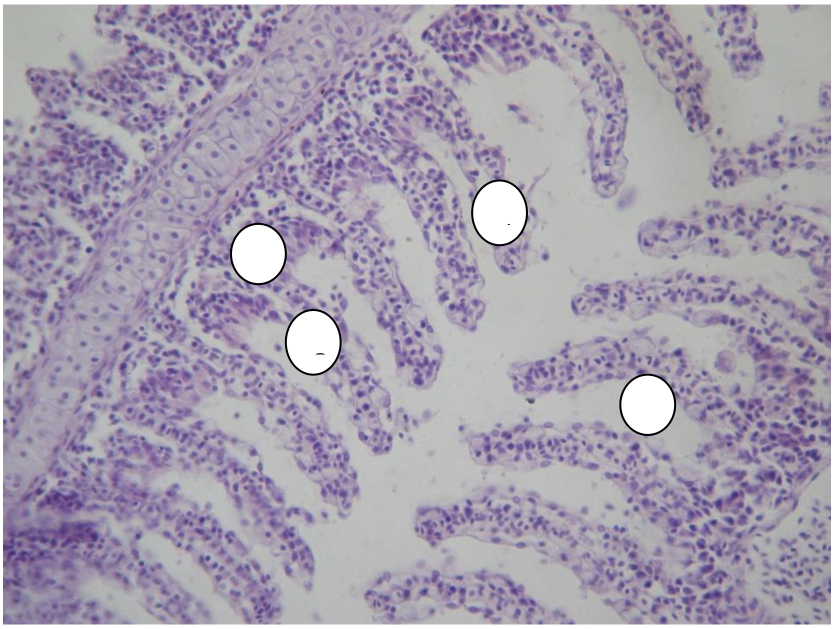

Fig.3 - Histostructure of gills of spotted stone loach that lives in Malaya Almatinka

1 - expansion of the intracellular space, 2 - mucous cells, 3 - edema

coloring: hematoxylin-eosin, ×200

Microscopic study of the liver revealed fatty degeneration of the liver cells (Fig.4). Hepatocytes staining with hematoxylin-eosin look exhausted. Along with atomized steatosis there were small fatty fields formed due to gaps in their hepatocytes overflow fat. Nuclei in the surviving hepatocytes offset large drops of fat on the periphery. Sinusoids were extended and full-blooded, the activation of Kupffer cells. Slight thickening of the connective tissue capsules of pancreatic acini and splenic part of hepatopancreas as well as interstitial and perivascular edema were observed.

For the kidneys of spotted stone loach generalized leukocyte infiltration, pronounced stromal edema were found (Fig.5). Glomeruli stretched, adhesions with a parietal layer of the capsule, the proliferation of the epithelial layer of the capsule and the absence of urinary space were revealed. There was a phenomenon of peri glomerular sclerosis and phenomena of glomerul nephritis wrinkling of glomeruli. The proliferation of mesangial matrix was in glomerular. Swollen hinges of capillaries with thickened walls were narrowed; in singly extended capillaries were detected leukocytes. Generalized membranous proliferative changes of kidney vascular glomeruli as well as dystrophies and necrobiotic changes of tubules were observed.

