ADAPTATION OF THE "BMWP" METHOD FOR WATER QUALITY EVALUATION TO RIO DAS VELHAS WATERSHED (MINAS GERAIS, BRAZIL)

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ABSTRACT: Adaptation of the "BMWP" method for water quality evaluation to Rio das Velhas Watershed (Minas Gerais, Brazil). It is presented a new score ponctuation with the support of hydrobiological data sampled in the years of 85, 86, 87, 91 and 1992 for Biological Monitoring Working Party Score System, (UK National Water Council) the communities of benthic macro-invertebrate taxonomic familia in the higuest of Rio das Velhas Watershed. This regional oriented version of "BMWP" for the waters of Rio das Velhas granted the possibility of scores determination as refered to the frequency distribuition of occurrences of the various familia according tho the different water saprobic condition levels as reported to the physical-chemical characteristics. The 1992 data about the biomonitoring and the water quatity classification of the studied watershed, were showed in cartografic maps.

Key-words: BMWP biotic index, macroinvertebrates, bioindicator, river ,basin, organic pollution,saprobity, tropical ecosystem, Brazil.

RESUMO: Adaptação do método "BMWP" para avaliação de qualidade de água da bacia do rio das Velhas (Minas Gerais, Brasil). O trabalho apresenta uma adaptação regional da metodologia do BMWP "Biological Monitoring Working Party Score System" (UK Nacional Water Council), com base numa série histórica de dados coletados em 85, 86, 87, 91 e 1992 na Bacia do Alto Rio das Velhas, que relacionou as caracteristícas fisico-químicas da água, quanto ao seu teor de carga orgânica e a frequência de ocorrência dos organismos macroinvertebrados da comunidade bentônica, para determinação da valência saprobiótica dos mesmos. Considerando as novas valências saprobióticas (scores) estabelecidas para as famílias da referida bacia, foi avaliada a qualidade da água com base nos dados de 1992, através de representação cartográfica.

Palavras-chave: índice biótico, macroinvertebrados, bioindicador, qualidade de água, poluição orgânica, saprobidade, biomonitoramento, ecossistema tropical.

INTRODUCTION

Employing bioindicators of water quality for the evaluation and control of aquatic resources has become established in industrialized countries (Hellawell 1989), but in Brazil, it is still in its incipient stages due to great deficiencies in the knowledge of tropical species.

In the State of Minas Gerais, studies of bioindicators have been undertaken since 1985 at CETEC with the goal of developing monitoring programs in the individual watersheds (Junqueira & Campos, 1991). For developing methods to employ invertebrates as bioindicators for the quality of the water in lotic tropical environments, a primary requirement is a thorough knowledge of the biology and ecology of these species, especially with regard to their tolerances to different amounts of organic substances. Methods similar to the saprobial system developed by Kolkwitz and Marsson and using the methods of Sladecek (1973) can then be employed.

More than 50 different methods for biological evaluation of water quality have been developed in countries of the temperate zones, (De Pawn and Wanhooren 1983). However, the application of such methods to tropical water bodies is limited because different species are present. Before such methods

can be applied in the tropics, it will be necessary to establish the ecological valencies of the local species, based on a knowledge of their autoecology. It is well established that benthic invertebrates can be important bioindicators because of their limited locomotory abilities, their attachment to solid substrates, and their relatively long life cycles. Thus, these organisms are well suited for monitoring the water quality in flowing water. However, because these animals are not cosmopolitan, the difficulties in identifying the tropical species greatly diminishes the advantages of using them for making comparisons.

