Application of biological indices in the assessment of pollution in the Mfoundi River Basin (Cameroon).

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ABSTRACT

The Saprobity index of Pantel and Buck (1955), the Diversity indices of Menhinick (1966) and that of Shannon and Weaver (1948) were applied in the assessment of the level of pollution in thirteen streams of the Mfoundi River Basin. The results obtained indicate that the source region is oligosaprobic, the middle region mesosaprobic and the lower course of the streams is mainly polysaprobic. These results suggest an intensification of pollution from upstream to downstream along the watershed and thus reveal the high impact of anthropogenic activities on this urban ecosystem.

Keywords: Saprobity index, Diversity indices, Pollution, Mfoundi River Basin

RÉSUMÉ

Le niveau de pollution de treize cours d'eau du réseau hydrographique du Mfoundi a été évalué à l'aide de l'indice de saprobité de Pantle et Buck, l'indice de diversité de Menhinick et celui de Shannon et Weaver. Les résultats obtenus indiquent que la source du bassin est oligosaprobique, le milieu est mésosaprobique et les parties inférieures sont majoritairement polysaprobiques. Ces résultats montrent une intensification de la pollution de l'amont du bassin vers l'aval et de ce fait révèle un grand impact des activités anthropogéniques sur cet écosystème urbain.

Mots clés : Indice de saprobité, Indice de diversité, Pollution, Réseau hydrographique du Mfoundi.

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INTRODUCTION

The aquatic ecosystem is constantly being subjected to various kinds of pollution (Houk *et al*; 2005). This system receives a huge quality and quantity of wastes either from point sources such as domestic and industrial discharges or from non-point sources like surface and agricultural runoffs (Moreno *et al*; 2005).The water system is under heavy anthropogenic pressure, due to various human activities (Ajeagah *et al*; 2005). It is in this respect that a constant monitoring of the world's major water resources is an indispensable means towards the preservation of their quality through the effective documentation of the deterioration statistics calculated (Giupponi and Vladimirova, 2006).This can be carried out by the application of physico-chemical and biological parameters, which are employed in the water quality assessment (Holtrop *et al*; 2002).These parameters vary with the season and the pollution stress (Kagalou, 2003).

Biological indicators are organisms which are applied to quantify and characterze the biologically available level of contamination in the aquatic ecosystem (Read *et al;* 2005).The concept of biodiversity in water quality evaluation has a considerable relevance only when the diversity indices are properly assessed and the usage fully justified by giving prior attention to the number of samples, population size, type of index and the nature of

