Water quality – Operative Evaluation of Small Streams' Biological Quality by Saprobity Index of Macroinvertebrates

Descriptors: water quality, saprobity index, benthic macroinvertebrates

Foreword

The Latvian Standard determines the method and procedure for the assessment of long-term impact of pollution in small streams; the method is based on cenosis of benthic macroinvertebrates. This method is applied for the assessment of biological quality of small rivers and streams at full length or at stretches, as well as for the determination of local impact of pollution.

According to this standard, only competent persons, or persons with higher education in biology can do the analyses

The technical committee "Environmental quality" has worked out the Standard.

1. Introduction

An assessment of ecological quality based only on the chemical parameters is incomplete because it reflects the ecological water quality only during the sampling. The methods of biological analyses reflect water quality over a longer period of time. In the assessment of water quality the cenoses of macroinvertebrates are more important than those of plankton and they are more stable in time and space [1]. In the states of European Union methods of biological analyses based on macroinvertebrates are used for routine monitoring of rivers and the assessment of integrative water quality, while they are less expensive and less time-consuming in comparison with chemical analysis [2]. The results of analyses of water quality are represented on coloured maps, therefore the information is easy available for none-specialists, as each quality class has a corresponding colour and each stretch of river has been coloured according to it's water quality. The maps of water quality contain information necessary for the boards of water resources, for frame of the regional development planning and other decisions related with environmental protection and conservation.

2. Scope

The method is used for assessment of long-term impact of organic pollution.

The method is used for the control of biological quality of small rivers and streams of rithral and potamal type, with current velocity above 0,1 m/s. The method can be applied for the investigation of the whole river or it's single stretches, as well as for the establishing of a local anthropogenic impact, for example, in the intake area of wastewaters.

3. Definitions

Biotope – an area of waters or terrestrial part of land in which the main environmental conditions as well as species composition are uniform;
Benthic macroinvertebrates – invertebrates living in sediments or on the bottom, or on underwater objects; the size of organisms exceeds 1 mm;

Small rivers – rivers, the length of which does not exceed 100 km;
Potamal rivers – sandy and silty soft bottom slow running lowland rivers with current velocity less than 0,2 – 0,3 m/s;
Rithral rivers – sandy and stony hard bottom fast flowing rivers with current velocity above 0,2 – 0,3 m/s;
Saprobity – pollution of organic matter;
Saprobity index - numerical estimation of the pollution of organic matter, from 0 to 4.
Indicator organisms of saprobity – organisms, conformed for living at a specific level of organic pollution.
Level of saprobity – a certain interval of organic pollution degree.
Zoocenosis – assemblage of organisms living in the biotope.

4. Principle

Sampling of indicator species of macroinvertebrates by using the bottom scraper. Identification of organisms to the species or to other taxonomical levels. The calculation of saprobity index.

5. Reagents

5.1. Ethyl alcohol, 70 %;
5.2. Formalin, 4 %;

6. Equipment and material

6.1. Bottom scraper; mesh size 0,5 or 1 mm;
6.2. Forceps;
6.3. Sorting tray (white);
6.4. Vials (10 ml) for transportation and storage of samples;
6.5. Thermooxymeter;
6.6. Turbidimeter;
6.7. Magnifying glass; amplification from 6 to 10 times;
6.8. Binocular;

7. The sampling and storage of samples

A typical river stretch of 20 – 50 m is selected for sampling, where all the biotopes are investigated (by type of river-bed, composition of bottom, aquatic vegetation and current velocity) and their relative occurrence is determined. Occurrence of various biotopes in river stretches is given in Appendix D.

The measuring of all the necessary parameters is done (water temperature, dissolved oxygen etc.). The physically – geographical state is described in the form "The protocol of testing the biological quality". Explanatory notes on filling up the form are given in Appendix A.

The macroinvertebrates are taken with a bottom scraper or picked with forceps from stones or branches or other underwater objects. At the selected reaches of rivers 20 individual samples of benthos are taken and tested like one median sample.

The individual samples are taken according to the occurrence of all biotopes. For example, if 50 % of bottom consists of sand, 50 % of samples are taken from sandy biotopes. Organisms, picked from stones and branches, are considered as individual samples.