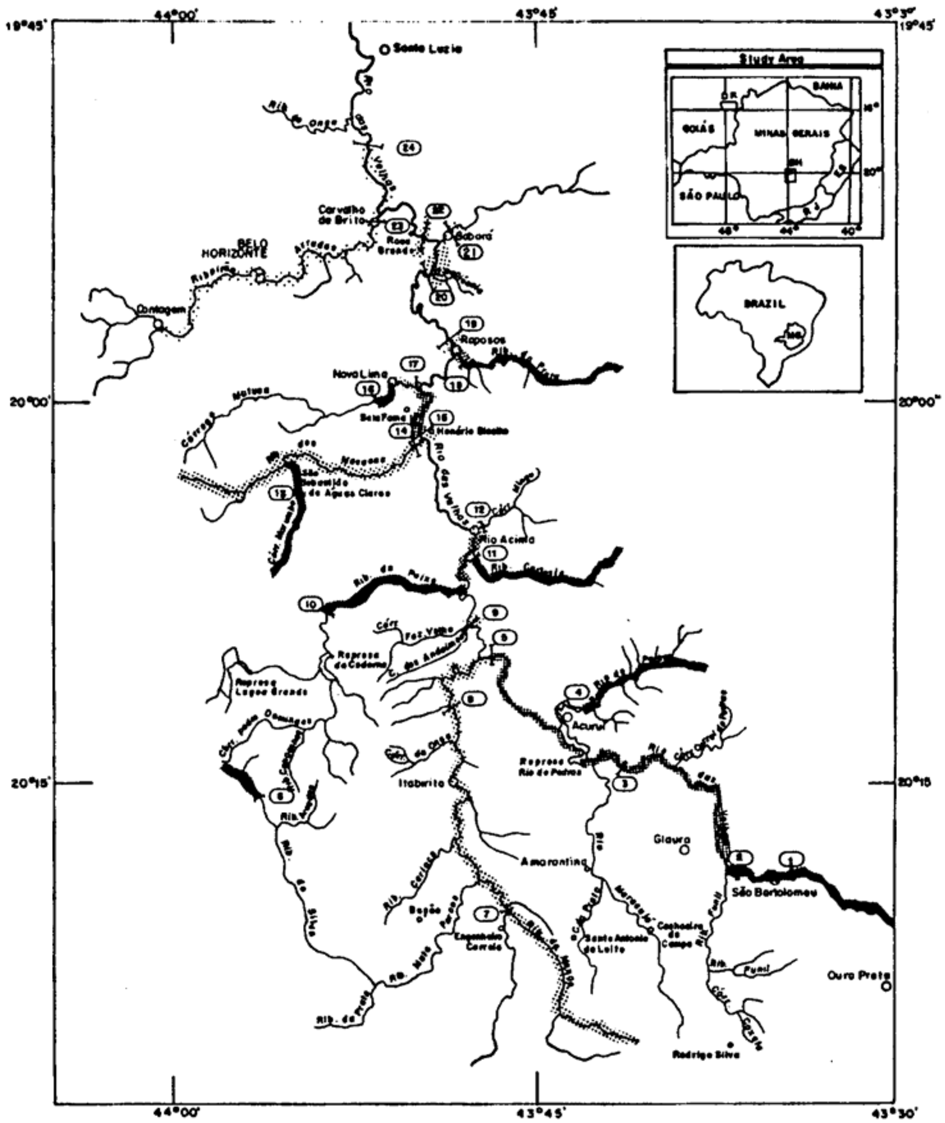
There is a lack of taxonomic keys to the Brazilian macroinvertebrate species, especially the immature stages of aquatic insects, and there are few specialists in the region. For these reasons, it seems convenient over the short term to adopt foreign systems that require the identification of the organisms only to the level of family, such as the Biological Monitoring Work Party Score System - BMWP (Hellawell, 1989).

STUDY AREA

The region studied encompasses the watershed of the Rio das Velhas from its source in the Serra de Antônio Pereira in the municipalily of Ouro Preto to a point 7km downstream from its confluence with the Arrudas River in the Sabará.

The area drained by the upper Rio das Velhas system is 1943km^2, and it is 108km long. The terrain in this region has a strong relief with its highest point at an elevation of 1160m, and its lowest at 680m. Its climate is among the coolest in the state with thermic indices between the 18°C and 20°C annual isotherms. At the southern end near Ouro Preto, there is an isolated area that receives considerable rainfall, from 1,800 to 2,000mm annually, and has a very high humidity.

