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Ecosystems of Lake Sevan Basin's Rivers in Armenia

Eugenie A. Kachvoryan, Astghik Z. Pepoyan, Maria V. Harutyunova, and Anahit M. Manvelyan

***Abstract*—**Taking into account the importance of Lake Sevan and Lake Sevan basin's rivers for Armenian economy, the main goals of our investigations were the documentation of water quality and the biodiversity of invertebrates developed in Lake Sevan basin's rivers and selected tributaries.

Moderately satisfied ecological condition for the biodiversity of Lake Sevan basin's rivers has been established, and the changes in species' composition of zoobenthos in Lake Sevan were detected.

A growing tendency of antibiotic resistance among *E. coli* isolates in water resources has been shown.

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***Keywords*—**Biodiversity, ecosystem, Lake Sevan, water-quality, zoobenthos.

I. INTRODUCTION

THE effects of climate, economical and social changes on the abundance and timing of species were reported in numerous ways [15]. Climate changes and increasing average annual temperature have great influences on terrestrial and aquatic ecosystems in the recent years. Tendencies of change in average temperature have deep influences on species composition in lakes even rather short periods of 10-15 years [2]. On the other hand, the pollution of natural waters by agricultural and domestic sources is a critical problem for Armenian ecosystem. For the past 10 years, intensive land reclamation, as well as uncontrolled building of reservoirs for fish breeding, has negatively affected streams and rivers here. As a result, the courses of the rivers have changed and so, too, have the physicochemical characteristics. In addition, the local and global changes have brought the changes in bacterial composition of water and surrounded ecosystems along [12].

The composition of the aquatic fauna, of which invertebrate animals are the dominant elements, is related to water quality, and the presence and abundance of invertebrate animals and antibiotic resistance spreading in gut commensal bacteria in communities close to rivers' regions are good indicators of the ecological conditions of the rivers [1].

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Eugenie A. Kachvoryan is with the Institute of Molecular Biology, Yerevan, 0044, Armenia.

Astghik Z. Pepoyan is with the Armenian State Agrarian university, Yerevan, 0009, Armenia (phone/fax: (+37491) 432493; e-mail: past@rambler.ru).

Maria V. Harutyunova is with the Institute of Molecular Biology, Yerevan, 0044, Armenia.

Anahit M. Manvelyan is with the Armenian State Agrarian university, Yerevan, 0009, Armenia.

Armenia is situated in the southern part of the Trancaucasus and has a combination of folded-block and volcanic mountains, alluvial plains, river valleys, and lakes. The landscape zones are typical of mountainous countries and the climate changes in short distances here [8].

Lake Sevan is the only powerful source of fresh water in Armenia and it has a great importance for the economical development of the Republic. The lake feeds mainly by waters of the rivers falling into it (http://enrin.grida.no/biodiv/biodiv/national/armenia/maps/sev_apv.htm). The 30 rivers fall into Lake Sevan, and the biggest rivers are Masrik, Gavaraget and Argichi. The Hrazdan is originated from Lake Sevan and enters the Araks River along the border with Turkey. It is a highly regulated river used for water supply, irrigation, energy, and recreation. Along the river, numerous cities and villages are situated, such as Sevan, Hrazdan, Charentsavan, Bjni, Arzni, Yerevan, and Masis, accounting for about 1,130,000 people.

No global investigation has been done on description of ecological state of the Lake Sevan basin's rivers: Rivers Hrazdan, Gavaraget, Argichi and Masrik, during the last 12 years. The most completed description of Lake Sevan [8] does not include qualitative and quantitative changes in the groups of larger and readily visible invertebrate animals, which colonize the substrata of all rivers, suitable resident organisms and tolerant species. The studies of the black flies in the Hrazdan River, for example, covers the period from 1947 to 1968 [14].

The main aim of these investigations was description of ecosystems of Lake Sevan basin's rivers in Armenia.

II. METHODS

The monitoring program was conducted in the following water reservoirs of the basin of Lake Sevan: Hrazdan, Gavaraget, Argichi, and Masrik, at the stations from source to mouth during 2002-2004.

Material collection, water samples and experimental work have been conducted in a range of ecologically satisfactory sections (prior to the polluting object: hydroelectric power station, industrial object), immediately after the drains of industrial objects, in the zones of polluted drains, and in the zones where the self-cleaning processes are taking place.