Investigating the water quality at all length of the river, the frequency of sampling depends on homogeneity of environmental factors and biotopes. For example, in forested regions, with less anthropogenic impact, reaches for analyses are taken after each 5 km. If environmental (riverbank) conditions are changing or some signs of anthropogenic impact (canalised river, regulated flow, input of wastewater) are observed, the samples are taken in areas, where the environmental conditions are changing.

If it is impossible to investigate the river at all it's length, three sites of river are chosen – at the upper (headwaters), the middle and lower reaches.

If it is necessary to establish the impact of point source pollution (input of wastewater's), a 50 to 300 m long stretch of river (depending on current velocity and intensity of water mixing) is taken upstream and downstream from the pollution source.

The samples should be taken conversely to the current direction, in order to prevent disturbance of confused bottom to biotopes downstream the sampling site.

An optimal season for sampling is the period of autumn – spring (from September until July), because in summer macrozoobenthos is relatively poor.

8. Working design

The samples are put in a sorting tray and investigated at the stream to the relevant taxonomical level, the number of individuals is counted and results are put in the protocol of results (Appendix B). A magnifying glass and keys of identification are used [6 – 10 or other]. If it is impossible to identify the organisms at the field, they must be put in vials and fixed in ethyl alcohol (70%) or formalin (4%). The fixed organisms should be kept in a dark place. Time of storage is unlimited.

At least 12 indicator organisms should be taken to obtain statistically significant results, the sum of relative occurrence of organisms should be at least 30.

The saprobity index is calculated.

In case of necessity, non-fixed samples can be analysed at the laboratory.

9. Interpretation of results

9.1. The calculation of saprobity index:

$$S = \frac{\sum s_i \times h_i}{\sum h_i} ,$$

where:

S - saprobity index;
s_i – individual saprobity index of i-th species [3];
h_i - relative occurrence of i-th species in a sample.

9.2. The appropriate saprobity level of water is determined by saprobity index (Appendix C).

9.3 The results of analyses are interpreted as a value of each saprobity index with representation error, and, if necessary, the uncertainness calculated as follows [4; 5]:

$$S_x^{\,2} = \frac{\sum h_p(4-S)^2 + \sum h_a(3-S)^2 + \sum h_b(2-S)^2 + \sum h_o(1-S)^2}{\sum h(\sum h - 1)};$$

$S_x = \sqrt{S_x^{\,2}}$;

$U = k \times S_x$ k = 2 by 95 % of confidence level;

where:

S_x – standard error;
S – value of calculated saprobity index;
h_p, h_a, h_b, h_o – the relative occurrence of species in samples at appropriate level of saprobity;
Σh – the sum of relative occurrence of taxa in samples;
U – uncertainty;
k - coefficient.

10. Interpretation of results

For the confrontation of several stretches of river it should be taken into account that stretches with similar surroundings, characteristics of streambed and relief can be compared.

The stretches of rithral and potamal type either in one or different rivers can't be compared.

11. Protocol of analyses

The following information should be included in the protocol of analyses:

- the reference of method applied;
- the identification number of protocol;
- the date of sampling;
- the name of the stream and it's basin;
- the sampling site, district, civil parish, geographical co-ordinates;
- the type of stream stretch;
- the physically-geographical characterisation of stream stretch;
- the number and relative occurrence of indicator organisms in sample;
- the saprobity index and saprobity level;
- investigator's name and signature;

12. Bibliography

1. Praktiskās hidrobioloģijas rokasgrāmata. Upju bioloģiskās analīzes metodes. P. Cimdiņa red.- Rīga: Vide, 1995., 71 lpp.

2. De Pauw N., Chetti P.F., Manzini P., Spaggiari R. Biological assessment methods for running water.- In: River water quality. Ecological assessment and control. - Luxemburg: Office for Official Publications of the European Communities, 1992, 217 - 249.

3. Cimdiņš P., Druvietis I., Liepa R., Parele E., Urtāne L., Urtāns A. A Latvian Catalogue of Indicator Species of Freshwater Saprobity.- Proc. Latvian Acad. Sci., 1995., 1/2, 122 - 133.

4. Report of the ICES/HELCOM Workshop on Quality assurance of Benthic Measurements in the Baltic Sea, Kiel, Germany, 23 – 25 March 1994.

