AMUR BASIN WATER QUALITY ASSESSMENT BASED ON ZOOBENTHOS COMPOSITION

SIROTSKY S.E., MAKARCHENKO E.A. AND MAKARCHENKO M.A.
Institute of Water and Ecological Problems, Far Eastern Branch of Russian Academy of Sciences

Biological assessment of water quality in natural streams based on the state of bottom organisms in them, as compared to zooplankton studies, has certain advantages as this method reflects hydrobionts conditions changes in a long period of time, as connected with benthos organisms long life cycle. Traditionally used hydrochemical parameters may classify the tested water as pure, whereas hydrobiological methods will indicate in this case some pollution characteristics [5]. Thus, hydrobiological methods of water quality assessment based on bottom organisms composition contribute to overall integral survey of water streams and reservoirs.

Hydrobiological surveys of Far Eastern rivers have indicated that water quality assessment with biological parameters is most representative in low water periods, when the abundance of aquatic organisms is at its maximum and benthos species composition is most diverse. Monsoon climate of the Far East region is characterized by heavy floods, especially in mountain streams, which nearly completely damage and wash out bottom communities. It takes 1-3 month for the new ones to appear [3]. In such cases hydrochemical and microbiological parameters should be best used for water quality assessment.

1. METHODS AND MATERIALS

To perform qualitative and quantitative analyses of bottom invertebrate populations, benthos sampling was done in July-August 1997 in the Amur River from the Sungary junction to Nikolaevsk-on-the-Amur, in several tributaries, in the Amur liman and big flood plain lakes of the Lower Amur.

All in all 40 samples, 6 samples per site, were analyzed. Sandy-silted, silt and clay samples, selected with Petersen tools, were first mixed, then sieved and put into plastic bags with clips and filled with 4% formaldehyde solution. MBC-2 microscope was used for the prepared sample analysis. Organism biomass was estimated with well-known methods [7].

As shown previously [1,2], in cases, when benthos composition is not well studied, like in the Amur River, the most reliable are those methods, which are based not on particular species but on large taxons. It was found out that some groups of aquatic larvae forms of insects under unfavorable conditions are able to drift with water [3]. Those organisms, which cannot migrate in the stream such as mollusks, oligochaeta and nematoda, usually are resistant to pollution [5, 8-10]. This principle is used for water quality assessment in a Handbook on methods for hydrobiological analysis of surface waters and bottom sediments and the State Standard 17.1.3.07-82.

The present study was focussed on the following issues:

1) water quality assessment, bases on correlation between zoobenthos number (without oligochaeta) and number of oligochaeta with regard to current speed (Fo);
2) King and Ball index (Ikb) [9], equal to proportion of insect biomass to oligochaeta biomass, with range from 0 ad infinitum; the more is this index the less is pollution;
3) Goodnight and Whitley index (G, %) as in the State Standard 17.1.3.07-82, equal to proportion of oligochaeta number to number of all benthos organisms, with range from 0 to 100%, and used to classify water quality as such: 1-20% - very pure, 21-35% - pure, 35-50% - moderately polluted, 51-65% polluted, 66-85% dirty, 86-100% - very dirty.

If Goodnight and Whitley index [8] ranges from 1 to 60% water object quality is assessed as good, if it is 60-80% water quality is considered endangered and > 80% water quality means that the situation is serious.

2. Qualitative and quantitative composition of benthos organisms in the Lower Amur

Qualitative zoobenthos composition is mostly represented by widely spread species and forms. Taxonomic analysis of three bottom invertebrate orders has been completed already. They include 2 *Ephemeroptera* species, 10 *Trichoptera* species and 43 *Chironomidae* species.

Preliminary list of bottom invertebrate species and forms in the Amur and streams of its basin (sampling in 1997)

Order *Ephemeroptera*

Baetis sp.

Brachycercussp

Order *Trichoptera*

Amphipsyche proluta McL.

Apatania sp.

Arctopsyche amurensis Mart.

Ceraclea sp

Hydropsyche sp.

Macrostemum radiatum McL.

Neureclipsis bimaculata L.

Rhyacophila sp

Setodes sp.

Stenopsyche marmorata Navas

Отряд Diptera, Family *Chironomidae*

Cardiocladius capucinus (Zett.)

