ASSESSMENT OF THE MINIMUM RIVER FLOW AS REQUIRED FOR BIODIVERSITY PROTECTION IN THREE BULGARIAN DANUBE TRIBUTARIES

Snejana DAKOVA[1*], Yordan UZUNOV[2], Konstantin TZANKOV[1]
[1] National Institute of Hydrology & Meteorology, BASc, 66 Tzarigradsko Shosse,1784 Sofia, Bulgaria, Snejana.Dakova@meteo.bg
[2] Central Laboratory of General Ecology, BASc, 2 Gagarin Str, 1113 Sofia, Bulgaria

***Abstract*:** A newly developed method for determination of minimum flow as required by the national legislation for the support of the optimum ecological state and biodiversity of riverine communities was implemented for the Danube tributaries Vit, Ossam and Belly Lom Several biotic parameters described the macrozoobenthos species diversity, equitability, dominancy and saprobic indices as standardized for water quality assessment were used in multiple regression models for estimation of the admissible minimum flow (Qmin) in maintaining the desired biological sufficiency of the discharge and respective water quality class within stretches of different levels of human impact.

Определение минимлального стока необходимы для охраны биологического разнообразия в трех болгарских притоков реки Дуная

РЕЗЮМЕ: *Создан метод для определения допустимого минимального стока как необходимое количество вод для поддержки оптимального экологического состояния речных сообщеcв и демонстрирован на болгарских притоков Дуная : реки Вит, р.Осам и р. Бели Лом имеющих различной степени и произхождения загрязнения вод..*
Различные биотические параметры, описывающиеся макрозообентоса, разнообразия вида, выравнивания, доминированость и сапробност, были используваны в множественой модельной регрессии для определения количество стока необходимы для подержки желаемая биологическая достаточность нагрузки и соответсвующей водной категории качества речных вод в процессе их изпользонании и управления.

Introduction

The admissible minimum river flow is an imperative legal requirement of the Water Act (Art. 117, item 1) aiming to ensure protection of riverine biological diversity and water sufficiency for maintenance the sustainability of the aquatic ecosystems. The provisions of the current Bulgarian environmental legislation are univocal with the Framework Water Directive (2000/60/EEC), which aims at maintaining and improving the aquatic environment in the Community. This purpose is primarily concerned with the quality of the waters. It recognize a necessity for a greater integration of both qualitative and quantitative aspects of surface waters, taking into account the natural flow conditions of water within the hydrological cycle.

While there is no warrantable definition for admissible minimum river flow, it could be defined as: *the state of discharge at which the river ecosystems maintain its optimum ecological balance and biodiversity adequate to the designated water quality class (category) within a given stretch.*

Following the requirements of an integrated water management policy, a methodological approach has developed recently by (Dakova et al., 1998, 2000, 2001) resulting in a method for calculation of the permissible minimum river flow (Dakova et al., 2002). This method has implemented on the flow of two main rivers of the South-West Bulgaria (Mesta and Struma) and it showed optimistic results.

The purpose of the present report is to represent the applicability of the method for assessment of admissible minimum river flow for three selected sites of different water quality for Danube tributaries of Vit, Ossam and Russenski Lom in Northern Bulgaria.

Noting Ideology, Concepts and Criterions

The methodology has founded in correspondence with the Water Directive 2000/60 EEC, the national legislation and with the experience in the examined problem.

The base idea is: the river flow is a surrounding habitat of the water ecosystems together with all others functions. The integrity of the water ecosystem function has based on the balanced interrelations among biological, chemical and hydrological factors. When the balance to be disturbed (as example diminishing of the stream by water intakes) the water ecosystems react replying. This reaction is indicator for the status of the steremflow. The hydrobiological processes by their nature are very complicated systems, consisting of many factors. With the view to find a possibility of quantitative estimation of the streamflow ecological status the follow hypotheses is accepted:

- Water discharge at a given river profile or stretch could be considered as both an unity of properties (quality) describing the environment of the riverine communities and the volume/space where the river continuum develops itself. To this end, there should be a measurable relation between the community biological parameters adequate to the water quality status and the water discharge at each river stretch. The aims of the biodiversity protection reject zero-hypothesis (no discharge or Q = 0), when the river communities destroy.
- There is a relation between biological elements, which indicate ecological status of the water as relevant to certain water quality class and discharge of the running water.