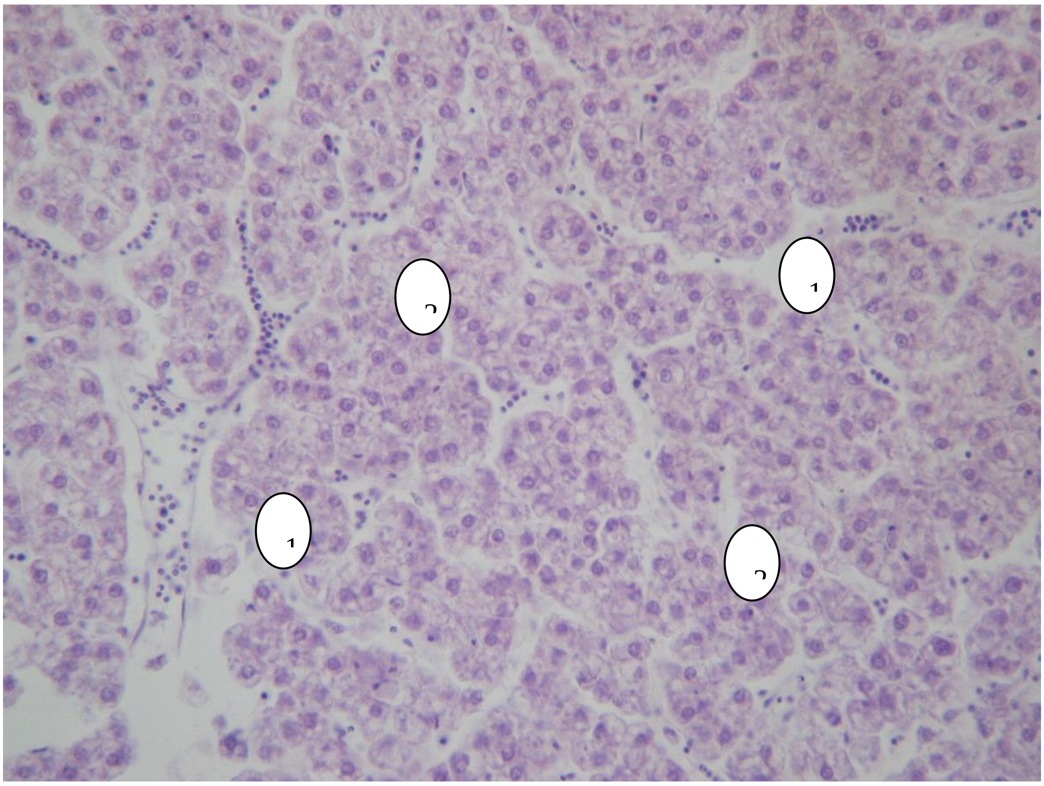

Fig.4 - Histostructure of liver of spotted stone loach that lives in Malaya Almatinka
1- expansion and hyperemia of sinusoids, 2 - atomized steatosis of hepatocytes
coloring: hematoxylin-eosin, ×200