The samples have been analyzed for the presence of heavy metals: copper, zinc, nickel, lead, cadmium, mercury, iron, manganese and magnesium as described in investigations [5]. The physical parameters, i.e. suspended matter, odour, color and turbidity; the general sanitary parameters, i.e. biological and chemical oxygen demand, dissolved oxygen, biogenous combinations (nitric and phosphorus), general hardness, alkalinity, sulphate, chlorides, dry residuum, mineralization, hydrocarbonate ions; specific ingredients, e.g. oil-products, surface-active matter, silicon and fluorine; and pH were determined.

The Brilliant Green Bile Agar was used for the calculation of coliforms in rivers.

The community cohorts were 100 healthy voluntary people from the following regions of Armenia: Yerevan, Ddmashen and Araksavan. None of the investigated people has been treated with antibiotics, hormones, radiotherapy or any other immunosuppressive or chemotherapeutic agents for 2-3 weeks before sampling.

Freshly voided faeces were collected in sterile plastic bags and transported to laboratory with ice. Faecal material (1 g) was mixed with 9 ml of phosphate buffered saline (PBS) and vortexed for 2 min. The debris was removed by low-speed centrifugation and the supernatant was serially diluted in PBS. The dilutions were plated on MacConkey agar for preliminary identification of *E. coli*, with further analysis using the selective media and conventional biochemical testing [3].

Taxonomically defined *E. coli* isolates were grown aerobically at 37˚C in LB medium (10g tryptone; 5g yeast extract; 10g NaCl per litre; pH 7,5), solidified with 1,8% agar when necessary.

The resistance of *E. coli* isolates was tested to the next antibiotics: tetracycline 15µg/ml (Oxoid), doxycycline 15µg/ml (Biomerieux), amoxicillin 25µg/ml (Biomerieux), ampicillin 35µg/ml (Biomerieux), kanamycin 50µg/ml (Oxoid), gentamicin 50µg/ml (Oxoid), chloramphenicol 30µg/ml (Oxoid), streptomycin 50µg/ml (Oxoid).

Statistical analysis has been performed using the CHITEST. The probability of $p<0.05$ was to reject the null hypothesis.

III. Results and Discussions

Investigations of the hydrochemical regime of the River Hrazdan were conducted during 2002 - 2004, at 12 stations from source to mouth.

It has been shown that the water, by chemical composition, is in hydrocarbonate – chloride – magnesium type in the upper reaches, and it is in hydrocarbonate – chloride – calcium type in the middle and low reaches.

The differences in concentrations of heavy metals depended on seasons and places were revealed during the investigations. For example, the concentration of zinc increased starting from the Hrazdan power station 0,02 mg/l to 0,55 mg/l at the mouth (maximum permissible concentration - MPC is 1,0 mg/l) in autumn 2002 and in spring 2003. The highest level of zinc (0,6 mg/l) was found at the source in autumn 2003, and it decreased to 0,2 mg/l at the mouth. The concentration of zinc increased from the source to the mouth, and it reached its maximal level of 0,6 mg/l in the low reaches in winter 2004. At the same time, the concentrations of copper in 2002 was 0,007 mg/l at the source and 0,76 mg/l at the mouth, but in 2003 copper was not found (Fig. 1), and the exceeded iron concentration above the sanitary standards was detected along the whole length of the River Hrazdan in spring 2003 (Table I).