Chironomus sp

C. borokensis Shoban.

Cladotanytarsm gr. *mancus*

Cl. gr. A

Cricotopus gr. *silvestris*

Diamesa sp.

Dicrotendipes sp.

Einfeldia carbonaria (Mg.)

Cr. gr. *tremulus*

Cryptochironomus gr. *defectus*

C. *ussouriensis* (Goetgh.)

C. aff. *vytshegdae*

Cryptotendipes sp.

Demicryptochironomus gr. *vulneratus*

Parachironomus varus (Goetgh.)

P. gr. *arcuatus*

? *Parakiefferiella* sp.

Eukiefferiella gr. *claripennis*
Glyptotendipes glaucus (Mg.)
G. gripekoveni (Kieff.)
G. paripes (Edw.)
G. viridis (Macquart)
Harnischiafuscimana Kieff.
Lipiniella moderata Kalugina
Microchironomus tener (Kieff.)
Monodiamesa gr. *bathyphila*
Neozavrelia sp.
Orthocladius (Euorthocladius) sp. 1
O.(Euorthodadius) sp.5
Orthocladius sp.5
Paralauterborniella nigrohalteralis (Malloch)
Polypedilum bicrenatum Kieff.
P. gr. *convictum*
P. scalaenum (Schrank)
Polthastia sp.
Procldius ferragineus
P. gr. *horeus*
P. nigriventris (Kieff.)
Rheotanytarsm sp
Stictochironomus sp.
Tvetenia gr. *bavarica*
T. gr. *discoloropes*

Other groups, found in samples, include *Oligochaeta, Bivalvia, Gastropoda, Nematoda, Arudinella, Ceratopogonidae, Coleoptera, Simulidae* and other *Diptera, Plicoptera, Odonata, Mysidae, Gammaridae, Asellidae, Coelentherata.*

Zoobenthos quantity and biomass data from the Amur, Tunguska, Silinka, Amgun rivers and the Amur liman are given in Table 1.

In particular passages of the Amur river sampling could not be done because of strong current and compact sandy bottom substrate. Those sites were upper the Sungary junction, lower the railway bridge at Khabarovsk, upper the railway bridge at Komsomolsk-on-the-Amur, near Nikolaevsk-on-the-Amur and in the Amur liman. To secure data reliability zoobenthos sampling was done 5 meters deep, thus flood plain areas were excluded.

Zoobenthos presence or absence was identified visually at the main hydrological cross sections of the Amur, when soil samples were collected. Most zoobenthos rich samples were collected near M.Gorky village (8 m deep) and near Nizhnyaya Gavan (14 and 20 m deep).

Table 1 Zoobenthos quantity and biomass in river water ecosystems of the Amur River and the Amur liman.

Date	Sampling Sites	Density, sp. /м^2 (N)	Biomass, g/м^2 (B)
26.07.1997	Amur River near Vertoprashikha Bay	320	0,907
27.07.1997	Amur River, Lugovaya sub-channel, 92-km (Middle Amur)	1408	0,547
28.07.1997	sub-channel Amurskaya, Bychikha vil.	1920 (40)	3,698 (497)
1.08.1997	Tunguska River	108	0,011
1. 08. 1997	Amur River, Sikachi-Alyan vil.	3302 (135)	0,472 (1415)
26.08.1997	City of Komsomolsk-on-the-Amur		
11.08.1997	Silinka River, Komsomolsk-on-the-Amur, near subway	20989	14,216
15.08.1997	Amur River, near Lake Khavanda	5391 (135)	5,177 (1108)
15.08.1997	Amur River, right bank near M. Gorky vil.	270	0,037
15.08.1997	Amur River, M. Gorky vil., 8 m deep	6580 (480)	74,314(8,4)
19.08.1997	Amur River, near Dudi vil.	60 (20)	2,054 (224,8)
19.08.1997	Amur River, N. Gavan vil. 20 m deep	3436	26,476
19.08.1997	Amur River, N. Gavan vil., 14 m deep	4440 (500)	56,57 (17,9)
24.08.1997	Amgun River, sub-channel Kapkudan	3571 (2965)	2,611 (945)
25.08.1997	Amgun River estuary	3400 (60)	1,429(1,2)
29.08.1997	Amur River, upper Tur vil., 1 00 m from Amgun River estuary	2906(13)	1,655(2,14)
28.08.1997	Palvinskaya sub-channel, lower Mago vil. Maro	3975 (741)	4,868 (14,9)
31.08.1997	Amur Liman, Oremif Island	21967 (5265)	37,045 (25,6)
31.08.1997	Amur Liman, Cape Pronge	755 (216)	0,52 (8,4)
31.08.1997	Amur Liman, Cape Dzhaore	11915	15,426
31.08.1997	Amur Liman, Ozerpakh vil.	269(606)	0,322(2,1)