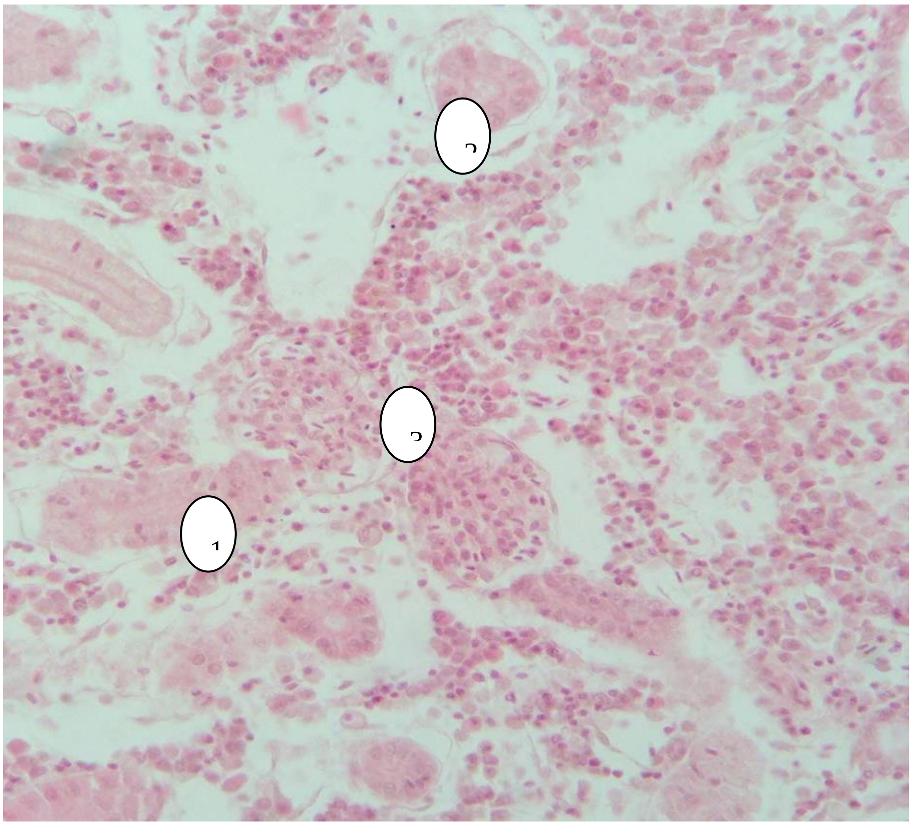

Fig. 5 - Histostructure of kidneys of spotted stone loach that lives in Malaya Almatinka
1 – proximal tubule, 2 – distal tubule, 3 – glomerulus, absence of urinary space
coloring: hematoxylin-eosin, ×200

4. CONCLUSION

Reduced abundance and shrinking water-bodies harbouring indigenous fish species together with morpho-pathological analysis of naked osman and loach sampled in the rivers Bolshaya Almatinka and Malaya Almatinka suggest unfavourable environmental conditions. Thus, the proposed more than 25 years ago recommendations (Glukhovtsev et al., 1988) are still acceptable and even became more actual. It is strongly required to clean up the river channels and block inflows of urban waste-waters. It is essential to keep the water protecting regime and restore the natural landscape adjacent to water bodies.

ACKNOWLEDGMENTS

We are thankful to Dr. Balabieva G.K., A.S.Linnik, D.A.Gapparova, G.S.Koishybaeva, N.N.Tulkibaeva, D.K.Bekkozhaeva and A.S.Salimbaeva for their helps in the fishes collecting.

This investigation was supported by Committee of Science of the Republic of Kazakhstan (grant No 0159).

REFERENCES

Alabaster, J.S. and Lloyd, R., Water Quality Criteria for Freshwater Fish. FAO and Butterworths. London, 1980.

Amirbekova R. 1990. Smog over city. Avtomobilniy transport Kazakhstana. - №9:36 (in Russian)

Anderson, J.P.E., Domsch, K.H. A physiological method for the quantitative measurement of microbial biomass in soils // Soil Biology and Biochemistry – 1978. V. 10. P. 215-221.

Baigeldiev U., Kurmankozhaev A. 1993. System assessments and decisions on the regulation of ecological status of the city. An analytical review. Alma-Ata. 110 p. (in Russian)

Baimbetov A.A., V.P. Mitrofanov and S.R.Timirkhanov. 1988. *Schizothorax argentatus* Kessler – Balkhash marinka. *In:* E.V.Gvozdev and V.P.Mitrofanov (eds.). Fishes of Kazakhstan. Alma-Ata, Nauka. V.3. P.57-83. (in Russian)

Bancroft J.D., Gamble M. 2002. Theory and Practice of Histological Techniques. - Churchill Livingstone. Elsevier Science. 796 p.

Berg, L.S., Division of Paleoarctic and Amur District into Zoogeographical Regions on the Basis of Freshwater Fish Distribution, in Izbrannye trudy (Selected works), Leningrad: Akad. Nauk SSSR, 1962, vol. 5, pp. 320–363. (in Russian)

Brown, D.A., Bay, S.M., and Hershelman, G.P., 1990. Exposure of Scorpionfish (*Scorpaena guttata*) to Cadmium: Effects of Acute and Chronic Exposures on the Cytosolic Distribution of Cadmium, Copper and Zinc, *Aquat. Toxicol.*, 16:4:295–310.

Bury, N.R., Walker, P.A., and Glover, C.N. 2003. Nutritive Metal Uptake in Teleost Fish, *J. Exp. Biol.* 206:1:11–23.

