URAL RIVER BENTHIC COMMUNITIES RESPONSE ON THE CHEMICAL SPILL

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ABSTRACT

An assessment of the Middle flow Ural River benthic communities by oil and phenols spill response is described. The paper is based on a study of the short-term response of benthic biocenosises compared with natural transformation of the community structure before pollution.

MATERIALS AND METHODS

Sediment and benthic samples were collected from the town of Orsk to the town of Novotroitsk 15-17 December 1991. The study areas are as follows: the Ural River waterway at 0.5 km up from Orsk's wastes water break collector of biodisposal station; the branch of the river at 0.5 km down from the collector; and the waterway near the water consumption stations of the Novotroitsk Metallurgical Works (about 15-18 km down from collector). Samples from the vicinity of the town of Novotroitsk were collected in 5-6 August 1991 too.

The 5-7 cm surface-sediment layer was sampled by quantitative bottom scraper (0.1 m2). The benthic animals were washed though a 0.6 mm sieve. The biodiversity of the fauna in each biocenosises was expressed as mean numbers of taxa per samples.

Maximov (1992) modified rank order method with dendrogram and graph interpretations were used for the analysis of the ecosystem state and its changes. These methods allow to the descrition of quantitative similarity of biocenosises structure and its transformations as a result of actions of natural and anthropogenic factors (Tarasov, 1993). So named "space-temporary elementary structures" (STES) of biocenosises on each station of sampling inscribed by four symbols (i.e. COpL or UptO) so named code "STES" of the biocenosis. The correlation matrix was calculated with the use of the programme ROMM version 1.2 (Y.M.Brumshtein and A.G.Tarasov, unpublished programme).

The balance of terms that we are using in this paper for descriptions of biocenosises at different levels of complexity are as follows: the biocenosis (communities) are included from one to few STES connect by measures of similarity (M) from 9 to 6; the form of dendrogram and graph are basis of separation of subbiocenosises and unification communities to superbiocenosis.

THE MIDDLE FLOW OF URAL RIVER CASE HISTORY

The Ural River is the second river of the North Caspian basin, on the north-west border of the Kazakhstan and Russian. The middle flow of the Ural River is limited by the dam of Iriklin water reservoirs (about 80 km up from Orsk town, Orenburg district) to the mouth of Barbastay River (about 45 km down from Ural'sk town.

On 13-17 November 1991, after an industrial incident in Orsk oil refinery enterprise effluent polluted the Ural River. The waste water was smell of carbonic acid and oil. The intermittent brown dense oil slick and iridescent sheer layer with brown spots were visible on the surface of the water for at least one day. The oil quantity on the water surface may be assessed from 0.98 to 1.95 ml/m^2 by Lesnikov (1974) visual scale.

Waste water from the river caused irritation of the skin and caused fish deaths. The oiled shore sediment, water-plant remains and hydrotechnical constructions were visible until the time of ice formation (i.e. about two weeks). The effluent included very high concentrations of phenols, hydrocarbons and other substances of oil processing. The contamination of phenols in the river water are from 0.680 to 0.002 mg/l. There as, the maximum of mean-monthly concentration of phenols (0.005 mg/l) in the period 1986-1990 was observed in March-April before flood-time.

BIODIVERSITY RESPONSE

The benthic macrofauna of the area 0.5-18.0 km down from the Orsk collector in December 1991 included only 18 pollution-tolerant taxa (Tab. 1). The toxicity tolerant organisms we know by data from Tauson (1955), Gromov, Demidova (1971) and many other authors.

There as, the benthos from station D1 (up from collector) included such pollution-sensitive organisms, as Simuliidae, Ortocladinae (Orthocladius gr. saxicola Kieffer, Cricotopus gr. algarum Kieffer) and Trichoptera (Hydropsyche ornatula McLachlan). These species were absent at all 0.5-18.0 km down.