The valuation of such a hypothesis requires a demonstration (at acceptable level of confidence) of the multiple interrelations between the species content and structure of the riverine communities and both the discharge parameters and water quality parameters, respectively the water quality classes. This has reflection on the selection of such biological, chemical and hydrological parameter, which are enough informative about water ecological status.

The parameters of the bottom invertebrate community (macrozoobenthos) were used as a model community for assessment of the minimum river flow because of following general and specific reasons:

- Bottom invertebrate fauna or macrozoobenthos is amongst basic biological elements for assessment of rivers' ecological status according to national and European legislation]
- The macrozoobenthos parameters are the only indices standardized for quality assessment of running waters in this country;
- Bottom invertebrate organisms indicate ecological status for long periods (weeks, months) because of their relatively longer life cycles (months, years) in rivers.

According to Bulgarian legislation, biological indices for assessment of water quality (classes, categories) are based on the parameters of the species content (biological diversity) and quantitative structure of the bottom invertebrates (macrozoobenthos) – key community of the inland riverine ecosystems and component of the basic biological elements for assessment of the rivers' ecological status in terms of the Framework Water Directive 2000/60/EEC. The tandardized levels of biotic indices for each of water quality classes are presented in Table 1.

In this case, the estimation of the biological diversity is to accept as an estimation of the species richness (α-diversity). The total number of presented species/groups (SPEC) is enough quantitative measure, together with list of species. Total number of specimens (NUMB) or community density (represented for unit of bottom surface) is not only an additional quantitative parameter but it is also a basic parameter for calculation of some cenotic indices, for example of SDIV as a demonstrative index for β-diversity.

Table 1. Biological indices for water quality assessment in Bulgaria (according to Regulation No 7/1986) as based on the macrozoobenthos.

Biological Indices	Water Quality Class		
	I	II	III
Saprobity	Oligo-	β-meso-	α-meso-
Saprobic index after Pantle & Buck (SPUB)	<1.5	<2.5	<3.2
Saprobic index after Rothschein (SROT)	>60	>40	>25
*Species diversity after Margaleff (SDIV)	>9.0	>7.5	>3.5
Diversity index after Shannon & Weaver (HIND)	>3	>2	>1
Eveness (equitability) after Pielou (EVNS)	>0.7	>0.6	>0.5
Dominancy after Simpson (DOMN)	<0.2	<0.3	<0.5

* Standardized but not listed in original Regulation No 7/1986.

To this end, the valuation of the above hypothesis about satisfactory correlation of water discharge and biological elements, which are informative for ecological status, could be focused on macrozoobenthos parameters as indicators of the water quality status (class, category).

The chemical indexes are accepted BOD – biochemical Oxygen Demand, nitrite ions (N-No2), and ammonium ions (N-NH4) and N-NO3, which have been involved in the current regulations.

The water discharge is to accept as an integral indicator of the river basin.

Materials and Methods

Two tapes of data massifs are requisite, as follow:

1. Synchronous information massifs – presumed that the series of biological data to be completed with corresponding chemical and hydrological characteristics i.e. in the day of taking, the biological samples it is necessary to have the corresponding chemical and hydrological information for the same sit. Next, this original date is to be used for calculation the respective indexes.
2. Massifs composed from the data of registered stremflow. This is the value of flow recorded and estimated at the hydrological gauging stations.

The availability of the biological data is leading in the process of composition of the series and receptively the massifs. The missing hydrological and chemical data have to fill by the traditional methods.

The preliminary investigation is to be focus to identification the specific issues of the river basin, water use, possibility of presence of pollution etc. The most important requirement is the choice of period with approximately similar crating streamflow conditions.

The inventory of the all-available information in Bulgaria fined out that there are no regular, purposive long time synhroned observations. The data were collected from different projects in different years. The unique integrating denotation is that the data have been obtained in the summer i.e. in the low flow conditions. Therefore, the data should be harmonized and joint to the extent necessary.

Using the multiple regression model and by the multiple regression the major influenced variables are selected. The most favorable combinations were included in multiple regression equations. Based on these equations and after substitution by standardized values for 3 water quality classes, the threshold levels of Qmin for each water quality class is to be calculated. The admissible minimum is be accepted according to the designated water quality class (category) for each site/stretch following the Order of the Minister of the Environment & Water (1998) on the projected water quality of the Bulgarian rivers.