Note: Mollusks data are given in brackets

According to 1997-year sampling estimates average Amur bed population density (mollusks not included) was 2830 specimens per sq. meter, minimal density 60 sp./sq. m was registered near Dudi village and maximal density 6850 sp./sq. m was at M.Gorky village (8 m deep). Average zoobenthos biomass (mollusks not included) was 14.7 g/ sq. m. Minimal and maximal biomass of benthos organisms were registered near M.Gorky village in silted sand of the right bank of the Amur and were 0.037 g/sq. m and 74.3 g/sq. m respectively. River bottom is formed with a gravel and pebble substrate. Similar bottom was soil type identified near Nizhnyaya Gavan village, 180 km from the estuary. Near M.Gorky village 14 m deep sampling revealed high amounts of zoobenthos biomass – 56.57 g/sq. m (17.9 g/sq. m of mollusks) and 26.5 g/sq. m, mostly represented by *Trichoptera* larvae. In silted soil *Chironomidae* and *Oligichaeta* dominated. High amounts of zoobenthos biomass were also found in samples from silted soils in the Amur liman near the Oremif Island (37.045 g/sq. m (25.6 g/sq. m small mollusks) and near Cape Dzhaore (15.4 g/sq. m).

In sandy and slightly silted bottoms near Cape Pronge and Ozerpakh village less zoobenthos biomass was registered, 0.52 g/sq. m (8.4 g/sq. m mollusks) and 0.32 g/sq. m (2.1 g/sq. m mollusks). It was mostly constituted by small forms of mollusks: *Bivalvia* and *Gastropoda.* Maximum density of benthos organisms was 21967 g/sq. m (5265 g/sq. m mollusks), registered near the Oremif Island in the Amur Liman.

In the Amur tributaries minimal zoobenthos biomass amounts was in the Tumguska River junction (0.011 g/sq. m) and in the Amgun River (1.4 – 2.6 g/sq. m). In the mountain type

Silinka River zoobenthos is rich both in species variety and in biomass (14.2 g/sq. m); population density there is 20 989 sp./sq. m.

Total population density and zoobenthos biomass data from the Lower Amur lakes are presented in Table 2.

In flood plain lakes larvae of *Chironomidae* and *Oligichaeta* dominated among benthos organisms groups. Maximum number and biomass data were collected in lakes with silt bottom, such as Lake Padali (density 23 382sp./sq.m and biomass 16.2g/sq. m), Lake Sharga (density 20 148 sp./sq. m and biomass 21.631g/sq.m), Lake Chlya central part (density 3 580 sp./sq. m and biomass 50.6 g/sq. m), sub-channel Ukhta, which connects Lake Udyl with the Amur (density 2 160 sp./sq. m and biomass 13.1 g/sq. m). In lake ecosystems with sandy silted soil biomass as a rule ranged from 1.7 to 5 g/sq. m. Lake Kaltakhyun, dam area in Lake Sharga, Lake Petropavlovskoe estuary zone, Lake Udyl, Lake Chlya near Chlya village may serve as examples. Minimal biomass (0.020 – 1 g/sq. m) was registered in sandy areas like Lakes Irkutskoe, Khummi, Mylka and others.

Table 2 Zoobenthos density and biomass in Lower Amur flood plain lakes.