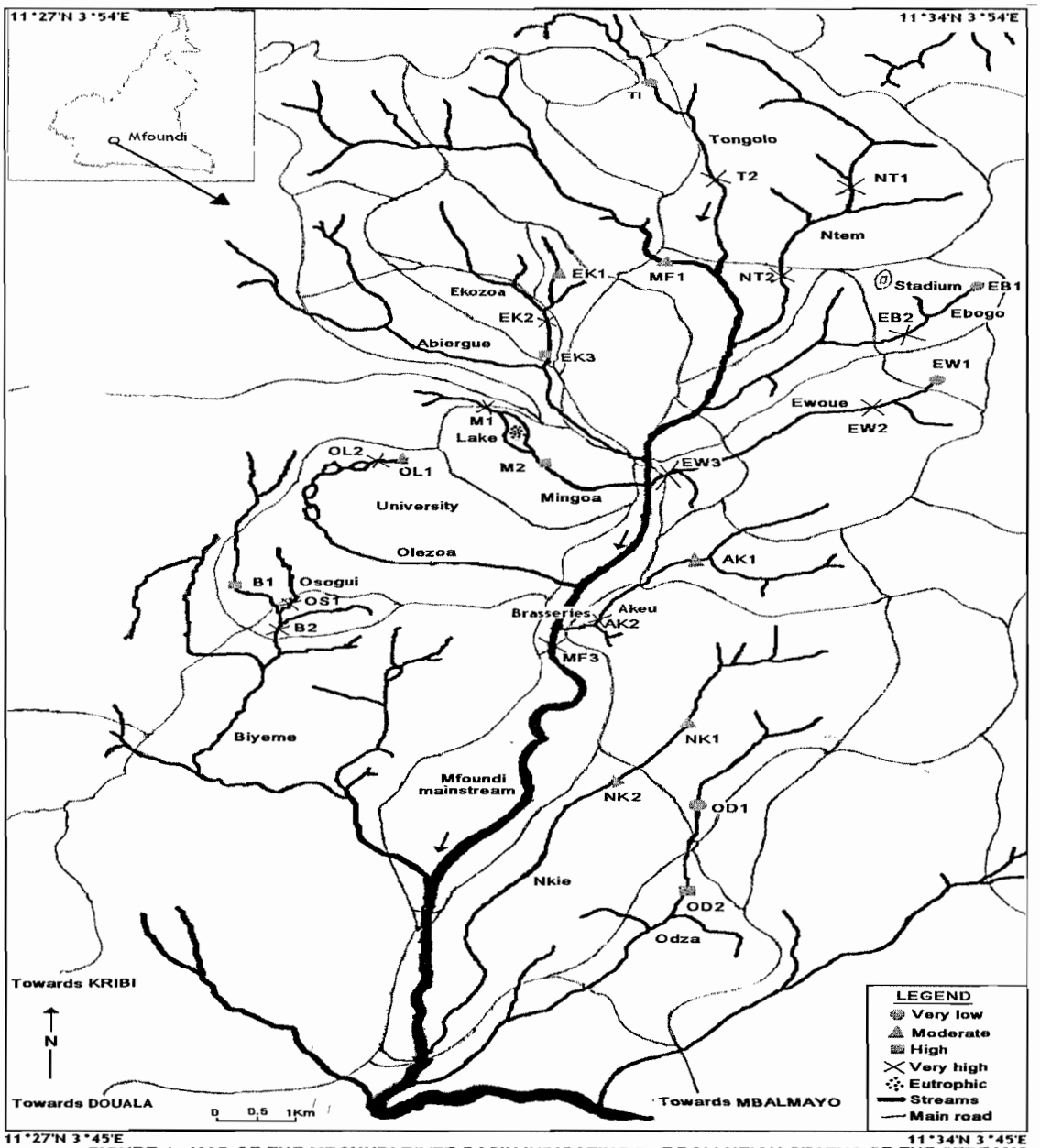

FIGURE 1: MAP OF THE MFOUNDI RIVER BASIN INDICATING THE POLLUTION STATUS OF THE STREAMS

Source: National Institute of Cartography

the taxon which is in question (Krishna *et al*; 2000).The application and validation of these indices are subjected to the sampling of the indicator organisms in a series of aquatic systems (Jian -gua *et al*; 2003) commonly used biological indicators are protozoa, phytoplankton, zooplankton and macro-invertebrates (Xu *et al*; 2001).Ciliates are the most successful heterotrophic protozoan group even in extreme situations (Robert *et al*; 2002).They are very sensitive to pollution and this is translated by the high population of species in response to a specific type of contamination of the hydrosystem (Vighi *et al*; 2006).Despite the presence of biological indicators, the translation of the species abundance into statistical data and the determination of the level of pollution of the streams remains a preoccupying problem (Mihailov *et al;* 2005).This watershed is the principal source of potable water production for the community of Yaounde and its environs.

Our objective was to calculate three biotic indices of pollution in the Mfoundi River Basin, with reference to the population dynamics of ciliates, then apply the values obtained in the categorization of the intensity of pollution in the watershed. These indices are the saprobity index of Pantel and Buck (1955), the diversity indices of Menhinick (1966) and that of Shannon and Weaver (1948).

MATERIAL AND METHODS

This research has been carried out in thirteen tributaries of the Mfoundi River Basin of Yaounde, from August 1999 to July 2000. This hydrosystem is situated at Latitude 3°50' North and Longitude 11°32' East ,with an altitude of 700-800m above sea level. The climate is equatorial and the soil is mainly ferralitic. The sampling stations were selected from upstream to downstream of each watercourse under verification. The streams studied are Akeu, Biyeme, Ebogo, Ekozoa, Ewoue, Mfoundi main stream, Mingoa, Nkie, Ntem, Odza,Olezoa, Tongolo, and Osegui (figure1). The ciliates are sampled in each station by polyurethane foams of 5cm by 6.5cm by 7.5cm of dimension and at a five days interval. They are transported to the laboratory of General Biology of the University of Yaounde 1, where they are identified live or by the application of the silver ammoniacal carbonate staining method of (Galiano ,1976). They are then counted under the optical microscope of mark wild at the 400 and 1000 magnification.