The Bivalvia and Gastropoda mollusc remains were found in samples down from the collector. The shells were opened, and decomposed soft-body remains were observed inside shells. Obviously, these molluscs were smothered and killed by the effluent waters. Only two species (Lymnaea (Peregriana) ovata (Draparnaud) and Physa (Physa) adversa (E.M.Costa) from 28 mollusc taxa were not described earlier from this area, but these species had widespread distributions in waterbodies of the secondary hydrographic net of the Ural River, mainly in wetlands by our data (Pirogov et al., 1994). Seventy-seven taxa of macroinvertebrates were collected from the vicinity of Novotroitsk town before pollution.

CHANGES OF THE BOTTOM BIOCENOSISES AS CHEMICAL SPILL RESPONSE

The five groups of biocenosises were identified from the resulting dendrogram by data from the December sampling of benthos. The biocenosises from the polluted area had very low biodiversity and biomasses (Tab. 2). The distributions of the biocenosises of the Ural River waterway in suburbs of Novotroitsk are shown in the Figure 1.A.

The bidominant biocenosis of Chironominae and Oligochaeta occupied oiled muddy grounds of stretch of water (stations D14 and D15). The similar bidominant biocenosises with (sub)dominant Oligochaeta and Chironomidae were described by many authors for polluted sediments and unpolluted waterbodies of the Caspian basin. The similar community OC-- we separated by data Drabkin (1977) collected from the Ural River and its little tributaries in Orsk-Novotroitsk towns area in 1966 The level of water pollution of the Ural River in the 1960's according to the data of Dementev (1963) had high concentrations of hydrocarbons (0.35-0.60 mg/l) and phenols (0.2-0.3 mg/l). Oiled muddy sand from Volga delta in the 1970's and 1980's occupied oligodominant biocenosis Oligochaeta, Chironomidae and Lithoglyphus naticoides (C.Pfeiffer) (Tarasov et al., 1989). A similar type of weight distribution of two dominant groups (OC--) was described on oiled mud sediment by Konstantonov (1953) 8-10 km down from Saratov oil refinery enterprise. The mean biomasses of organisms corresponded to 0.537 and 0.001 g/m^2. Analogous transformations of bidominant biocenosises (OC--"CO--) may be separated by data of Tauson (1955) for the oiled muddy sediments of middle the un-named river that was the tributary of the Kama River in 40-120 km down from collector of coke-chemical enterprise. Unfortunately, she described abundance data only. The number of oligochaetes changed from 800 to 1200 ind/m^2, chironomides from 80 to 3500 ind/m^2, there as in Ural River about 18 km down from the Orsk industrial collector found from 30 to 70 ind/m^2 chironomides and from 10 to 30 ind/m^2 oligochaetes .

The chironomides and oligochaetes biocenosises were widespread on unpolluted sandy and gravelly bed load of the Vjatka River (unpublished data by author) and unpolluted muddy sediments of the Volga foredelta (Tarasov, Filchakov, 1994) by data authors and predecessors investigations. Often these structures transformed to oligodominant type.

The oiled gravelly-sand (sandy-gravel) and sandy sediments of shallow occupied similar bidominant biocenosis of larvae Chironominae and other Diptera (subdominant groups in this biocenosis changed from station to station or were absent, i.e. biocenosises reduced to monodomonant type). The similar type of biocenosises we described (Tarasov, 1993) from unpolluted sandy bed load of shallows of the Cheptsa River (tributary of Middle flow of the Vjatka). So-called "transit biocenosises" included some groups of organisms from drift in the different parts of square. Probably, that found mono- and bidominant biocenosises are the first step of recovery of bottom communities. For example, the STES of bidominant biocenosis from stations D7 assumed a character similar to STES biocenosis up from collector (station D1) and sample site D2 from river creek that down from wastes water break. The measure of similarity were corresponded from 6 (D1xD7) to 5 (D1xD2).