This area has great economic importance for the region because it contains deposits of gold, iron, manganese, bauxite, and other minerals, as reported by CETEC (1978). The choice of this watershed for the pilot study on bioindicators is justified by the important role it plays in the state, draining regions of intensive mining activity and much of the metropolitan area of Belo Horizonte. It therefore receives high loads domestic and industrial wastewater. At the same time, it supplies most of the water to the city of Belo Horizonte.



WATER QUALITY EVALUATION THROUGH BIOINDICATORS

Legend

WATER QUALITY CLASS

Excellent
Good
Regular
Bad
Very Bad

CARTOGRAPHIC CONVENTION

Localities
Drainage
Sampling Station

0 km 5 10 15 20 km

METHODS

Selection and use of the sampling network

The demarcation of the sampling network for the study of the communities of benthic aquatic macroinvertebrates was completed with reference to the network established for the determination of physical and chemical qualities of the superficial water, which was initiated by CETEC in 1978 in the uppermost part of the Rio das Velhas watershed. In this way, the results could be correlated with those obtained on the physical and chemical characteristics of the water.

Available information on the region includes descriptions of the agricultural and mining activities and on the erosion processes. The sampling sites were selected during visits to the region using the criteria for selecting then in the German Manual of Technical Norms (Fachgruppe Wasserchemie in der Gesellschaft Deutscher Chemiker, 1979). These include hydrological characteristics, such as the influence of the tributaries, size fractions of the substrate, the presence or absence of human settlements, other anthropic influences, inputs of liquid effluents, characteristics of the littoral vegetation, occurrence of aquatic vegetation, accessibility,and similarity of the distances between the sites.

Through this process of selection, a network of 24 sampling sites was established, 10 of which were along the Rio das Velhas and the other 14, in the drainage areas of its main tributaries. These tributaries include the Rio de Pedras, Cortesia and Mingu Streams, and the Prata and Sabará Rivers on the right side of the main river, and the Itabirito and Peixe, dos Macacos, Água Suja, and Arrudas Rivers on the left side. At the sites in this network, physical, chemical, and biological parameters were recorded.

Determination of the physical and chemical conditions and the study of the zoobenthos at the sities in the network were undertaken during the months of May, August, and September of 1992, when various analytical data were collected simultaneonsly. Sampling was conducted only during the annual period of low water levels, during which the zoobenthic communities were more stable because movement of the sediment by the water flow was minimal and the sampling sites were more accessible. Furthrermore, sampling in dry season can always be compared in a long term biomonitoring program, with not so much expensive costs.

Collection and analysis of the samples

The water samples used for the analysis of these parameters were collected at an average depth of 20cm, using small containers with a volumetric capacity of about 10 l. The samples were fixed,tested, and analyzed according to the procedures described by APHA (1980).

The zoobenthos samples were collected near the banks of the water courses or from the river bed in the channel, when the depth permitted.The communities of macroinvertebrates present, including both epifauna and infauna, were collected by the kicking method of Macan (1958), using a dredge with a mesh size of 0.3mm for a period of three minutes. Parallel samples were collected manually using pincers and small brushes. The specimens collected were placed in plastic bags and pails for fixation in 10% formalin.

The initial part of the analysis consisted of seiving the samples through a 0.3mm mesh. Next, the specimens were sorted under a dissecting microscope, and then placed in a 10 or 20ml glass tube containing 70% alcohol to be used later for qualitative analyses. The analysis involved taxonomic identification of the organisms using keys, illustrations, and techniques of optic microscopy.

Determining the ecological valences of the benthic organisms in tropical lotic ecosystems, especially in the limits of tolerances to the content of organic substances, is necessary for developing a method of bioindication for water quality and for establishing the degree of saprobity. There fore, the following parameters were selected as a basis for this study: water temperature, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, and ammonium-nitrogen concentration, determined according to the Richtlinie für die Ermittlung der Gewässergüte-Klasse by LAWA (1982). This manual stablish the method used to determine saprobity level of the water, using the folowing parameters on Table I. From the values for the physical and chemical parameters determined, it was possible to establish a system for classifying the degrees of saprobity as shown in Table 1, based on the studies of LAWA (1982).