The bio-indicators were determined by the identification key proposed by Dragesco *et al* (1986).The statistical analysis is carried out by the application of the saprobic index and the diversity indices. The specific saprobic value for each specie is represented in a table proposed by sladecek(1973).

The degree of organic pollution was determined using the saprobic index of Pantle and Buck (1955). The formula is represented below.

$$S = \frac{\sum_{i=1}^{h} hs}{\sum_{i=1}^{h} h}$$

Where S = saprobic index of the station under consideration (Table 1).

H = relative abundance of each species.

s = saprobic valency for the biological indicator.

The diversity indices of Shannon and Weaver (1948) and Menhinick (1966) were used to assess the equilibrium of the community. Their formula is represented below.

$$H = \sum_{i=1}^{h} \frac{ni}{N} \log_2 \frac{ni}{N}$$

Where:

H = Shannon and Weaver index (Specific diversity in bits/cell).

Ni = total individuals of I species.

N = total individuals of specimen.

The higher the value of this index the lower the degree of diversity and the lower the pollution gradient, while the lower the value of the index ,the higher the intensity of pollution,

and $S = \frac{s}{\sqrt{N}}$

Where:

S = Menhinick index.

s= Number of species in the sample.

N = number of individuals in the sample. This index varies on a scale, from 0 to 1 , and a higher value indicates a higher degree of pollution.

Four levels of organic pollution which have been realized from the analysis of the saprobity scale for water contamination are represented in table I below.

Table 1: Saprobity scale for water pollution.

Value of biological index	Saprobity	Degree of pollution
1.0 -1.5	Oligosaprobic	Very low
> 1.5 – 2.5	β-Mesosaprobic	Moderate
2.5 – 3.5	α-Mesosaprobic	High
> 3.5 –4.0	polysaprobic	Very high

RESULTS

The calculated values of the saprobity index of Pantle and Buck (1955) and the diversity indices of Shannon and Weaver (1948) and that of Menhinick (1964) for a one year period of ciliates sampling are presented in table II. A calculation of these biotic indices with the use of the biological indicators express a generalized increase in pollution from upstream (oligosaprobic) to downstream (polysaprobic), passing through an intermediary mesosapropic zone.

The lowest value of the Pantle and Buck index is 0.25 at the source of Ewoue 1,while the highest value of the Pantle and Buck index is 3.92 at downstream of the Mfoundi main stream. These points are oligosaprobic and polysaprobic respectively with the other level of pollution situated between them. The lowest values of the diversity index of Menhinick (1964) is 0.28 at Ewoue1 while the highest value is 0.83 at Akeu 1.These indices present a varied level of pollution between the points. The lowest value of the Shannon and Weaver (1948) index is 2.01 in Akeu 2 this is a sampling point located below a brewery effluent. The highest value is 3.90 in Tongolo 1 which is located at an uninhabited zone. These sampled stations are polysaprobic and oligosapobic respectively.

The values of the biotic indicators in the Municipal lake of Yaounde locate this lentic ecosystem in an eutrophic medium. This is materialized by the growth of macrophytes around the lake.The streams at the periphery of Yaounde such as Nkie and Odza are lowly polluted with respect to the streams flowing across the city center. The former category of streams have an oligosaprobic and mesosaprobic status while the later have a polysaprobic status.

DISCUSSION

The saprobity and diversity indices calculated in the aquatic system show that the Mfoundi River Basin is highly polluted (Table II). This pollution influences the multiplication of ciliates in response to the waste water and the organic matter discharged into the streams (Bherati *et al*; 2001).The biotic indices calculated in this study show different levels of pollution (Czapik,2000;Novotny *et al*; 2005).The oligosaprobic zone located upstream is characterized by apparently clean water which is highly saturated in oxygen and which has a low level in organic matter content (Berry *et al*; 2006).

The degradation of the water system is observed along the stream course due to an incomplete mineralization of the organic matter by the microflora (Sagidullaev and Novozhilova, 1971). This state of the ecosystem can be observed in Akeu1, Odza 2 which are â-mesosaprobic and á-mesosaprobic respectively (Cifluentes *et al*; 2006). The intensity of pollution continues downstream where there is a high level of organic pollution with reactions of decomposition prevailing (Kostanjsek *et al*; 2005).