Five groups of stations were identified from the dendrogram on unpolluted sediment of the Ural River of the vicinity of Novotroitsk town in August 1991 (i.e. before pollution). These (sub)biocenosises had different quantity characteristics (Tab. 3, 4) and taxonomic structure (Fig. 1.B). The superbiocenosis included seven subbiocenosises were described on different types of grounds of shallow and stretch of water. The transformation of subbiocenosises structure was made by different type of sediment, water velocity, absence or presence of water-plant associations and their type. For example, the phytoreophilous biocenosis from station 3 (the naiads of Odonata as dominant, Oligochaeta - as subdominant of first rank) was connected with P. pectinalus and P. perfoliatus on compact mud sediment of shallow with very high current of water. The transformation of biocenosis structure in creek (station 10) and stretch of water (st. 14,15 and 15) from structure of biocenosises of shallow was the result of water velocity slowing, mud sedimentation and overgrowing by limnophilous water-plant.

The similar quantity distributions of organisms of different taxonomic level. Distribution of some benthic organisms had high level correlation that was marked on structure of biocenosises changes. For example, Valvatidae and Bithyniidae were included in dominant complex at least of four stations. The group of taxa Ortocladinae, Unionidae and Mysidae was identical to structure from station 17. After pollution were relations between benthic organisms disintegrated and high level correlation was marked only for very pollution-tolerant groups as Chironominae and Oligochaeta.

The changes of frequency distribution of ranks in correlation matrix after pollution show the disintegration of relations between "temporary elementary structures" of (sub)biocenosises. The increase of frequency indices of similarity M=4 and absence of measures of rank correlation from 9 to 7 reflects the simplicity of structure of bottom biocenosises and predominance of simple (mono-, bi- and oligodominant) communities with single dominant and different subdominants groups. The changes of simple temporary communities were described for bottom communities from polluted and very polluted areas of inland and brackish waters of Caspian sea basin (Gromov, 1954, Starostin, Tyrpaeva, 1967, Liperovskaja, Droshbina 1972).

The chemical pollution of water smothered and killed many groups of invertebrates and destroyed structure and lowered diversity of benthic biocenosises. However, natural decomposition of organic matters in black mud with hydrogen sulphide exuding on ox-bow lake (st. 8,9) smothered and killed benthos macroinvertebrates. The very high water velocity "blowouts" of surface-dwelling organisms and conducted to visual similar result (st. 7.1, 7.2).

However, we must note that difference in quality and quantity of characteristics of biocenosises down from Orsk industrial collector in winter and summer 1991 can not be explained by seasonal changes of bottom community. It was known that biomasses of benthos organisms in winter increased because the surface of bottom in winter regression of water level decreased (Drabkin, 1977). These literature describes are similar with data that we presents below.

Reconstructions of benthic community structure by Mollusca remains and biomasses of dominants groups showed that structures of bottom biocenosises from stations D14 and D15 were similar with pre-polluted stations 14 and 15 (Fig. 3, Tables 2 and 4). Reconstructions stricture subbiocenosises from bay with oiled muddy ground (st. D2) were similar with station of 10 unpolluted creek in August 1991.

The biocenosis from station D1 on the shallow up from collector attributed to polydominant type (Tab. 2). The biocenosises with similar structures had widespread distributions in the Ural River and similar streams (i.e. Cheptca River). For shallow of the Ural River in the vicinity of Novotroitsk in August 1991 we described similar STES of subbiocenosises (LCpK, CLvl, LCTK), they had measure of similarity (M) from 7 to 6. (stations 1, 4, 12 by Fig. 3).

Similar polydominant biocenosises with Ephemeroptera dominant, Chironomidae and Trichoptera subdominants were separated by data Drabkin (1977) collect from unpolluted area of the Ural River up from Orsk town in 1966 If dominant species (P. virgo and H. ornatula) in this biocenosis were similar with other parts of Ural River in middle 60-st (Drabkin, 1977), at that time M for two biocenosises (D1=3DLCHP and 1966=3DpCHO) were 5 i.e. they were almost identitical.