Results and discussion

The admissible minimum discharge was be calculated for three water–quality statuses:

1) High status - mountain pure water flow which is represented by river Belly Vit

2) Moderate status – stremflow with commonly domestic sewer pollutants is represented by river Osam at point Lovetch and
3) Bad status – diminution streamflow and contaminate from industrial sewer waters is represented by river Rusenski Lom – sit under town Razgrad.

Hydrographic characteristics and hydrological features:

Sit at river Belly Lom to village Belly Lom

This sit is situated at upper reaches of river Vit that is right tributary of Danube. Take its source from the north slops of the Central part of Balkan Mountain under the top Vejen 2030-m a.s.l.

Hydrographical characteristics:	catchment's area	A = 306 km^2
	Mean elevation of the watershed	H=1007 m
	Mean slope of the river	Jr = 53,3%
	Mean slope of the basin	Jb = 0,383‰
	Density	0,64 km/km^2

Generally, the streamflow of upper Vit is almost uninfluenced from the human activities. The water supplying impoundage of 1-2 l/sec on the small tributaries of Vit can be marked.

The water quality is corresponding to 1st class (category).

Sit at river Osam under town Lovetch

The watershed of the Osam river is situated on the east of the Vit watershed. The Osm river spring from the Central part of Balkan (Stara planina) mountain at 1821 m a.s.l. and run North crossing Danube plain and flow into Danube river. The sit on Osam river under town Lovech is located in the middle reaches of the river, in the Danubian plain.

Hydrographical characteristics:	catchment's area	A = 908,5 km^2
	Mean elevation of the watershed	H=723 m
	Mean slope of the river	Jr = 25,2 %
	Mean slope of the basin	Jb = 0,303 ‰

Generally, the runoff of Osam river is disturbed from 14 water intakes and 19 small reservoirs constructed in period 1958-1962 and utilized for meliorate purposes. Besides, a few small water powerplants have been constructed in the 1928-1929 of the last century. To this end the hydrological regime could be estimated as strongly affected. The water quality is estimated as transitional between 2nd and 3rd class (category).

Sit on the Roussenski Lom river under town Razgrad

The river Roussenski Lom is the most eastern tributary of Danube from the Bulgarian part of the basin. Take its water from the Razgrad hills at 360 m a.s.l.

Hydrographical characteristics:	catchment's area	A = 377,8 km^2
	Mean elevation of the watershed	H=327 m
	Mean slope of the river	Jr = 4,4 %
	Mean slope of the basin	Jb = 0,124 ‰

The streamflow of Roussensky Lom is strongly dominated, because the water is cached and stocked into the reservoir " Belly Lom" (1960) with volume 25 mill. m^3. Besides, another 8 small reservoirs for irrigation have been built on the basin above the sit.

To this end, the effects of the industrial wastewater are very strong in spite of local treatment. The water quality is beyond the standard classes (categories).

All mentioned rivers are right tributaries of Danube. They generate the flow from raining – snow supplementation commonly in the period March- June. This is a typical property of the Bulgarian right tributaries of Danube in Continental Climatic conditions.

The stremflow of Roussenski Lom is a little influenced by the Mediterranean Climatic conditions.

The distributions of the each tree rivers flow into the year are shown in fig 1 and fig 2.