Table I - The degree of saprobity calculated according to physical and chemical parameters.

Classes	*Saprobity level*	*Degree of organic pollution*	*Phisical and chemical parameters*				
			D.O.				
			Saturation Deficit (%)	*Over Saturation (%)*	*BOD_5 ($mg.L^{-1}$) 20° c*	*NH_4N ($mg.L^{-1}$)*	*COD ($mg.L^{-1}$)*
I	Oligosaprobic (Os)	none or slight	0 - 5	0 - 3	0.0 - 0.5	< 0.1	1 - < 3
I - II	Oligo-to-β-mesosaprobic (Os-βms)	slight	5 -15	3 -10	0.5 - 2.0	0.1	3 - < 6
II	β-mesosaprobic (βms)	moderate	15 - 30	10 - 25	2.0 - 4.0	> 0.1 - < 0.3	6 - < 10
II - III	β-to-α-mesosaprobic (βms-αms)	problematic	30 - 50	25 - 50	4.0 - 7.0	> 0.3 - < 0.7	10 - < 19
III	α-mesosaprobic • (αms)	high	50 - 75	50 - 100	7.0 - 13.0	> 0.7 - < 3.0	19 - < 75
III - IV	α-meso-to-polysaprobic (αms-ps)	very high	75 - 90	+100	13.0 - 22.0	> 3.0 - < 9.0	> 75
IV	Polysaprobic (ps)	extremely high	+90	-	+22.0	> 9.0	-

RESULTS AND DISCUSSION

The regional adaptation of the BMWP model involves calculating a new score for each family of macroinvertebrate present in the river system. The saprobiotic valencies of the macroinvertebrate families in the watershed of the upper Rio das Velhas were determined by correlating the frequencies of occurrence with the different degrees of saprobity and physical,chemical parameters of the water.

The BMWP method for evaluating water quality (National Water Council, 1981 *in* Hellawel,1989) was chosen because among the methods requiring taxonomic identification only to the level of family, previous experience showed it to give the best results (Junqueira & Campos 1988). Its sensitivity is great due to the number and variety of taxonomic groups which are included for comparison .

Calculation of the degree of saprobity was based on the DO, BOD, NH^4-N and COD values obtained in each sampling station on August/85, July and September/86-87, November/91, May, August and Septemer/92. These values were classified according to the Table I criteria. The degrees of saprobity at each of the stations in the watershed of the upper Rio das Velhas during the period from 1985 to 1992 are shown in Tables II and III.

Table IV shows the frequency of occurrence of the families of benthic macroinvertebrates in waters, at each level of saprobity in the watershed during the period from 1985 through 1992. Relationships between the occurrences of the families of macroinvertebrates and the degrees of saprobity in the watershed investigated were established using a historical series of data obtained since 1985. These relationships form the basis for determining the saprobity scores assigned to the families encountered in this watershed. The new list of BMWP scores

Table II - The level of saprobity at the Rio das Velhas sampling stations from 1985 to 1992.

Date	*1985*	*1986*		*1987*		*1991*	*1992*		
Sampling Station	***Aug***	***Jul***	***Sep***	***Jul***	***Sep***	***Nov***	***May***	***Aug***	***Sep***
(RVSB)				Os - βms	βms				
5 (RVMI)	Os	Os	Os	Os	βms	Os	Os	Os	05
1 (RVMS)						Os	Os - βms	Os - βms	05
9 (RVMF)	βms	Os - βms	Os	Os				βms	05
2 (RVJB)						Os	Os - βms	Os - βms	05 - βms
(RVJF)				βms	βms-αms				
3 (RVMR)						Os	Os	Os	05
19 (RVJP)						βms	βms	βms-αms	βms
15 (RVHB)	Os - βms	Os - βms	Os	Os - βms	βms	βms	Os - βms	Os - βms	Os
(RVJA)	βms	βms	βms	βms	βms				
20 (RVMV)				Os - βms	Os - βms	Os - βms	βms	βms	βms
(RVJV)	Os	Os	Os						
22 (RVRG)				βms	Os - βms	Os - βms	βms	βms	βms
(RVJR)	βms-αms	αms	βms						
24 (RVBR)				βms-αms	αms	αms	βms-αms	αms	αms

os=olisaprobic, bms=betamesosaprobic, ams=alfamesosaprobic, ps=polisaprobic

Table III - The level of saprobity in tributaries of the Rio das Velhas from 1985 to 1992.