And so the biological methods based on characteristics of biodiversity of bottom fauna and assessments changes of structure benthic communities with using of Maximov modified rank order method with dendrogram and graph interpretations was be used for the analysis of the biocenosises changes as result oil and phenols spill. Only two types oligo- and bidominant biocenosises were marked on shallow and strench of water the Ural river in Orsk-Novotroitsk area after pollution, there as five polydominant subbiocenosises lived on area re-investigations in August 1991.

The assessment of biological response by method calculating ranks frequency distribution from correlation matrix needs addition testing.

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REFERENCES

Gromov V.V.. 1954. "Bottom fauna of the Low flow of Chysovaja River and its possible changes." *Proceedings of Research Institute of Natural Science of Perm' State University.* Perm'. V.13, No8. pp. 885-910. (In Russian).

Dementev N.D., 1963. "Study of water physical characteristics of the Ural River with connect industrial pollution." *XX Science Sections of Orenburg Medical Education Institute.* Orenburg. pp. 191-192. (In Russian).

Drabkin B.S. 1971. *Hydrobiology of Ural River.* Chelyabinsk, Yuznouralskoye izdatelstvo (in Russian).

Konstantinov A.S., 1953. "The Volga River benthos of the vicinity of Saratov town and it pollution influence." *Proceedings of Saratov division of Caspian filial of VNIRO.* Saratov. V.2. pp. 73-151. (In Russian).

Lesnikov L.A., 1974. "Protection of waterbodies by the Fish Industry viewpoint." *Proceeding of State Research Institute of Lakes Fisheries* (GosNIORKh), V.98. pp. 3-8. (In Russian).

Liperovskaja E.S., Droshbina T.M., 1972. "Characteristics of pollution mud sediment of the Moscow River and its influence of distribution of oligochaetes." *Processes of pollution and cleanup of the Moscow river.* Moscow. Stroiizdat. pp. 130-138. (In Russian).

Maximov V.N. 1992. "Estimation of community similarity by a modified rank order method for the analysis of the ecosystem state." *Ecological modification and criteria for ecological standardization.* Leningrad. Hydrometeoizdat. pp 192-199.

Pirogov V.V., Tarasov A.G., Kazantseva S.Z., 1994. "Malacofauna of typical waterbodies of the middle and lower flow of Ural river." *Ruthenica.* V.4, No1. pp. 61-65.

Starostin N.V., Tyrpaeva E.P., 1967. "Influence of industrial effluent of synthetic rubber on bottom fauna of the Caspian Sea near Symgait town." *Transactions of Oceanology Institute of AN SSSR.* V.85. pp 54-66. (In Russian).

Tarasov A.G 1993. "Research of changes in benthocenocis caused by dredging of the cluster analysis method." In: *Proceedings of the Astrakhan Technical Institute of Fisheries,* V.1. p. 80-83.(In Russian).

Tarasov A.G., 1993. *Biotic index of the Volga delta and North Caspian Sea.* Ph.D.B Thesis, Moscow State University, Deponent in VNITICentre 17.02.93, N 04.9.30.002119. (In Russian).

Tarasov A.G., Pirogov V.V., Edskyi L.B., 1989. "Influence of water pollution on quantity and quality characteristics of Volga delta benthos." *Ecological problem of Volga River.* Saratov, Part II. pp. 251-252. (In Russian).

Tauson A.O. 1955. "The influence of industrial waste waters and timber-rafting on bottom fauna of rivers." *Scientific Notes of Molotov State University.* Molotov. V.VII, No3. pp. 71-111. (In Russian).