Date	Sampling Sites	Density, sp. /м^2 (N)	Biomass, g/м^2 (B)
2.08.1997	Lake petroparlovskoe	2896	1,176
8.08.1997	Lake Kaltakhyun	4245	4,997
21.09.1995	Lake B. Sharga, near dam	1760	3,256
21.09.1995	Lake B. Sharga, center	32	0,054
8.08.1997	Lake M. Sharga	20148	21,631
21.09.1995	Lake M. Sharga, macrophytes zone	1829	3,079
21.09.1995	Lake M. Sharga, center	608	2,408
8.08.1997	Lake Dzhalunskoe	3235	4,778
12.08.1997	Lake Khummi, Kholodny stream	3908	2,145
23.09.1995	Lake Khummi, Kholodny stream	264	0,630
23.09.1997	Lake Khummi, Gaiter bay	12	0,020
10.08.1997	Lake Padali	23382 (404)	16,236(0,114)
23 09.1995	Lake Mulka, entry	8	0,128
23.09.1995	Lake Mulka, middle	576	0,915
23.09.1995	Lake Mulka, exit	848	1,176
13.08.1997	Lake Beach-Khouni	544	0,303
19.08.1997	Lake Irkutskoe	538	0,341
19 07.1997	Lake Kizi, chilba vil.	1818 (943)	2,835 (6,0)
23.08.1997	Lake Udyl	2160(360)	1,72(13,6)
23.07.1997	Ukhta sub-channel, Kolchem vil.	12937 (17523)	13,117(2019,1)
27.08.1997	Lake Chlya (middle)	3580 (60)	50,613 (247,8)
28.08.1997	Lake Chlya I, Chlya vil.	1280	3,276

Note: Mollusks data are given in brackets

Data, collected throughout the Lower Amur river passage from Slavyanka village to Savinskoe village, indicated average benthos organisms density - 938 sp./sq. m and biomass - 0.74 g/sq. m. Maximum values were registered upper the Komsomolsk-on-the-Amur bridge – 6700 sp./sq. m and 2.4 g/sq. m respectively [6].

Analysis of zoobenthos samples, collected in 1980 [1], shows that in the Amur river passage from Slavyanka village to Bogorodskoe village average zoobenthos density was 5 640 sp./sq. m and biomass was 5.011 g/sq. m. Maximum density 30 000 sp./sq. m (biomass 6 g/sq. m) was registered near the city of Amursk 599 km and maximum biomass 42.5 g/sq. m (density 1 200 sp./sq. m) was registered at the right bank near Bogorodskoe village.

Data, acquired in 1946-1947 by the Amur ichthyologic expedition [4], revealed that average biomass near Elabuga village was 0.036 g/sq. m (*Oligichaeta* 14%, *Chironomidae* 50% , mollusks 36%).

Near Slavyanka village average biomass was 0.02 g/sq. m (*Chironomidae* 50% , *Ephemeroptera* 50%).

Near Malmush village average biomass, revealed by two-year observations, fluctuated between 0.0050 and 1.58 g/sq. m and the average was 0.24 g/sq. m. *Chironomidae* and *Ephemeroptera* dominated.

Near Verkhne-Tambovskoe village average biomass was 0.031 g/sq. m (*Chi-ronomidae* 84% , *Ephemeroptera* 10%, *Oligichaeta* 6%).

Near Achan village and Siy sub-channel average biomass was 0.036 g/sq. m(*Chironomidae* 55% , *Oligichaeta* 22%).

Near M. Gorky village average biomass was 0.008 g/sq. m and *Chirono-midae* constituted 100%.

Average biomass 10 km upper Dudi village was 0.013 g/sq. m (*Chirono-midae* 77% , *Mysidae* 23%).

Near Savinskoe village average biomass was 0.992 g/sq. m and mollusks constituted 97%.

At all sites, mentioned above, benthos average biomass was 0.172 g/sq. m. Thus in different years of observations, carried out in the Lower Amur, average biomass values were as follows: 0.172 g/sq. m in 1946-1947; 5.011 g/sq. m in 1980; 0.74 g/sq. m in 1989 and 14.2 g/sq. m in 1997.

It should be mentioned that only during 1997 sampling big numbers of large mollusks *Gastropodae* were registered at some sites, their average biomass ranging from 225 g/sq. m near Dudi village to 1415 g/sq. m near Sikachi-Alyan village (Table 1). Maximum mollusks biomass in quantitative zoobenthos samples of more than 2 kg/sq. m was registered near Ukhta sub-channel near Kolchem village (Table 2).