Date	*1985*	*1986*		*1987*		*1991*	*1992*		
Sampling Station	***Aug***	***Jul***	***Sep***	***Jul***	***Sep***	***Nov***	***May***	***Aug***	***Sep***
Rio Itabirito	Os - βms	βms	βms	βms	βms	Os - βms	βms	βms	βms
Rib. Água Suja	αms	βms-αms	βms	βms-αms	βms-αms	αms-ps	αms	ps	ps
Rib. Sabará	βms-αms	αms	βms-αms				βms	βms-αms	βms-αms
Rio Arrudas	ps	ps	ps	ps	ps	ps	αms	ps	ps
Cor. Mingu						Os - βms	βms	βms-αms	βms
Rib. Macacos						Os - βms	Os - βms	Os	Os - βms
Rib. Prata						Os	Os - βms	Os	Os - βms
Cor. Cortesia						Os	Os	Os - βms	Os - βms
Rib. do Silva						Os	Os	Os - βms	Os - βms
Rib. Mango						Os	Os - βms	Os - βms	Os
Rio do Peixe						Os	Os	Os	Os
Cor. Marumbé						Os	Os	Os	Os
Cor. Pedras						Os	Os		
Rib. Cristais						Os	Os	Os	Os - βms

os=oligosaprobic, bms=betamesosaprobic, ams=alfamesosaprobic, ps=polisaprobic

Table IV - Frequency distribution of occurrences of the invertebrate families in water at the different saprobity level in the upper Rio das Velhas Watershed during the period 1985 to 1992.

Family of organisms	***Saprobity level***						
	os	*os-ms*	*ms*	*ms-ms*	*ms*	*ms-ps*	*ps*
Dugesiidae	35,5	29,0	29,0	6,5	-	-	-
Tubificidae	28,5	14,5	14,5	14,0	14,0	-	14,5
Glossiphoniidae	25,0	24,0	25,0	8,0	12,0	2,0	4,0
Erpobdelidae	-	-	-	-	-	-	100
Piscicolidae	-	-	-	100	-	-	-
Leptohyphidae	52,0	37,5	10,3	-	-	2,0	-
Baetidae	37,0	29,0	28,0	3,0	2,0	1,0	-
Siphlonuridae	100	-	-	-	-	-	-
Leptophlebiidae	50	35,5	14,5	-	-	-	-
Calopterygidae	50	50	-	-	-	-	-
Coenagrionidae	60	13,5	26,5	-	-	-	-
Gomphidae	26,0	26,0	43,5	4,5	-	-	-
Libellulidae	50,0	29,5	17,5	3,0	-	-	-
Perlidae	50,0	37,5	12,5	-	-	-	-
Gripopterigydae	57,0	37,0	6,0	-	-	-	-
Belostomatidae	33,5	-	66,5	-	-	-	-
Corixidae	100	-	-	-	-	-	-
Naucoridae	33,5	44,5	16,5	5,5	-	-	-
Veliidae	50,0	33,5	16,5	-	-	-	-
Nepidae	100	-	-	-	-	-	-
Gelastocoridae	-	-	100	-	-	-	-
Hebridae	33,5	66,5	-	-	-	-	-
Corydalidae	42,5	25,5	27,5	4,5	-	-	-
Hydroscaphidae	100	-	-	-	-	-	-
Elmidae	38,0	30,5	25,5	3,0	3,0	-	-
Gyrinidae	66,5	-	33,5	-	-	-	-
Dytiscidae	-	-	100	-	-	-	-
Hydrophilidae	40	30	10	10	10	-	-
Psephenidae	60	30	10	-	-	-	-
Glossosomatidae	40	30	30	-	-	-	-
Helicopsychidae	100	-	-	-	-	-	-
Hidropsychidae	47,0	32,0	18,5	2,5	-	-	-
Hydroptilidae	44,0	29,0	27,0	-	-	-	-
Leptoceridae	37,5	50,0	12,5	-	-	-	-
Philopotamidae	62,5	31,0	6,5	-	-	-	-
Odontoceridae	100	-	-	-	-	-	-
Polycentropodidae	-	100	-	-	-	-	-
Hydrobiosidae	54,0	38,5	7,5	-	-	-	-
Pyralidae	100	-	-	-	-	-	-
Athericidae	-	20	80	-	-	-	-
Ceratopogonidae	32,0	24,5	30,0	7,5	5,0	-	1,0
Chironomidae	28,5	25,0	22,0	8,0	11,0	2,0	3,5
Empidoidea	41,0	29,0	24,5	5,5	-	-	-
Psychodidae	19,0	17,0	39,5	9,5	9,5	-	5,5
Simuliidae	49,0	24,0	22,0	5,0	-	-	-
Tabanidae	44,5	22,0	22,5	11,0	-	-	-
Tipulidae	33,5	26,5	26,5	3,5	6,5	-	3,5
Dixidae	50,0	50,0	-	-	-	-	-
Culicidae	-	-	50,0	25,0	25,0	-	-
Stratiomyidae	16,5	33,5	16,5	16,5	-	-	16,5
Syrphidae	-	-	-	-	100	-	-
Physidae	7,5	7,5	40,5	26,0	15,0	3,5	-
Ancylidae	66,5	-	33,5	-	-	-	-
Planorbidae	-	-	100	-	-	-	-
Sphaeridae	-	-	50,0	50,0	-	-	-