5. Оценка степени загрязнения вод по организмам планктона и бентоса. Методическое руководство. Красноярский гос. унив., 1982. 20 стр.

The keys of identification of benthic macroinvertebrates and other taxonomical literature

6. Engelhardt W. Was lebt in Tümpel, Bach und Weicher? Stuttgart, 1989., 270 S.

7. Latvijas PSR dzīvnieku noteicējs. 1. daļa. Bezmugurkaulnieki (red. E. Tauriņš, E. Ozols).Rīga: Latvijas Valsts izdevniecība, 1957., 871 lpp.

8. Lillehammer A. Stoneflies (Plecoptera) of Fennoscandia and Denmark. Copenhagen: Scandinavian Science Press. 1988., 165 pp.

9. Определитель пресноводных беспозвоночных Европейской части СССР (планктон, бентос).Ленинград: Гидрометеоиздат, 1977., 510 с.

10. Хейсин Е. М. Краткий определитель пресноводной фауны. Москва: Государственное учебно-педагогическое издательство. 1962., 147 с.

APPENDIX A
(normative)

Explanations on filling up the protocol

1. Symbols of the elements of physically geographical characterisation:
(x) – episodic occurrence of the element of physically-geographical characterisation;
xx – dominance of the element (if several elements of physically-geographical characterisation are observed)

2. The macrovegetation is characterized as follows:
x - few;
xx - common;
xxx – dominating;

3. In case of necessity, the lacking names of macrovegetation groups, fish species or elements of physically geographical characterisation in protocol can be added in the vacant cells.

4. An assessment of physical condition reflects the diversity of biotopes and their suitability for the existence of fishes and invertebrates. Poor physical condition indicates to rivers with low diversity of biotopes, as well as soft bottoms and bad aeration conditions. If there is a considerable fall in the river, it's bottom is of gravel and stones providing optimal aeration conditions, and there is a high diversity of biotopes, the physical conditions of such river are estimated as good.

5. If the biological quality of the river has been influenced by hydrotechnical modification, the type of alteration should be marked in the protocol (symbols are given in the form).

APPENDIX B
(normative)

The protocol for biological quality assessment (no.)

Identification no.		Protocol no.		Date	
Stream basin				Water temperature (°C)	
Stream name				Dissolved oxygen	
District, civil parish				Oxygen (mg/l)	
				Conductivity (µS/cm)	
Sampling site				pH	
				Stream velocity (m/s)	
				Stream type	
				rithral	
				potamal	
Notes					
Characteristics of flow		**Overgrowing**		**Stream shading**	
natural		stones with slimy		total	
regulated		overgrow		partly	
		plants with slimy		no	
Stream		overgrow		**Bank vegetation**	
width (min-mean-max), m				plants	
depth (min-mean-max), m		**Water visually:**		bushes	
Characteristics of stream		clean		trees	
no current		unclean		**Observed fishes**	
slow (< 0,1 m/s)		**Water colour**			
even		**water odour**			
fast flowing		no			
with riffles					
Surrounding of river		**River bed**		**An assessment**	
lowland		hard		**of physical condition**	
hilly area		soft		good/very good (4 - 5)	
meadows		boulders		satisfactory (2 - 3)	
pastures		stones, pebbles		unsatisfactory (0 - 1)	
tilled lands		gravel		**Saprobity index:**	
deciduous forest		sand		**Saprobity level:**	
coniferous forest		clay			
mixed forest		black mud		**An assessment**	
bushes		brown mud		**is impossible:**	
settlement		detritus		stream dried up	
bog		macrophytes		stream overflowed	
				stream velocity < 0,1 m/s	
Macrophyte		**Hiding places for fishes**			
Coverage (%)		washed out banks			
Phragmites sp.		tree roots		**Factors of impact**	
Nuphar luteum		stones		emissions from WTP	
Chara sp.		**The stability of banks**		industrial waste waters	
Potamogeton sp.		stable		municipal waste waters	
Lemna sp.		unstable		waste waters from farms	
Carex sp.		**Banks**		agriculture	
Scirpus sp.		flat		Hydrotechnical modification:	
Elodea canadiensis		steep		Symbols:1-straightening, 2-broadening,	
Sparganium erectum		gentle		treatment, 3- bank fixation,	
				4-hydrotechnical constructions	
				5-impact of beavers	
		Investigator			
Symbols: x-few, xx-common, xxx-dominating					