Collected data revealed as a whole an evident benthos biomass increase in the Lower Amur which may indicate the increase of trophic status of the studied water object at least in the recent 50-year time frame.

3. Quality assessment of Middle and Lower Amur basin water based on benthos organisms composition

To assess water quality and determine water purity classes by benthos community composition (Table 3) according to the State Standard 17.1.3.07.82 Goodnight-Whitley index was selected as the best suitable at the present state of the Lower Amur benthos organisms research. It makes possible the comparison of observation data and, hence, the assessment of Amur water quality.

The Amur river water ecosystems studied in 1997 present the full range of purity classes from I to VI. Thus, according to zoobenthos parameters the passage of the Middle Amur between 240 and 92 km corresponds to class I, meaning “very clean”. The Tunguska and Silinka tributaries belong to this class I as well. Thought the Amur passage from Bychikha village (Amurskaya sub-channel) up to Sikachi-Alyan village purity classes change from class III to VI, from “moderately polluted” to “very dirty”. Down the Amur stream upper Lake Khavanda, near Tyr village, in the Palvinskaya sub-channel lower Mago village class V is indicated, i.e. “dirty”. Amur liman water near the Oremif Island is ranked class IV, “polluted”. But near Capes Pronge and Oserpakh water quality corresponds to class I. It’s worth notifying that by benthos parameters of samples from deep pebble and gravel river bottoms near N. Gavan village (14 and 200 km deep), M. Gorky village (8 m deep), the water there can be ranked class I, whereas samples from silted bottom near M. Gorky village indicated class III and IV characteristics. Class II is presented by the Amur River segment near Dudy village. The Amgun River, the left tributary of the Lower Amur, can be ranked class III (“moderately polluted” water).

Amongst big flood plain lakes class I was attributed to water in Lake M.Shanga estuary, Lake Padaly and Lake Beach-Khouni (Gorin River estuary), in Konsomolsk state reserve, part of lake Kizi near Chilba village. Water in Lake Khummi near the Kholodny stream was ranked class II. Water in Lakes Potropavlovskoye, Irkutskoe, Kaltakhyun and the middle part of Lake Chlya were ranked class III. Class IV was indicated in lakes Chlya near Chlya village and Dzhalunskoye. As maximum, class V was given to water from Lake Udyl and sub-channel Ukhta, which flows out of it, near Kolchem village (table 3).

Benthos communities studies in 1980 and 1989 [1, 6], based on index (G, %) calculations, revealed the following water quality in the Lower Amur. The most favorable conditions were registered in 1980 in the Amur passage from Slavyanka village to the City of Amursk. Bottom part was classified as very pure. Lower this point up to Bogorodskoe village the water was found dirty (class V) and near Kalinivka village – very dirty (class VI). In 1989 in the Amur passage from Slavyanka village to the City of Amursk the pollution tendency was revealed as water quality these changed from class I (1980) to class II-III. The most dangerous water quality situation – classes VI and V, as also registered previously, was in the Galbon sub-channel estuary (Lake Padali), near the Sakhalyan Island at Amursk and at the right bank at 575 km mark. Down the river from this area classes ranged from I to IV, but classes III and IV were mostly common. It should be noted that 575 km samples, collected at the right river bank revealed class V characteristics, whereas the samples, collected at the left bank – only class I. The same situation was registered in 1997 near M. Gorky village. Different types of bottom sediments at those sampling site may account for this.

Table 3 Some zoobenthos indexes of water quality in the Lower Amur basin.