There is a high multiplication of ciliates such as *Metopus* sp., *Metopus ovatus* and *Caenomorpha medusula* (Yatish, 2000). This type of water content is characteristic of the Mfoundi River Basin (figure 1) of Yaounde which present polysaprobity at most of the sampled stations as confirmed by the comparison of the various biological indices (Cao *et al*; 2004). The municipal lake is eutrophic as a result of the continuous accumulation of waste water from the residential quarters, public buildings and a near by hotel (Pers, 2005). There is not any prior purification of effluent water and the possibility of a bacteria breakdown of the sewage and garbage is low (Vassiljev *et al*; 2005).This leads to a nutrient rich and eutrophic lake like the pond of Udaipur(Rajasthan,1999).Only species which can survive the abiotic conditions of the system

Table II. Values of the pollution indices in the various sample locations with the respective confidence intervals.

Stream/ point	Label	Shannon and weaver (1948)	Pantle and Buck (1955)	Menhinick (1964)	saprobity	Degree of pollution
Akeu 1	AK1	3.40±0.01	2.45±0.04	0.83±0.02	β-mesosaprobic	moderate
Akeu 2	AK1	2.01±0.01	3.85±0.03	0.31±0.01	polysaprobic	very high
Biyeme 1	B1	2.60±0.02	3.10±0.01	0.80±0.02	α-mesosaprobic	high
Biyeme 2	B2	2.40±0.03	3.64±0.04	0.71±0.01	polysaprobic	very high
Ebogo 1	EB1	3.80±0.01	0.35±0.03	0.38±0.02	oligosaprobic	very low
Ebogo 2	EB2	2.90±0.02	3.61±0.01	0.76±0.02	polysaprobic	very high
Ekozoa 1	EK1	3.70±0.02	2.40±0.01	0.81±0.01	β-mesosaprobic	moderate
Ekozoa 2	EK2	2.40±0.02	3.61±0.01	0.71±0.01	polysaprobic	very high
Ekozoa 3	EK3	2.50±0.03	3.32±0.02	0.76±0.03	α-mesosaprobic	high
Ewoue 1	EW1	3.90±0.01	0.25±0.03	0.28±0.02	oligosaprobic	very low
Ewoue 2	EW2	2.10±0.01	3.78±0.04	0.69±0.03	polysaprobic	very high
Ewoue 3	EW3	2.00±0.02	3.90±0.04	0.68±0.02	polysaprobic	very high
Mfoundi 1	MF1	3.10±0.01	2.31±0.02	0.54±0.02	β-mesosaprobic	moderate
Mfoundi 2	MF2	2.60±0.02	2.81±0.01	0.73±0.03	polysaprobic	very high
Mfoundi 3	MF3	2.40±0.01	2.92±0.02	0.76±0.02	polysaprobic	very high
Mingoa 1	M1	2.30±0.02	3.75±0.03	0.70±0.01	polysaprobic	very high
Municipal Lake	Lake	2.50±0.02	3.50±0.01	0.78±0.03	eutrophic	very high
Mingoa 2	M2	2.65±0.05	3.30±0.01	0.71±0.02	α-mesosaprobic	high
Nkie 1	NK1	3.30±0.02	2.30±0.02	0.44±0.01	β-mesosaprobic	moderate
Nkie 2	NK2	3.30±0.01	2.31±0.01	0.46±0.02	β-mesosaprobic	moderate
Ntem 1	NT1	2.70±0.02	3.64±0.03	0.72±0.02	polysaprobic	very high
Ntem 2	NT2	2.55±0.04	3.71±0.01	0.73±0.03	polysaprobic	very high
Odza 1	OD1	3.30±0.02	1.10±0.01	0.42±0.01	oligosaprobic	very low
Odza 2	OD2	2.80±0.01	3.30±0.02	0.45±0.02	α-mesosaprobic	high
Olezoa 1	OL1	3.00±0.02	2.10±0.01	0.51±0.01	β-mesosaprobic	moderate
Olezoa 2	OL2	2.05±0.04	3.76±0.03	0.69±0.03	polysaprobic	very high
Tongolo1	T1	3.90±0.02	0.27±0.02	0.39±0.01	oligosaprobic	very low
Tongolo2	T2	2.40±0.02	3.70±0.02	0.74±0.02	polysaprobic	very high
Osegui	OS1	2.20±0.01	3.75±0.03	0.70±0.01	polysaprobic	very high

will continue to multiply while other species will extinct out due to the biotoxicity of the contaminant introduced into the ecosystem (Weston *et al;* 2005).