for the families of zoobenthic species in the river system are presented in Table V. The scores assigned to the families in the original BMWP method and those established for the modified method for this watershed are different for the following families:

Gripopterygidae, Pyralidae, Hydroscaphidae, Helicopsychidae, Hebridae, Veliidae, Psephenidae, Dixidae, Leptohyphidae, Glossosomatidae, Gelastocoridae, Belostomatidae, Corydalidae, Dugesiidae, Elmidae, Athericidae, Empidoidea, Tabanidae, Ceratopogonidae, Culicidae, Psychodidae, Stratiomyidae, and Syrphidae.

From an analysis of the results, it was found that the scores calculated for the families Siphlonuridae, Odontoceridae, Philopotamidae, Polycentropodidae, Hydroptilidae,

Table V - Family scores assigned under the "Biological Monitoring Working Party Score System (BMWP)" modified for the uppermost part of the Rio das Velhas Watershed.

Families	Score
Siphlonuridae. Gripopterygidae. Pyralidae Odontoceridae, Hydroscaphidae,. Helicopsychidae	10
Leptophlebiidae. Perlidae. Hebridae. Hydrobiosidae, Philopotamidae. Calopterygidae. Psephenidae. Dixidae.	8
Leptohyphidae,Veliidae. Leptoceridae, Polycentropodidae.	7
Glossosomatidae, Hydroptilidae Gyrinidae Coenagrionidae Ancylidae	6
Naucoridae, Belostomatidae, Corixidae, Nepidae. Hydropsychidae Gomphidae, Libellulidae. Dytiscidae Corydalidae Dugesiidae Simuliidae	5
Baetidae Elmidae, Hidrophylidae. Piscicolidae Athericidae, Empidoidea, Tabanidae.	4
Physidae, Planorbidae, Sphaeriidae Glossiphoniidae Ceratopogonidae, Tipulidae, Culicidae	3
Erpobdellidae Chironomidae, Psychodidae, Stratiomyidae, Syrphidae	2
Oligochaeta (Whole class)	1

Coenagrionidae, Ancylidae, Calopterygidae, Naucoridae, Hydropsychidae, Corixidae, Nepidae, Dytiscidae, Simuliidae, Baetidae, Piscicolidae, Physidae, Planorbidae, Sphaeriidae, Glossiphoniidae, and Chironomidae, as well as for the Oligochaeta, were the same as those in the original BMWP list.The Naucoridae and Nepidae were given the same scores as those in the original BMWP list because they occur very infrequently in the watershed of the upper Rio das Velhas.