Table 1. Biodiversity of taxa macroinvertebrates found during the 1991 August (08) and December (12) Ural River survey

Taxonomic groups	Number of taxa		T.c.	B.c.
	before pollution	after pollution		
Oligochaeta	1 (classes)	1 (classes)	O	O
Hirudinea	2 (species)	2 (species)	Hir	-
Unionidae	4 (species)	0 (species)	U	U
Pisidioinei	14 (species)	4d (species)	-	P
Sphaeriidae	2 (species)	1d (species)	Sph	-
Pisidiidae	4 (species)	1d (species)	Ps	-
Euglesiidae	8 (species)	2d (species)	Eu	-
Valvatidae	3 (species)	1d (species)	v	v
Bithyniidae	1 (species)	0 (species)	b	b
Lymnaeidae	2 (species)	2d (species)	l	l
Physidae	2 (species)	1d (species)	Ph	@
Planorbidae	2 (species)	1d (species)	Pl	@
Malacostraca	1 (species)	0 (species)	m	m
Heteroptera	1 (species)	0 (species)	A	A
Odonata	4 (species)	2 (species)	c	c
Ephemeroptera	6 (species)	1 (species)	Eph	-
P. virgo	+	-	-	p
C. macrura	+	+	-	K
Ameletus sp.	+	-	-	a
Trichoptera	2 (species)	0 (species)	Tr	-
H. ornatula	+	-	-	H
Coleoptera	1 (genus)	1 (genus)	Col	-
Chironomidae	* (species)	* (species)	-	e
Ortocladinae	6 (species)	0 (species)	Ort	-
Tanipodinae	4 (species)	1 (species)	Tn	-
Chironominae	14 (species)	8 (species)	C	C
Other Diptera	7 (families)	3 (families)	D	-
Limonidae sp. sp.	+	+	-	L
Tabanidae sp. sp.	+	-	-	T
Tipulidae sp. sp.	+	+	-	t

Notes: d - smothered and killed by the effluent waters (decomposed soft-body remains observed inside shells); abbreviation. Taxonomic (T.c.) and biocenosis (B.c.) codes.

Table 2. Biomasses dominant and subdominant groups of bottom biocenosis from Orsk-Novotroitsk towns area in December 1991 (g/m^2, m±CD)

Ranks j	Biocenosis and subbiocenosises					
	Stations					
	D1	D2	$D2^r$	D7,D11,D13 D16.1,D17	D14,D15	$D14^r$,$D15^r$
	LCHP	cLC-	$Pcbv^r$	C+--	CO--	$bvlC(O)^r$
D	6.83	4.46	~6.89	0.03± 0.02	0.39± 0.28	3.32± 1.38
Sd1	0.49	3.87	~4.46	0.01± 0.02	0.35± 0.30	1.50± 0.99
Sd2	0.30	0.71	~4.20	-	-	0.40± 0.29
Sd3	0.06	-	~3.87	-	-	0.39± 0.28
Sd4	0.04	-	~2.81	-	-	0.35± 0.30
n	11.00	8.00	>16.00	1.50± 0.50	2.00± 0.00	>9.00

Notes: D - dominant, Sd - subdominant groups, n - number of taxa. r - reconstructions structure and data.

Table 3. Biomasses dominant and subdominant groups of bottom biocenosis on "coarse" sediment of the Ural River from vicinity of Novotroitsk town in August 1991 (g/m^2, m±CD)

Ranks j	Biocenosis and subbiocenosises				
	Stations				
	1,4,11,12	2,13	3	10	17
	CLKt(v)	CKOP(p)	COpL(K)	PbVO(K)	UptO(P)
D	1.80± 0.53	8.84± 7.94	8.47	4.25	1052.70
Sd1	2.77± 2.55	1.12± 0.96	0.99	3.49	3.22
Sd2	0.29± 0.33	0.72± 1.05	0.58	3.17	1.00
Sd3	0.21± 0.41	0.48± 0.67	0.54	2.70	0.81
Sd4	0.06± 0.10	0.37± 0.53	0.50	1.83	0.39
n	16.00± 2.00	19.00± 2.00	17.0	23.00	21.00

Notes: D - dominant, Sd - subdominant groups, n - number of taxa.