The background table for calculation of saprobity

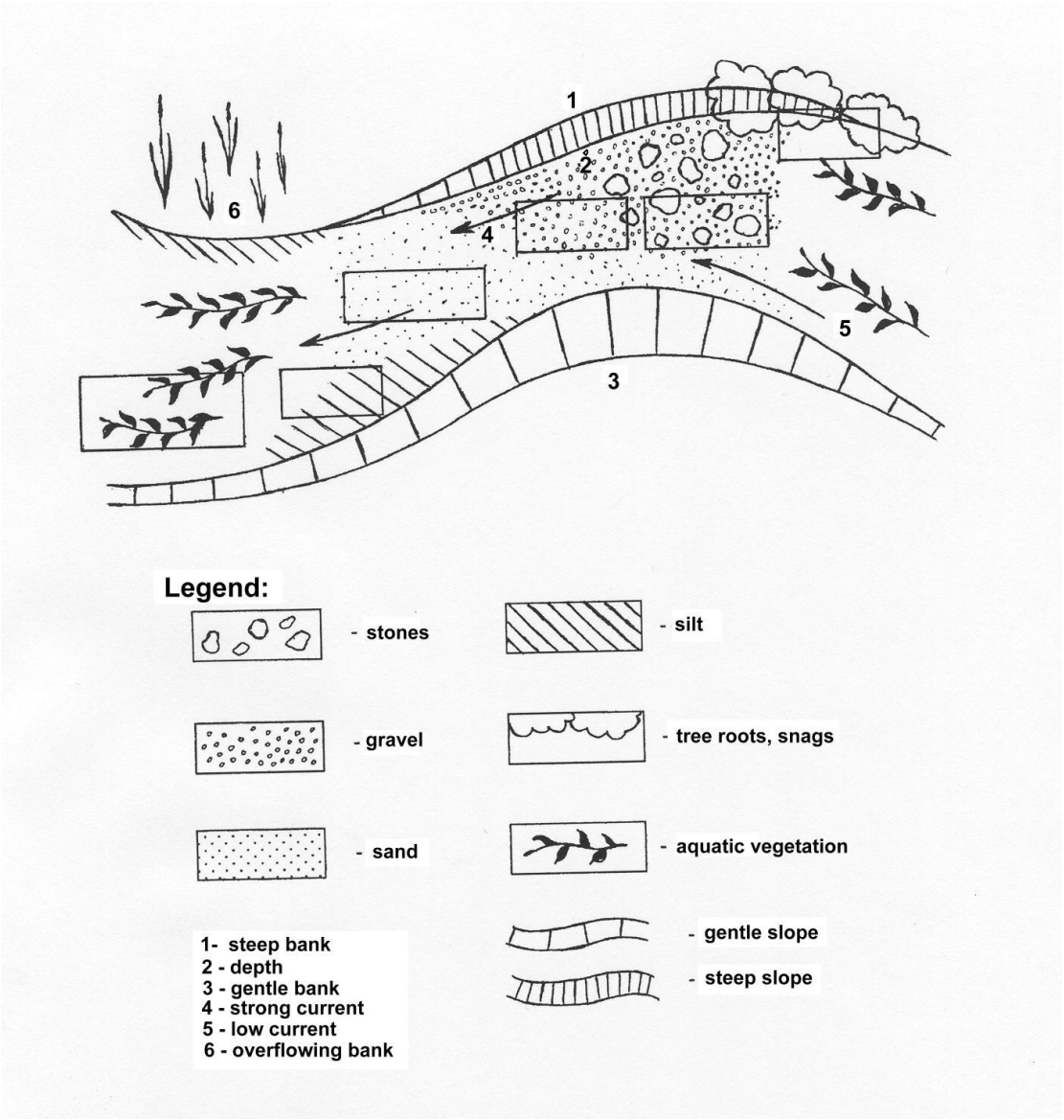
Taxa	Species or groups	Number	h	s	s x h	Level
Spongia	*Spongia* sp.			1,8	0	β
Turbellaria	*Polycelis cornuta*			0,8	0	o
	Polycelis nigra			2,15	0	β
	Planaria torva			2,2	0	β
	Euplanaria lugubris			1,6	0	β
	Dendrocoelum lacteum			2	0	β
Nematomorpha	*Gordius aquaticus*			0,8	0	o
Oligochaeta	*Tubificidae* sp.			3,5	0	α
	Naididae sp.			2,0	0	β
	Lumbriculidae sp.			2,2	0	β
	Piscicola geometra			2	0	β
	Haemophis sanguisuga			1,7	0	β
	Erpobdella sp.			2,65	0	α
	Glossiphoniidae sp.			2,3	0	β
Gastropoda	*Ancylus fluviatilis*			1,35	0	o
	Lymnaea stagnalis			1,85	0	β
	other Lymnaeidae sp.			2,2	0	β
	Planorbarius corneus			2,35	0	β
	Bithynia tentaculata			2,2	0	β
	Theodoxus fluviatilis			1,3	0	o
	Viviparus viviparus			1,65	0	β
	Valvata sp.			1,65	0	β
Bivalvia	*Pisidium, Euglesa* sp.			2,1	0	β
	Sphaerium sp.			2,4	0	β
	Unionidae sp.			1,8	0	β
	Dreissena polymorpha			1,5	0	o
Crustacea	*Asellus aquaticus*			2,8	0	α
	Gammarus pulex			1	0	o
Plecoptera	*Plecoptera* sp.			1,2	0	o
Ephemeroptera	*Ecdyonurus* sp.			2,3	0	β
	Heptagenia sp.			2	0	β
	Habrophlebia sp.			1,5	0	o
	Paraleptophlebia sp.			1,5	0	o
	Potamanthus lutens			2,25	0	β
	Ephemera sp.			1,8	0	β
	Baetis rhodani			1,15	0	o
	other Baetidae sp.			2,1	0	β
Heteroptera	*Aphelocheirus aestivalis*			1,5	0	o
Megaloptera	*Sialis sp.*			2,35	0	β
Trichoptera	*Agapetus sp.*			0,5	0	o
	Sericostoma sp.			0,75	0	o