The streams located at the highly populated urban zone are more polluted , than those situated at the periphery (Yang *et al*; 2004).This is likely due to the high anthropogenic impact on the Yaounde watershed, as the increasing human activity reduces the possibility of self purification of the stream (Schincariol *et al* ; 2004).Given the widely accepted importance of water and sanitation to health, poor environmental conditions are a major cause of poor health in remote communities (Hunt, 2006).There is need for better quality information systems to monitor progress, equity and accountability in the delivery of water and sanitation services (Bailie *et al*; 2004; Ajeagah et al, 2006).

CONCLUSION

The biological indices of saprobity and diversity have been calculated in the Mfoundi River Basin, by using ciliated protozoa as the bio-indicators of pollution. The values calculated express an increasing level of pollution of the watershed from upstream to downstream.The upstream is oligosaprobic, the midstream is mesosaprobic, while the down stream is polysaprobic. The streams flowing across the center of the metropoly are more polluted than those located at the periphery. This is an indication of anthropogenic activity as an important source of contamination of the hydrosystem. These indices are recommended in the evaluation of pollution in the aquatic medium.

REFERENCES

Ajeagah A.G.; Foto S.M.; Njine T., Wouafo M., Moyou R.S.; Nola M.; Monkiedje A.; Ngassam P., Zebaze S.T., Kemka N.(2005).Distribution of the *Giardia* sp. Cysts in the Mfoundi Water Basin(Cameroon):influence of some physico -chemical factors of the medium. Journal of the Cameroon Academy of Sciences.5(2,3):85-90.

Ajeagah A.G., Njine T., Foto S.M. and Nola M. (2006) Assessment of Cryptosporidium spp. oocysts in some urban water systems in Yaounde (Cameroon). Cameroon Journal of Experimental Biology. 02(1): 9-15

Bailie, R.S;Carson, B.E. and Mcdonald, E.L. (2004).Water supply and sanitation in remote indigenous communities priorities for health development .Aust N Z J Public Health.28(5):409-14.

Basemer, K.; Moeseneder, M. M.; Arrieta J. M. Herndl, G. J. and Peduzzi, P. (2005). Complexity of bacterial communities in a river floodplain system(Danube,Austria). App Environ Microbiol. 71(2)609-20.

Berry D.; Xi C. and Raskin L. (2006). Microbial ecology of drinking water distribution systems.Epb.

Bharati, V.R.; Khan, R.N.; Kalavati, C. and Raman, A.V. (2001). Protozoan colonization of artificial substrates in relation to water quality in a tropical Indian harbour.J Environ Sci(China). 13(2):143-7.

Cifluentes E.; Atamo U. ; Kendall T. ; Brunkard J. and Scrimshaw S. (2006). Rapid assessment procedures in environmental sanitation research :a case study from the northern border of Mexico. Can J Public Health .97(1):24-8.

Coa,Y.; Larson, D. P. and White, D. (2004). Determining regional species diversity. A comparison of statistical estimators. Ecoscience .11:23-35

Czapik, A.(2000).The effect of waste water on ciliate communities in the Biala Premsza River .Acta Hydrobiol.24,29-37.

Dragesco, J and Dragesco, K. (1986). Cilies libres de l' afrique Intertropical.Introduction a la connaissance et à l'etude des cilies.Faune tropical XXVI,edition de l orstom. 1-559.

Galiano, F.D.(1976).Une nouvelle methode pour la mise en evidence de l'infraciliature des cilies. Labo microbiologie.universite de Madrid (Espagne) 2p.

Giupponi C. and Vladimirova I.(2006).Ag-PIE:a GIS-based screening model for assessing agricultural pressures and impacts on water quality on a European scale.Sci Total Environ.359(1-3):57-75.

Holtrop, A.M. and Fischer, R.U.(2002). Relations between biotic integrity and physical habitat in the Embarrass River Illinois. Journal of Freshwater Ecology.17:2.