Chebotareva Yu.V. et al. – Чеботарева Ю.В., Савоскул С.П., Пичугин М.Ю., Савваитова К.А., Максимов С.В. Характеристика аномалий в строении внешних и внутренних органов у рыб// Разнообразие рыб Таймыра. – М.: Наука. 1999. С.142-146.

Chowdhury, M.J., Baldisserotto, B., and Wood, C.M., Tissue-Specific Calcium and Metallothionain Levels in Rainbow Trout Chronically Acclimated to Waterborne or Dietary Cadmium., *Arch. Environ. Contam. Toxicol.*, 2005, vol. 48, no. 3, pp. 381–390.

Clearwater, S.J., Baskin, S.J., Wood, C.M., and McDonald, D.G., Gastrointestinal Uptake and Distribution of Copper in Rainbow Trout, *J. Exp. Biol.*, 2000, vol. 203, no. 16, pp. 2455–2466

Dean J.R. 2005. Practical inductively coupled plasma spectroscopy (Analytical techniques in the Sciences (ants) – N.Y.: John Wiley & Sons,– 208 p.

Farkas, A., Salanki, J., and Specziar, A. 2003. Age- and Size-Specific Patterns of Heavy Metals in the Organs of Freshwater Fish *Abramis brama* L. Populating a Low-Contaminated Site, *Water Res.*, 37: 5: 959–964

Glukhovtsev, I.V., Dukravets, G.M., Karpov, V.E., and Mitrofanov, V.P. 1988. Composition and Modern State of Ichthyofauna, in *Pozvonochnye zhivotnye Alma_Aty (fauna, razmeshchenie, okhrana)* (Vertebrate Animals of Alma-Ata (Fauna, Location, Protection)), Alma-Ata: Nauka. Pp. 187–198. (in Russian)

Greenberg AE, Cleseeri LS, Eaton AD 1992: Standard methods for examination of water and wastewater. 18th Edition, American Public Health Association, Washington DC.

Heilman B., Beese F. 1992. Miniaturized method to measure carbon dioxide production and biomass of soil microorganisms. *Soil Science Society of America Journal* – 56:596-598.

Holcik J. 1989. General introduction to fishes. 2. Determination criteria// The freshwater Fishes of Europe – Aula-Verlag Wiesbaden.– Vol.1. Part 2. P.38-58

LeLouarn, H., 1992. Comparaison entre les ecailles et d`autres structures osseuses pour la determination de l`age et de la croissance. In: Tissus durs et age individuel des vertebres. Paris: ORSTOM-INRA. 325-334

Kamunde, C.N., Grosell, M., Higgs, D., and Wood, C.M. 2002. Copper Metabolism in Actively Growing Rainbow Trout (*Oncorhynchus mykiss*): Interactions Between Dietary and Waterborne Copper Uptake, *J. Exp. Biol.*, 205:2:279–290.

Kuroshima, R., Kimura, S., Date, K., and Yamamoto, Y., 1993. Kinetic Analysis of Cadmium Toxicity to Red See Bream, *Pagrus major*. *Ecotoxicol. Environ. Safety*, 25:3:300–314.

Mamilov A.Sh., Byzov B.A., Stepanov A.L., Zvyagintsev D.G., 2000. Measurement of fungal and bacterial biomass in soil amended with plant residues. Eurasian Soil Science, 33:12:1282-1286.

Martekhov P.F. 1963. - Мартехов П.Ф. 1963. Гольцы Балхашской провинции и их биоценотическое и хозяйственное значение// Вопросы рыбного хозяйства Казахской ССР. – Алма-Ата. – Вып.4. – С.124-151

Mason, R.P., Laporte, J.M., and Andress, S. 2000. Factors Controlling the Bioaccumulation of Mercury, Methylmercury, Arsenic, Selenium, and Cadmium by Freshwater Invertebrates and Fish, *Arch. Environ. Contam. Toxicol.*, 2000, vol. 38, no. 3, pp. 283–297.