Several other families have been given scores for the watershed of the upper Rio das Velhas different from those in the original BMWP list, as shown in the table 5. It should be mentioned that it was necessary to reevaluate the method because many of the families present in the watershed did not appear in the list employed originally developed in Europe. Furthermore, the values assigned to some of these families did not reflect the situation actually observed in the water courses studied, perhaps because they were calculated for lotic environments in the temperate zones.

The differences are attributable to the fact that the families are represented by species in the watershed of the upper Rio das Velhas with tolerances for organic matter different from those of the species for which the original BMWP score was calculated. This demonstrates the main limitation of the taxonomical level choosed. A more acurated biological results would be obtained, using specific level, however, the lack of taxonomists makes this a very hard work. So, the methodology proposed in this study, employs family taxonomic level and must be applied only in regional scale.

The original BMWP method was not a classification system for water quality. However, based on the results obtained from the study of the zoobenthos in the watershed of the upper Rio das Velhas, it was possible to establish a series of scores to determine the water quality classes for use exclusively in that watershed, as shown in Table VI. To test the BMWP method, data from the most recent investigations on zoobenthos in the watershed , conducted during May, August, and September, 1992, were evaluated.

Table VI - The water quality classification system established for the zoobenthic organisms inhabiting riffles in the uppermost part of the Rio das Velhas Watershed.

Class	*Score*	*Water quality*
I	≥ 86	Excellent
II	64 - 85	Good
III	37 - 63	Satisfactory
IV	17 - 36	Bad
V	≤ 16	Very Bad

CONCLUSION

The cartographic representation of the water quality in the watershed of the upper Rio das Velhas (Fig. 1) was produced using the BMWP method. The data used to produce the map are limited to those obtained from the study of the bioindicators (**macroinvertebrate communities**) during the most recent period of the study, from May through September, 1992.

The map shows that the water quality decreases dowstream from the mountains as it is joined by tributaries, some of which are heavily contaminated with organic substances. Among these tributaries is the Rio Itabirito, which receives industrial and domestic wastewater from the city of Itabirito, in which several tanneries are located. Downstream from the confluence with this tributary, Mingu Stream joins the Rio das Velhas after receiving domestic wastewater from the town of Rio Acima, which is, however, quantitatively of litlle significance. Farther downstream is the confluence with the River Água Suja, which receives wastes from the city of Nova Lima and from the Morro Velho Gold Mine. The Rio das Velhas next receives wastewater and solid wastes from the city of Raposos.

The Sabará River empties into the Rio das Velhas a short distance upstream from the Arrudas River. It receives domestic wastes from the city of Sabará as well as effluents from the Belgo Mine, which processes iron ore. At the end of the stretch of river investigated is the confluence with the Arrudas River, which carries the greatest volume of organic and toxic substances from the watershed. It receives domestic and industrial wastes directly from the majority of the municipal districts in the region of greater Belo Horizonte without any sewage treatment whatsoever.

Although this method of evaluating and monitoring water quality using bioindicators is not as precise as methods which utilize organisms identified to the level of species, it is sufficiently accurate at the level of family for use in the region studied. The score based only on families represents an average tolerance of all species ocurring locally to the organic substances present in the water. Therefore, the score determined for each family is applicable only in the region in which it was calculated. This score can then serve as a standard for comparison with conditions in the future in order to facilitate a system of continuous monitoring of the changes. It can be concluded that the BMWP index calculated to evaluate the water quality is an excellent tool that is easer to employ because it requires little taxonomic knowledge and enables rapid responses for managing watersheds. It is economical and requires little time to obtain results.

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