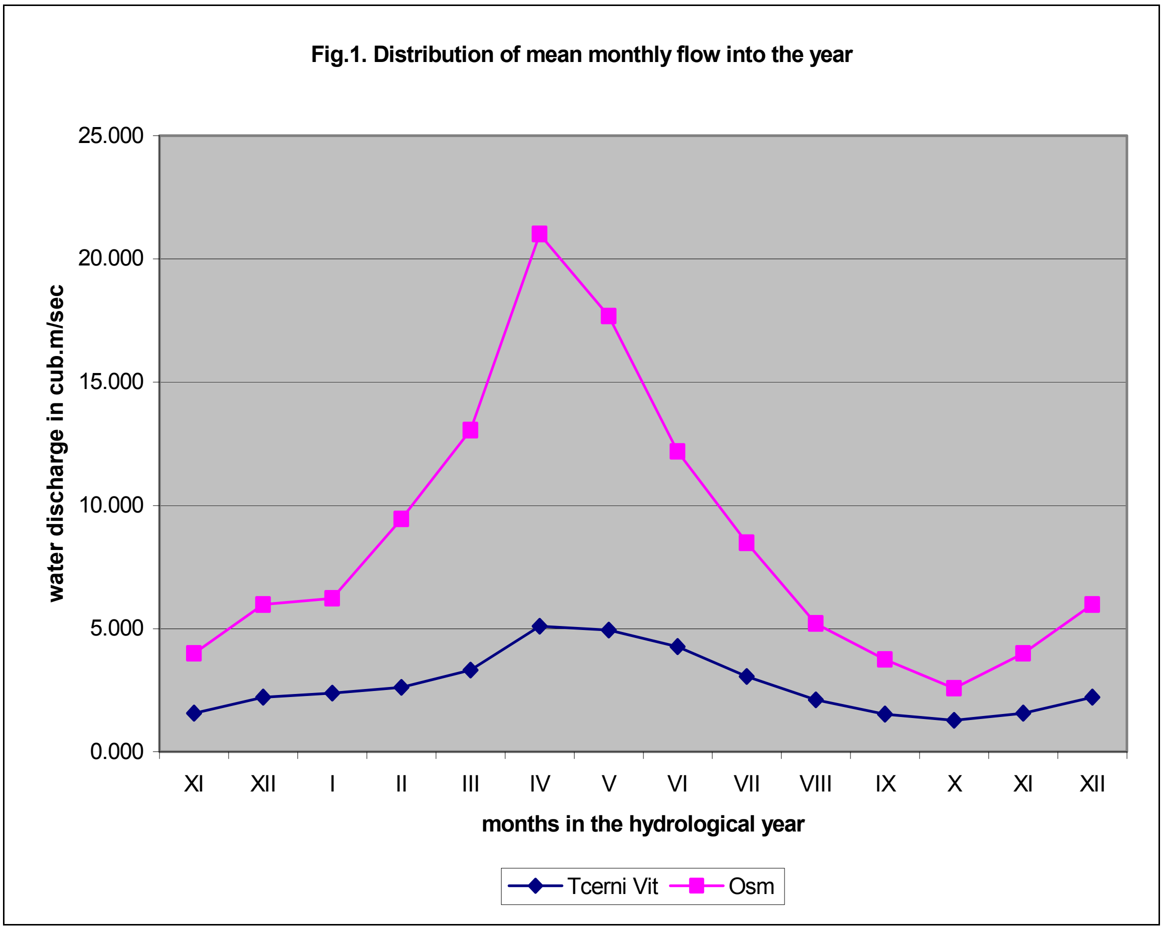


Fig.1. Distribution of mean monthly flow into the year
water discharge in cub.m/sec
25.000
20.000
15.000
10.000
5.000
0.000
XI XII I II III IV V VI VII VIII IX X XI XII
months in the hydrological year
Tcerni Vit
Osm