	Silo sp.			0,6	0	o
	Goera sp.			1,5	0	o
	Brachycentrus subnubilus			0,8	0	o
	Hydroptilidae sp.			1,7	0	β
	Mystacides sp.			1,7	0	β
	Anabolia sp.			2,3	0	β
	Molanna sp.			1	0	o
	Limnephilus sp.			1,75	0	β
	others with cases			2	0	β
	Plectrocnemia sp.			0,8	0	o
	Rhyacophila sp.			0,9	0	o
	Hydropsyche sp.			1,8	0	β
Odonata	*Agrion* sp.			1,3	0	o
	Gomphus sp.			2,5	0	β
Diptera	*Chironomus plumosus*			3,7	0	p
	Chironomidae sp.			2,0	0	β
	Eristalis sp.			4	0	p
	Culicoides, Bezzia sp.			2,2	0	β
	Atherix sp.			1,1	0	o
	Tabanus sp.			2,35	0	β
	Simuliidae sp.			1,15	0	o
		Sum: A=	0	**B=**	**0**	
Occurrance (h): 1=1-3 organisms; 2=4-10 org.; 3=11-50 org.; 5=51-150 org.; 7=151-500 org.; 9= >500 org.			**Saprobity index = B/A =**		**Result**	

APPENDIX C
(normative)

The saprobity levels of running waters

Saprobity level	**Symbol**	**Saprobity index (S)**	**Evaluation of pollution**	**Colour**
Xenosaprobity	x	0 - 0,5	Very clean	Dark blue
Oligosaprobity	o	0,5 - 1,3	Clean	Blue
Oligo-β-mezosaprobity	o-β	1,3 - 1,7	Clean to slightly polluted	Light blue
β-mezosaprobity	β	1,7 - 2,3	Slightly polluted	Dark green
β-α-mezosaprobity	β-α	2,3 - 2,7	Slightly polluted to polluted	Light green
α-mezosaprobity	α	2,7 - 3,3	Polluted	Yellow
α-mezosaprobity-polisaprobity	α - p	3,3 - 3,7	Polluted to strongly polluted	Orange
Polysaprobity	p	3,7 - 4,0	Strongly polluted	Red

APPENDIX D
(informative)



Occurrence of various biotopes in the reaches of river