Date	Sampling Site Location and number of samples	King and Ball idex, (Ikb)	Fo	Goodnight – Whiley Idex St. Std.17. 1.3 .07-82, G(%)	Class of Water Purity
River Sites					
26.07.1997	Amur Riv.near Vertoprashikha bay, 240 km, right bank, № 9, 4 samples	302,3		6,25	I
27.07.1997	Riv. Amur, Lugovaya sub-channel, 92km	-	-	0	I
2807.1997	Amurskaya sub-channel, Bychikha vil.	22,1	-	38,8	III
01.08.1997	Riv.Tunguska, 3 samples, № 8, 03615	10	7,3	12	I
01.08.1997	Riv.Sikachi-Alyan, right bank, № 9, 4 samples	0,18	0,13	88	VI
12.08 1997	Riv. Amur, Komsomolsk-on-the-Amur, silt beach				
12.08.1997	Riv.Silinka	-	-	0	I
15.08.1997	Riv. Amur, upper Lake Khavanda, 4 samples, 03614	2,12		75,6	V
15.08.1997	Riv. Amur, M.Gorky vil., 8m deep, 2 samples	3694621		<1	I
15.08.1997	Riv. Amur, M.Gorky vil., № 25a, right bank, 4 samples, 03610	1,18	1,0	50	(III-IV)
19.08.1997	Novy Amur sub-channel, Dudi vil., 2 samples	-	-	25	II
23.08.1997	Riv. Amur, N. Gavan vil., 14 m deep	-	-	0	I
23.08.1997	Riv. Amur, N. Gavan vil., 20m deep	-	-	0	I
24.08.1997	Riv. Amur, Kapkudan sub-channel, 4 samples	0,133	1,43	41,2	III
25.08.1997	Riv. Amur, estuary, 2 samples, 03601	0,57	1,16 .	46,2	III
29.08.1997	Riv. Amur upper Tyr vil., 100 m from Amgun riv., 3 samples, 03595	0,07	0,18	84,96	V
28.08.1997	Palvinskaya sub-channel lower Mago vil., 4 samples, 03605	1,37	0,399	71.4	V
31.08.1997	Amur liman, Oremif isl., 4 samples, 03622	0,09	0,91	52,2	IV
31.08.1997	Amur liman, Cape Pronge, 5 samples, 03602	0,75		11,1	I
31.08.1997	Amur liman, Cape Ozerpakh, 4 samples, 03606	9,93	12,1	7,66	I
Lakes					
02.08.1997	Lake Petropavlovskoe near Petropavlovka vil, 4 samples, 03620	1,76		40,5	III
08.08.1997	Lake Dzhalunskoe, 4 samples, 03598	3,15	-	52	IV
08.08.1997	LakeM Sharga, 4 samples, 03596	31,2	-	14,4	I
08.08.1997	LakeKaltakhyun, 4 samples, 03597	2,36	-	42,9	III
12.08.1997	Lake khummy	4,94	-	29,3	II
10.08.1997	LakePadaly, 4 samples, 03608	16,9	-	8,92	I
13.08.1997	Lake Beach-Khouny (Riv. Gorin), 25 x 25 m, 03613	3,04	-	14,71	1
0907.1997	Lake Kizi, Chilba vil., 4 samples, 03612	181,95	-	2,37	I
19.08.1997	LakeIrkutskoe, 4 samples, 03607	3,0	-	37,5	III
23.08.1997	LakeUdyl, 3 samples, 03611	0,8	-	61,4	V
23.07.1997	Ukhta sub-channel, Kolchem vil., 4 samples, 03609	0,09	-	78,5	V
28.08.1997	Lake Chlya, 3 samples, 03619	2,84	-	51,1	IV
27 08.1997	Lake Chlya (middle), 2 samples, 03599	17,5	-	40,7	III

Conclusions

Quality assessment of the Lower Amur basin water on the basis of zoobenthos communities composition, carried out in 1980, 1989 and 1997, revealed that there is no water quality improvement in this area. On the contrary, according to 1980 and 1989-year data there is a tendency of water quality decrease in the Amur passage from Slavyanka village to the City of Amursk. The worst water quality situation according to 1997 data is registered upstream from Sikachi-Alyan village and the Amur estuary, ranging class IV-VI.

The research, undertaken in 1997, provides deeper knowledge of zoobenthos biomass state in the Amur water ecosystem and helps to make more precise estimations of Amur fish feeding base, as well as damage of water and biological resources of the Amur River, caused by industrial activities or pollutants in case of oil spills, untreated sewage, etc..

Zoobenthos biomass increase tendency in the Lower Amur, revealed by comparing 1946-1947and 1997 research data, may be explained by the water object trophic status increase as well as may be attributed to improved sampling methods used in 1980 and 1997.

The present study was a part of the target program "The Lower Amur", theme " Formation Mechanisms of Toxic Compounds, Which Cause Water Pollution and Fish Contamination in the Lower Amur", undertaken under the Khabarovsk Krai Ordnance #273, 07.07.97.