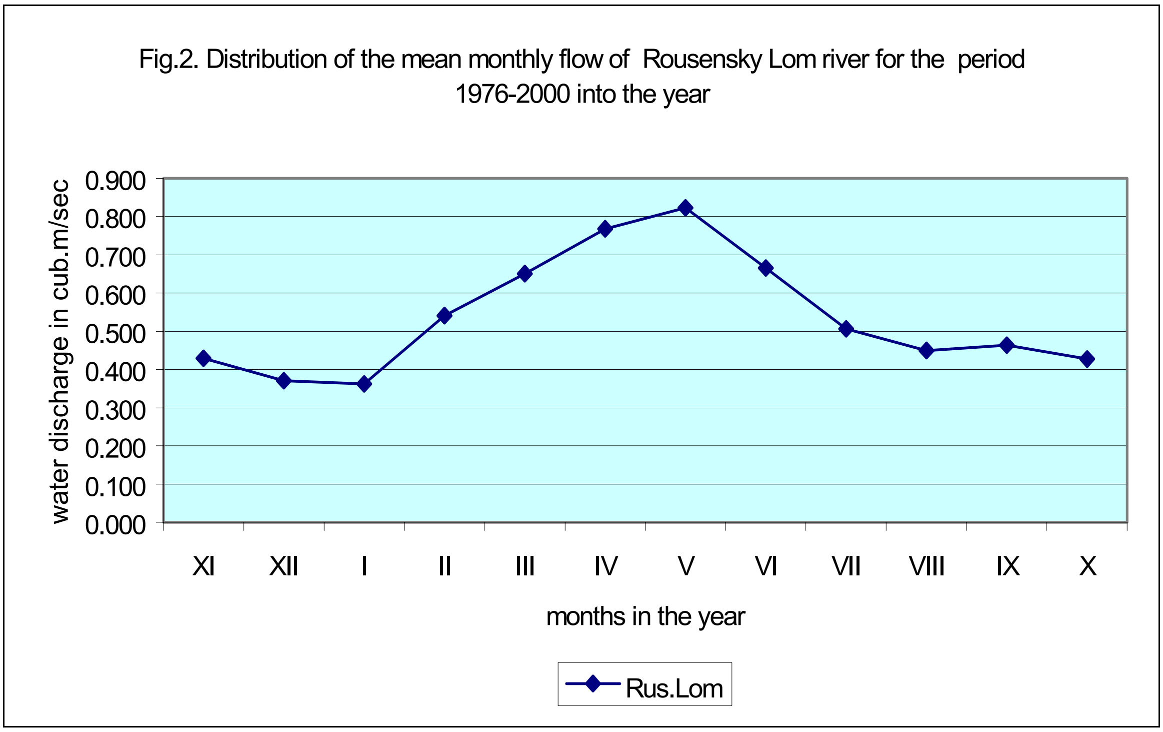


Fig.2. Distribution of the mean monthly flow of Rousensky Lom river for the period 1976-2000 into the year
water discharge in cub.m/sec
0.900
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
XI XII I II III IV V VI VII VIII IX X
months in the year
Rus.Lom

Low flow conditions on the rivers and drought over the catchment cause problems in water uses and the rivers ecological functioning.

The results of calculation of the hydrological characteristics for period 1976-2000 are shown in table 2.

Table 2. Mean hydrological parameters for the period of 1978-2000 at studied sites

River and place	Qann	Qmes	Qan 95%P	Qmes 95%P	Q20d	Q10d	Q3days	Qmin
Tcherni Vit	2,83	1,068	2,44	0,981	0,99	0,93	0,90	0,85
river Osam- Lovetch	9,67	1,72	3,932	0,675	1,583	1,407	1,259	1,153
river Bely Lom-Razgrad	0,36	0,133	0,082	0,057	0,229	0,216	0,201	0,189

Results

The reactions of biological indexes to the changes of the discharges at the mentioned above three sits in the river Vit, Osam and Roussenski Lom are interpreted by the follow regression models:

VIT $Qi = Q_{mm}. * (-0.03*SDIV/ SDIV_{mm} +5,406*EVNS/EVNS_{mm})$

OSAM $Qi = Q_{mm} * (0,584* SDIV/ SDIV_{mm} +0,997 * SPUB/ SPUB_{mm})$

Roussenski Lom $Qi = Q_{mm} * (+0.268* SDIV /SDIV_{mm} +0,344*SPUB/SPUB_{mm})$

where index mm is the mean value measured data

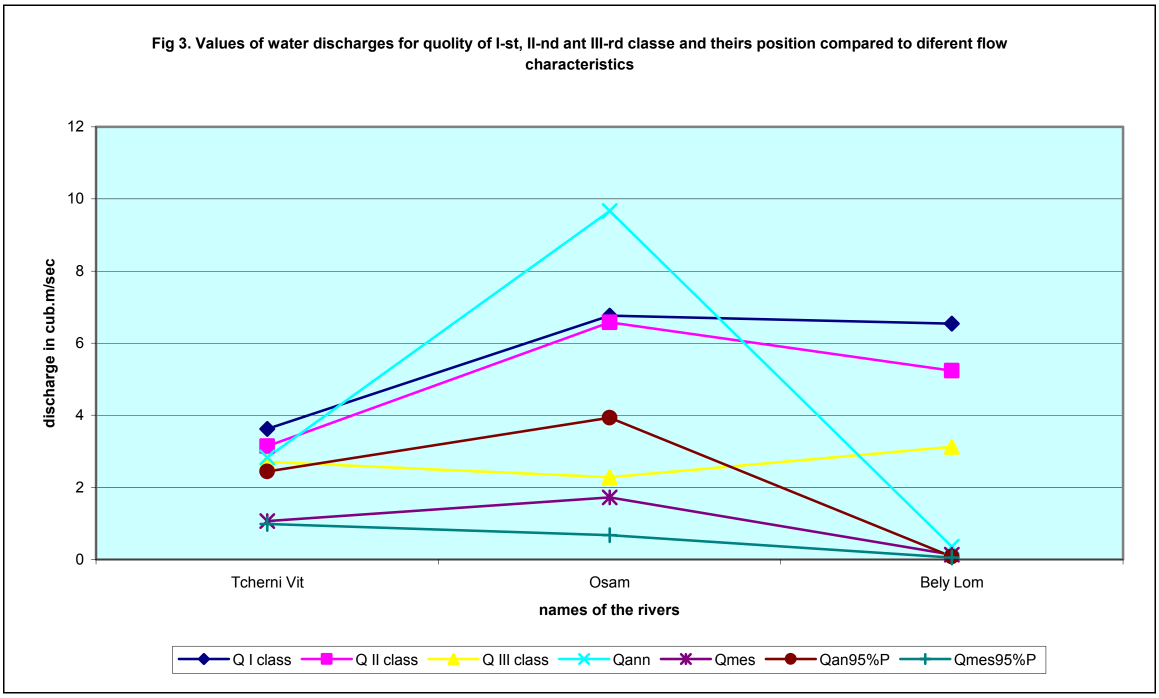
The obtained permissible discharges together of indexes and multiple regression coercion are shown on table 3.