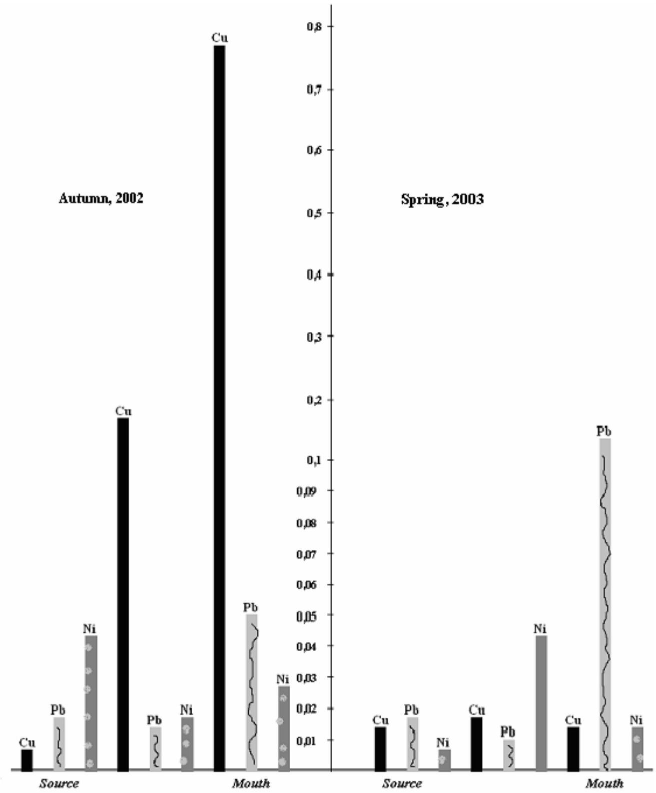

Fig. 1 The dynamics of heavy metals' composition changing in the Hrazdan River, Armenia

TABLE I
CONCENTRATIONS OF IRON IN THE RIVER HRAZDAN IN SPRING 2003

	Site of collection in river				
	Source	Village Bjni	Yerevan	Village Ghukasavan	Village Araksavan
Concentration of iron* in mg/l	2.0	2.5	5.8	2.8	1.8

*MPC for iron for reservoirs with general water consumption is 0.3

The high concentrations of manganese (at the station Darbnik it was 0,12 mg\l; MPC: 0,10mg\l); silver (at the source it was 0,10 mg\l; MPC: 0,05 mg\l); lead (at the mouth it was 0,12 mg\l; MPC: 0,10 mg\l); and magnesium (at the mouth near village Araksavan it was 111.1 mg\l; MPC: 50 mg\l) were also detected in spring 2003.

The recorded considerable concentration of ammonium salts in the river was registered: from the source- 1,42 mg/l; to the low reaches of the river- 3,51 mg/l; and at the mouth- 2,52 mg/l - MPC: 2,00 mg/l in September 2003. The concentration was considerably higher along the river in winter 2004, at the mouth it was 3,4 mg/l. The concentration of phosphorus in winter 2004 was considerable in the middle reaches of the river, i.e. 23,7 mg\l (MPC: 3.5 mg\l).

One of the main parameters of sanitary condition of water is a value of biological oxygen demand – BOD. At the source of the river the BOD_{20} was comparatively low - 12,6 mg/dm^3 O_2 with MPC – 6 mg/dm^3 O_2.. Down stream the biological oxygen demand increased and reached its maximum (57,6 mg/dm^3 O_2) at Darbnik (middle reaches), which indicates increased pollution level of the water. The analysis of water samples in winter 2004 showed higher levels of all these parameters at the source and at the mouth. Despite a great quantity of oxygen in the water, in winter, the processes of destruction of organic matters are considerably slow and the self-cleaning abilities of the river are very little.

The river is polluted by industrial and domestic flows within Yerevan city. There is a self-cleaning process on the way to the River Araks, but as the distance from Yerevan to the River Araks is not large, and the number of polluting objects is considerable, the process of self-cleaning is slight. The increase of concentrations of some metals was recorded in the mouth.

Thus, the water quality of the River Hrazdan is not stable and it undergoes changes both in seasonal and spatial aspects. In addition, the changes of water quality are conditioned by the presence of point sources of pollution along the river.

The analysis of the hydrochemical regime of the River`s Gavaraget, Masrik and Argichi was also carried out. If the concentrations of heavy metals are within the sanitary standards in these rivers, the concentrations of organic compounds were considerably higher than the standard. The value of permanganate oxidability in the mouth was 2,8 times higher than at the source coming to 4,5 mg/l (MPC - 2 mg/l). Phosphates at the source and at the mouth were 5,3 mg\l, which exceeded MPC (MPC: 3,5 mg\l). At the source of the River Masrik BOD was 10,8 mg\l$O_2$, i.e. it was higher than the MPC by the factor of 3,6 (MPC = 3 mg\l O_2). There was an upward trend of pollution in the studied rivers in 2004 comparing with 2002 and 2003, connected with the emergence of the point sources of pollution.

On the other hand, the ecological conditions of rivers were estimated by the presence and abundance of invertebrate animals. We described the fauna of black flies [4; 5], chironomids [6] and mollusks [7] of the River Hrazdan and its tributaries partially in our previous publications. To sum the results of our investigations, we revealed 25 species of black flies, 33 species of chironomids, and 12 species of mollusks inhabited the River Hrazdan system finally. 4 species of chironomids (Subfamily Orthocladiinae) have been found on 10 kilometers from the source of the Hrazdan, and 10 species of chironomids (Subfamily Diamesinae and Subfamily Orthocladiinae) have been found in the Bjni settlement of the Hrazdan River (Table II).