Mitrofanov, V.P. 1986. Formation of the modern fish fauna of Kazakhstan and icthyogeographical demarcation. Pp.20-40. *In: E.V.Gvozdev and V.P.Mitrofanov (eds.). Fishes of Kazakhstan. V.1. Nauka. Alma-Ata.* (in Russian)

Mitrofanov, V.P. and Dukravets, G.M. 1992. Some Theoretical and Practical Aspects of Fish Acclimatization in Kazakhstan. *In: E.V.Gvozdev and V.P.Mitrofanov (eds.). Fishes of Kazakhstan. Alma-Ata: Gylym, vol. 5, pp. 329–371*.

Mumford S., J. Heidel, Ch. Smith, J. Morrison, B. MacConnell and V. Blazer. 2007. Fish Histology and Histopathology. USFWS-NCTC. 359 p.

Olin, Yu.A. and Baishev, K.S. 2001, *The State of Small Rivers as Sources of Drinking Water Supply and Health of Population of the City of Almaty*, Vestnik KazGU, Seriya Ekologicheskaya, 1: 80–85.

Pravdin, I.F., 1966. Handbook on the techniques in fish studies. Pischevaya Promyshlennost', Moscow. 376 p. (in Russian)

Slaschev V.S. - Слащев В.С. 1990. Пути формирования урбанизированных структур Прибалхашья. *Научно-технические проблемы освоения природных ресурсов и комплексного развития производительных сил Прибалхашья: Материалы научной конференции. 3 секция – Алма-Ата: Наука. С.145-147.*

Tchoughounova, N.I., 1952. Methods of fish age and grow investigation. Pischevaya Promyshlennost', Moscow. 115 p. (in Russian)

Thomas R. 2003. Practical guide to ICP-MS (Practical spectroscopy).- N.Y.: Marcel Dekker – 336 p.

Zaikov, B.D., 1946. The Mean Runoff and Its Distribution in the USSR Territory. In: *Trudy nauchno-issled. uchrezhd. Gidromet. Sluzhby* (Proceedings of Research Institution Gidromet Service), Leningrad, 1946. (in Russian)

Reshetnikov Yu.S., O.A.Poppova, N.A.Kashulin, A.A.Lukin, P.-A.Amundsen, F.Staldvik. 1999. Estimating the favorable state of a fish community using morphopathologic analysis of fishes. // Advances in current biology. №2. P.165-177. (in Russian)

Sastry, K.V. and Gupta, P.K., The Effect of Cadmium on the Digestive System of the Teleost Fish, *Heteropneustes fossilis*. *Environ. Res.*, 1979, vol. 19, no. 2, pp. 221–230.

Sidorova A.F. and S.R.Timirkhanov. 1988. Diptychus dybowskii Kessler – naked osman. In: E.V.Gvozdev and V.P.Mitrofanov (eds.). Fishes of Kazakhstan. Alma-Ata: Nauka. V.3. - P.93-105. (in Russian)

Straus, D.L., The Acute Toxicity of Copper to Blue Tilapia in Dilutions of Settled Pond Water, *Aquaculture*, 2003, vol. 219, no. 1–4, pp. 233–240.

Taylor, L.N., McGeer, J.C., Wood, C.M., and McDonald, D.G. 2000. Physiological Effects of Chronic Copper Exposure to Rainbow Trout (*Oncorhynchus mykiss*) in Hard and Soft Water: Evaluation of Chronic Indicators, *Environ. Toxicol. Chem.*, vol. 19, pp. 2298–2308.

West A. W, Sparling G. P. 1986. Modifications to the substrate induced respiration method to permit measurement of microbial biomass in soil of differing water contents. *Journal of Microbiological Methods* – 5:2:177-189

Zakharov V.M. et al., 2000 – Захаров В.М., Баранов А.С., Борисов В.И., Валецкий А.В., Кряжева Н.Г., Чистякова Е.К., Чубинишвили А.Т. 2000. Здоровье среды: методика оценки – М.: Центр экологической политки России. 2000. 68 с.