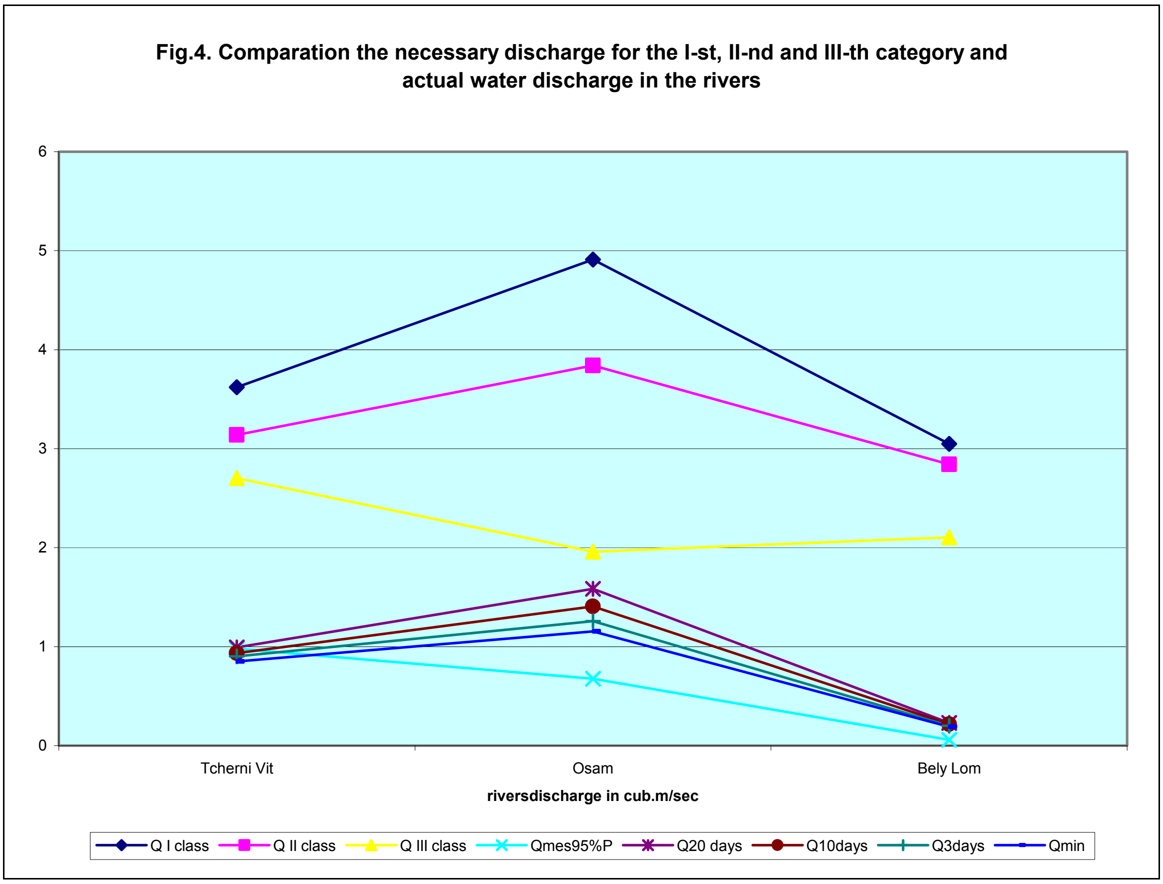
Table 3. Correlation coefficient R, involved biological indices and minimum admissible river flow (Q) for three water quality classes at studied rivers/sites