Table 4. Biomasses dominant and subdominant groups of bottom biocenosis on "soft" sediment of the Ural River from vicinity of Novotroitsk town in August 1991 (g/m^2, m±CD)

Ranks j	Biocenosis and subbiocenosises		
	Stations		
	5,7	14,15,16.1	6,16
	LtCc(A)	vbcC(l)	lvcC(O)
D	3.82± 1.51	3.83± 1.31	9.29± 0.96
Sd1	3.36± 3.02	2.24± 1.58	2.38± 1.72
Sd2	1.26± 1.28	1.17± 0.91	2.43± 2.12
Sd3	1.08± 1.53	1.37± 2.31	3.72± 5.14
Sd4	0.69± 0.10	0.29± 0.25	0.56± 0.77
n	17.00± 0.00	14.00± 2.00	23.00± 3.00

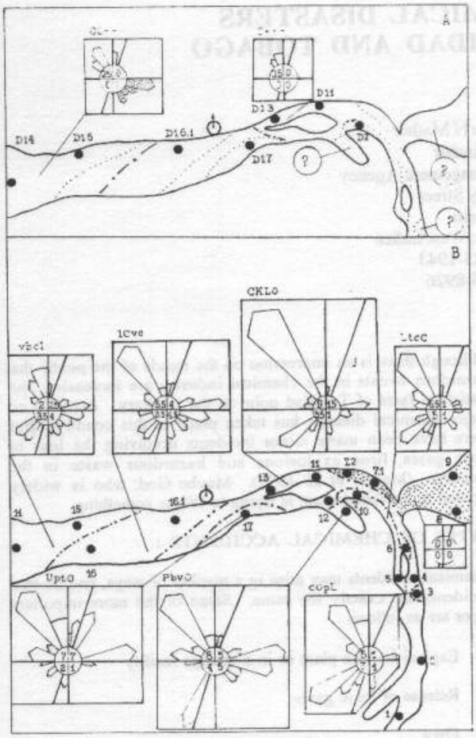

Figure 1. Vicinity of Novotroitsk town, showing location Water Consumption Station of NOSTA, study sites and distribution of bottom biocenosises and subbiocenosises. A. in December 1991 B in August 1991 Showing native organisms and died Mollusca with decomposed body remains inside shells (for sites of sampling D14, D15). The bordies of biocenosises (-*-) and subbiocenosises (-**-) and its structure. See Fig. 2 and Tab.1 for additional taxonomic details.

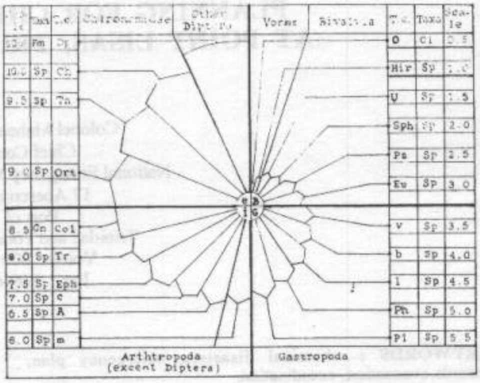

Figure 2. Taxonomic structure of bottom biocenosises and subbiocenosises. Showing: in centre of round: B - mean number species of Bivalvia per samples. G - mean number species of Gastropoda per samples. I - mean number taxa of Insecta (excluded Diptera) per samples. c - mean number species of Chironomidae per samples. See Tab.1 for additional taxonomic details.

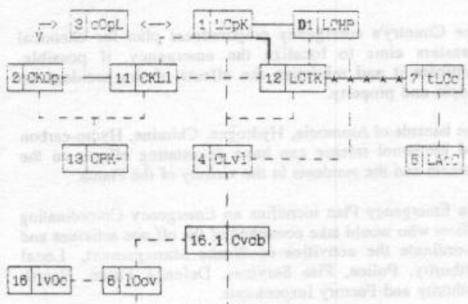

Figure 3. Graph of the route of maximum correlation with additional relations of biocenosises structure. Showing M (measures of similarity) from 8 to 5 by biomasses (Mb) and abundance (Ma) characteristics. See Fig. 2 and Tab.1 for additional codes of biocenosises structure.