No new mollusks' species have been found in the rivers, but its composition was changed considerably. Some species (*Planorbis carunatus, P.laevis*) vanished, while other (*Costatella (Physa) acuta, Lymnaea (Radix) auricularia)* appeared (the species' composition of mollusks in the Hrazdan River in spring and summer is shown in Table III.

TABLE II
SPECIES OF CHIRONOMIDS IN THE VILLAGE DDMASHEN AND IN THE BJNI SETTLEMENT OF THE RIVER HRAZDAN

Site of collection	Name of the species
Village Ddmashen	Subfamily Orthocladiinae, 1. *Acricotopus lucens Zett., 4L* 2. *Eukiefferiella hospita Edw., 1L.* 3. *Eukiefferiella claripennis (Lundbeck), 1L.* 4. *Thienemanniella clavicornis Kieff, 2L.*
Bjni settlement	Subfamily Diamesinae 1. *Diamesa tsutsuii* Tokunaga, 2L Subfamily Orthocladiinae 1. *Acricotopus lucens* (Zett.), 1♂ 2. *Eukiefferiella hospita* Edw. 1L 3. *Eukiefferiella ilkleyensis* (Edw.), 1L 4. *Cricotopus (C.) curtus* Hirvenoja,1L 5. *C.(C.)bicintus (Mg.), 1L* 6. Orthocladius (O.) saxosus (Tokunaga), 2L 7. O.(Euorthocladius) thienemanni Kieff.,4L 8. Tvetenia discoloripes(Goetgh.),1L

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TABLE III
MOLLUSKS' COMPOSITION IN THE HRAZDAN RIVER

№	Site of collection	Name of the species
1	Source of the Hrazdan River	1. Family Valvatidae Valvata piscinalis (Muller,1774) 2. Family Lymnaeidae Lymnaea stagnalis (Linnaeus,1758) Lymnaea (Radix) ovata (Draparnaud, 1805) 3. Family Planorbidae Gyraulus acronicus euphraticus (Mousson, 1874) 4. Family Pisidiidae Euglesa lilljeborgi (Clessin, 1886)
2	Ddmashen, the Hrazdan River	1. Family Lymnaeidae Lymnaea (Radix) lagotis (Schrank, 1803)
3	Bjni, the Hrazdan River	1. Family Bithyniidae Gabbiella araxena Akramowski, 1970 2. Family Physidae Costatella (Physa) acuta (Draparnaud, 1805)
4	Araksavan, the mouth of the Hrazdan River	1. Family Lymnaeidae Lymnaea stagnalis (Linnaeus,1758) Lymnaea (Radix) auricularia (Linnaeus, 1758) 2. Family Physidae Costatella (Physa) acuta (Draparnaud, 1805)

The investigation of the biodiversity revealed a considerable number of hydrobionts' species in the Rivers Masrik, Gavaraget and Argichi, only 22 groups of hydrobionts were determined in the macrozoobenthos's composition of the Rivers Argichi and Masrik. Species' composition and distribution of benthofauna and chironomids in the River Argichi is presented in the Table IV.

It is significant to note the presence of synantropic species of *Simulium noelleri* in Armenia. These species are widely distributed in the Palearctic and northern Nearctic Regions. In Armenia, the species have been found in a small stream flowing into the Hrazdan River within the precincts of Yerevan city for the first time. *S. noelleri* in the middle reaches of Hrazdan River was found as well. Despite the fact that the Dr. A.E. Terteryan had investigated the stream every year since 1949 [14], this species was not detected in Armenia until 1994. This stream is highly polluted by domestic sewage, and it has exceeded levels of zinc above maximum permissible concentration. In other parts of the world, this species can be observed at the outlet of organically enriched reservoirs. Thus, Armenia is the most southern location where this species are developed. Also, we detected *Simulium murvanidzei Rubz* in the middle course of Hrazdan for the first time in 2004.