River and place	R	indexes	Q I class	Q II class	Q III class
Tcherni Vit	0,87	SDIV, EVNS	3,62	3,14	2,703
river Osam- Lovetch	0,78	SDIV, SPUB	6,76	6,58	2,28
River Bely Lom-Razgrad	0,72	SDIV, DOMN	6,54	5,24	3,123

The obtained values of Q could compare with some of the hydrological characteristics from table 1.

Compression among the permissible flow for трете categories and flow patterns (as mean annual flow, mean monthly flow, minimum monthly flow with probability 95%, annual flow with probability 95%, moving average for N days and so on.) can seen on fig 3





Conclusions:

- The discharge affects both the biological diversity and cenotic structure of the bottom community depending on the ecological status of the water as reflection of the water quality (pollution level);
- At low flow situations the community structure may change towards a destruction, which is demonstrative for worse ecological status;

- Maintenance of projected water quality class (category) requires higher discharge in order to protect biological diversity and ecological balance at desirable state corresponding to the state standards for water quality in rivers.
- This is an easy tool for the decision makers for governing water wisely with respect to ensure protection of riverine biological diversity and water sufficiency for maintenance the sustainability of the aquatic ecosystems.

Acknowledgments: The authors are thankful to Dr.Ivanka Janeva from Institute of Zoology ,BASc Sofia, for his kind permission of use the initial biological data.

References

Андриянов В.Г. (1957): Методические основы исследования и расчета внутригодового распределения стока,Тр.ГГИ вып.61.

Бонев Д.,Ив.Милушев (1984): Върху възможностите за оценяване и моделиране качествата на повърхностните води, Сб.Научни трудове КОПС,т II,Земиздат, София

Bovee K.D&Milhous R.T. (1978): Hydraulic simulation in instream flow studies: theory and techniques. Instream flow information USDI Fish Wild.Serv.FWS/OBS/78/33, paperN5.

Bovee K.D. (1982): A guide to stream habitat analysis using the instrem Flow Incremental Methodology.Instrem flow information.Western Energy and Land Use Team U.S.Fish and wildlife Service. Ft.Collins Colorado. FWS/OBS82/26.paper N12.

Bonnacci O. (2000): Report on the XX Conference of the Danubian Countries. Bratislava.

Cochnauer (1976): Instrem flow techniques for large rivers. Proceedings on Insteram flow needs.Orsborn and Allman ed.

Дакова Сн. (1977): Влияние на водостопанската дейност върху оттока през периода на лятно маловодие,сп."Хидрология и метеорология" кн.4.

Дакова Сн (1985): Минимален отток на реките в България при естествен и нарушен режим, дисертация, Ленинград.

Дакова Сн. (1989): Определяне на оразмерителното водно количество на реките с оглед допустимата степен на замърсяването им. Сп."Проблеми на хидрологията"

Dakova Sn, Y. Uzunov, D. Mandadjiev (2000): Low flow- the river's ecosystem limiting factor, ELSEVIER –Ecological Engineering 16 (2000).

Dakova Sn, Y. Uzunov, B. Vachev, K. Tzankov (2001): Preliminary results of an approch in assessing the ecological status low flow in Bulgarian rivers, UNESCO, IHP V, Document Techniques en Hydrologie N51.

De Pauw, N., P.F. Ghetti & D.P. Manzini (1992): Biological Assessment Methods for Running Waters. - In: (eds. Newman et al.) River Water Quality: Ecological Assessment and Control.

De Pauw, N. & H.A. Hawkes (1993): Biological Monitoring of River Water Quality. - In: (eds Walley, W.J. & S. Judd) River Water Quality Monitoring and Control, Ashton Univ.: 87-111.

Mihailov, Arsov R, Nikolova R, Tzachev Tz, Gustard A, Cole G, Marshall D&Bayliss A (1987): A study of compensation flows in the UK , Report99 – Institute of hydrology.