TABLE IV
BENTHOFAUNA AND CHIRONOMIDS IN ARGICHI

Species	Station 1 (source	Station 2 (middle reaches)	Station 3 (mouth)
Hidracarinae	+		
Nematoda	+		
Oligochaeta	+	+	+
Hirudinea	+		
Herpobdella octoculata			
Crustacea			
Amphipoda		+	
Gammarus lacustris			
Ephemeroptera		+	+
Caenis sp.	+		
Heteroptera	+	+	
Plecoptera		+	
Tricoptera	+	+	
Hydropsyche sp.		+	
Ecnomus sp.		+	
Diptera	+		+
Pericoma sp.	+		
Ceratopogonidae gen. sp.	+		
Chironomidae			
Chironomus anthracinus			+
Chironomus piger			+
Chironomus sp.			+
Cricotopus bicinctus		+	+
Diamesa sp.			+
Odontomesa fulva			+
Metriocnemus atratulus		+	
Orthocladius oblidens	+		
Orthocladius sp.			+
Orthocladius thienemanni		+	
Orthocladius rivulorum		+	
Paratendipes albimanus			+
Paracladius conversus			+
Polypedilum scalaenum		+	
Paraphaenocladius sp.			+
Stictochironomus crassiforceps			+
Stictochironomus sp.		+	+
Tanytarsus pallidicornis	+		
Tanytarsus sp.	+	+	
Thienemanniella clavicornis		+	
Thienemannimyia sp.	+		
Coleoptera	+	+	
Dupophilus brevis		+	
Riolus cupreus	+		
Elmis aenea	+		
Oulimnius turbeculatus		+	
Mollusca	+		
Acroloxus lacustris		+	
Lymnae sp.			
Aranei	+	+	
Shannon diversity index	3,07	2,91	1,52
Vudiviss`s biotic index	6-8 “clean”, “moderately polluted” water	8-9 “clean” water	2-5 “moderately” water

This species normally inhabits the northern part of Armenia, and has been never detected in the river Hrazdan. Thus, the migration of species occurs from north to south.

The bacteriological analysis of water showed the lack of pathogenic microorganisms (*Shigella* and *Salmonella*) in the investigated rivers. The extremely unfavorable levels of coliform bacteria considerably exceeded the standard in the Rivers Hrazdan, Gavaraget, Masrik, and Argichi. Their concentrations changed in both seasonal and spatial aspects in the water. The highest level for *E. coli* was $2{,}4\cdot10^6$ (standard: $5\cdot10^4$) established in the lower reaches of the River Hrazdan. The coli indexes for the different sources of the River Hrazdan are presented in Fig. 2. It has been also established that the coli indexes for the source and for the mouth of River Argichi was $1{,}1\cdot10^5$ and $4{,}6\cdot10^5$, correspondingly.

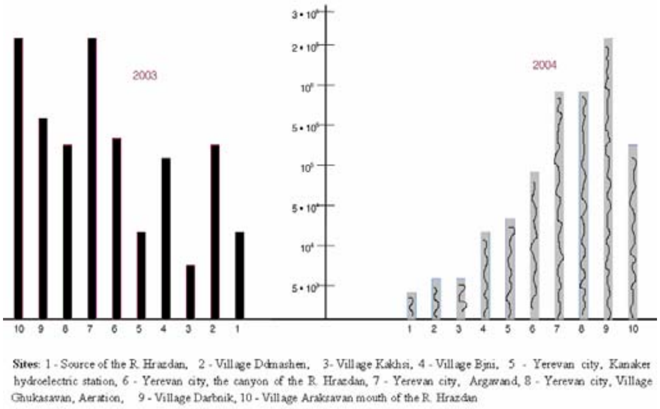

Fig. 2 Microbial pollution (*Escherichia coli*) of the River Hrazdan

On the other hand, the high quantities of antibiotic resistant *E. coli* isolates in waters were revealed (Table IV).

The spreading of antibiotic resistant bacterial isolates is associated with the risks to public health [9], [13], [10]. The established high quantity of *E. coli* in waters of Armenia is dangerous for human and animal health.

TABLE V
ANTIBIOTICRESISTANCE PROFILES OF *ESCHERICHIA COLI* FROM THE LAKE SEVAN BASIN’S RIVERS IN ARMENIA

Isolates; %	Susceptible to all classes of antibiotics*	Resistance to at least one classes of antibiotics
E. coli; n=527 (year 2006)	41	59
E. coli; n=450 (year 2005)	53	47

Tetracycline, doxycycline, amoxicillin, kanamycin, gentamicin, chloramphenicol and streptomycin.

IV. CONCLUSION

Thus, the significant ecological changes in Lake Sevan basin’s rivers during recent years were revealed. The changes of water quality are conditioned by the presence of point sources of pollution along the rivers. And the considerable number of black flies testifies a relatively satisfactory water quality for past several years in the River Hrazdan system and its tributaries.

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