Nehring R. (1979): Evaluation of instream Flow Methods and Determination of Water Quantity Needs for Streams in the state of Colorado. Colorado Devision of Wildlife Fort Collins

Hartmann L. (1990): Methodological guidnes for integrated environmental evaluation of water resources development .The impact of large water project on the environment, Paris, UNESCO

Hellawell, J.M. (1986): Biological Indicators of Freshwater

Hugler L.W.G. (1990): Classification of water systems for the environmental evaluation of water resources development, UNESCO,Paris.

Зарбова, К. 1985. Разработване за усъвършенствувани методи за планиране на комплексното използване и опазване на водните ресурси.- Годишен отчет на НВИЦ на МОСВ, С.

Зарбова, К. 1989. Оценка на някои екологични изменения при нарушаване режима на речния отток в поречията на Янтра и Осъм.- Годишен отчет, НВИЦ на МОСВ, С.

Зарбова, К., И. Янева, А. Хамамджиева. 1990. Методичен подход за оценка влиянието на речния отток върху структурата на зообентосните ценози.- Сб. научни. тр. НВИЦ на КОПС.

Зарбова, К., А. Хамамджиева, Е. Григорова. 1993. Изследване влиянието на събирателна деривация "Костел" върху речните екосистеми.- Водно дело, 3, 16-19.

Zaharieva, V., I. Janeva (in print). Assessment of the dependencies between the characteristics of the flow and the content and the structure of the river benthic zoocenoses in conditions of natural flow regime.

Knoben, R.A.E., C. Roos & M.C.M van Oirschot (1995) Biological Assessment Methods for Watercources. - UN/ECE Task Force on Monitoring & Assessment, Vol. 3, Lelystad, 86 pp.

Митропольский А.К. 1971. Техника статистический вычислений , Москва,

Научен отчет НИ-МОНТ 1995, Дакова Сн.р Й.Узунов, Д.Мандаджиев и др. "Хидроекологични аспекти за оценка на антропогенните въздействия"

Ненов Ив.1984, Руслови деформации при хидротехнически и комуникационни съоръжения попадащи в зоните на влияние на русловите кариери, сп."Хидрология и метеорология" кн3

Metcalfe, J.L. (1989) Biological Water Quality Assessment of Running Waters Based on Macroinvertebrate Communities: History and Present Status in Europe. - Environ. Pollut., 60: 101-139.

Русев, Б. 1977. Замърсяване и самопречистване на р. Осъм според изменението в състава на бентосната й фауна.- Хидробиология, 5, 3-22.

Tennant,1976 Instream flow regimes for fish,wildlife,recreation and related environmental resources.Proceedings on Instream flow needs, Orsborn and allman ed.

Узунов, Й., С. Ковачев (1984) О некторых принципах структуры и организации гидробиологического мониторинга рек. - Хидробиология, 21: 34-41.

Узунов, Й., И. Янева (1999) Видово разнообразие на съобществото. - В: (ред. Д. Пеев, С. Герасимов) Национална програма за биомониторинг на България. Експресни и перспективни методи за биологичен мониторинг, С., Гея-Либрис: 150-152.

Uzunov, Y., L. Penev, S. Kovachev & P. Baev (1998) Bulgarian Biotic Index (BGBI) - an Express Method for Bioassessment of the Quality of Running Waters.- Comp. Rend. Acad, Bulg. Sci.

Узунов, Й., Н. Начев. 1984. Динамика на олигохетния комплекс в река Благоевградска Бистрица в зависимост от някои фактори на средата.-Хидробиология, 21, 56-67.

Чеботарев А.И. 1974. Статистические методы в гидрологии, Ленинград,.

Янева, И., Б. Русев. 1985. Тенденции в измененията на хидробиологичното и сапробиологичното състояние на р. Тунджа. II. Май и ноември, 1981г.- Хидробиология, 26, 15-36.

Janeva. I., B. Russev, Y. Vidinova, V. Tyufekchieva (in print).- River benthic zoocoenoses in conditions of natural flow regime.

* * * Математические методы в биологии , Сб. Укр.АН, Киев, 1977

* * * Statistical methods in Hydrology, Canada,1986.

* * * Хидрологичен наръчник том.I и II, Техника, София, 1979.

* * * Отраслови нормали, НИМХ-БАН, 1999.

* * * **Pollution and Environmental Management, London,** 546 pp.

* * * Guidelines on monitoring and Assessment of Transboundary Rivers UN/ECE Task Force

ANNEX 1

CHART OF PROCEDURE