Houk, P., Didonato,G., Iguel, J., and Woesik, R.(2005). Assessing the effects of non-point source on American Samoas coral reef communities .Environmental monitoring Assesssment.107(1-3):11-27.

Hunt P.(2006).The human right to the highest attainable standard of health:new approaches and challenges.Trans R Soc Trop Med Hyg.100(7):603-7.

Jian-guo and Yun-fens S.(2003).Application and validation of a new biotic index using data from several water systems. J.Environ Monit .5(6) :871-875.

Kagalou, D.P. (2003).Seasonal variation of water quality parameters and plankton in a shallow Greek lake. Journal of Freshwater Ecology .18:4.

Khrisna, P.V.; Rajagopal,T. and Kant,Y. (2000).Quantifying community diversity from heterogeneity measures,an overview .India J. Environ Sci .4(1):61-72.

Kostanjsek, P.; Lapanje, A.; Drobne, D.; Perovic, S.; Perovic, A.; Widar, P.; Strus, J.; Hollert, H. and Karaman, G. (2005). Bacterial commuity structure analysis to assess pollution of water and sediments in the Lake Shkodra/

Skadar,Balkan peninsula.Environ Sci Pollut Res Int.12(6):361-8.

Menhinick E.F.(1964).A comparison of some species individuals diversity indicies applied to samples of field insects .Ecology.45:859-861.

Mihailov, G.; Simeonov, V.; Nikolov, N. and Mirinchev,G. (2005).Multivariate statistical assessment of the pollution sources along the stream of Kamchia River, Bulgaria. Water Sci Technol.51(11):37-43.

Moreno, J.L.,Navaito ,C and De Las Heras, J.(2006).Abiotic ecotypes in South Central Spanish rivers,Reference conditions and pollution. J.envpol. 2005(12):012.

Novotny, V.; Bartosova, A.; Oreilly, N., and Ehlinger,T. (2005).Unlocking the relationship of Biotic integrity of impaired waters to anthropogenic stresses.Water Res .39(1):184-98.

Pantle, R. and Buck, H.(1955).Die biologiesche uber wachung der ger wasseer und die Darstellung der Ergbnisse. Gas Und Wasser Fach.96:604.

Pers, B.C.(2005).Modeling the response of eutrophication control measures in a Swedish lake.Ambio.34(7):552-8.

Rajasthan (1999). Study of some physico-chemical characteristics of sewage fertilised pond of Udaipur .J.En.Polln .6(4):255-260

Read, J. L.; Kovac, K. J. and Fatchem,T.J. (2005). Biohyets :a method for displaying the extent and security of environmental impacts. J. Environ Manage .77(2):157-64.

Robert, E.C., Prisca, J.C. and Laybourn-parry, J. (2004). Micro plankton dynamic in a perennially ice-covered Antarctic lake Hoare. Journal of Freshawater Biology .49(7):853-869.

Sagidullaev N.S. and Novozhilova M.I. (1971). Heterotrophic microflora of Amu-Darya surface waters and their significance in the mineralization of organic matter .Mikrobiologiia.40(4):714-7.

Schincariol, A.R, Maun, A.,Crows, A.C, Wikland, J.A. and Steinbacks, J.N. (2004) .Response of an aqauatic ecosystem to human activity: Hydro-Ecology of a river channel in a Dune Watershed. Journal of Freshwater Ecology . 19.

Shannon,C.E and Weaver W. (1948).A mathematical theory of communication Urbanna,Univ,III press.41-125.

Sladecek, V. (1973).System of water quality from the biological point of view .Arch.Hydrobiuol.Beih.7(1-IV):1-2.8.

Vassiljev, A. and Stalnacke,P. (2005).Statistical modeling of riverine nutrient sources and retention in the Lake Pepsi drainage basin.Water Sci Technol.51(3-4):309-17.

Vighi, M.; Finiwio, A. and Villa,S. (2006).The evolution of the Environmental Quality Concept :From the US EPA Red book to European Water Framework.. Directive .Environ Sci Pollt Res Int.13(1):9-14.

Weston, D.P.; Holmes, R.W.; You,J. and Lydy M.J. (2005).Aquatic toxicity due to residential use of pyrethroid insecticides .Environ Sci Technol.39(24):9778-84.

Xu F.L. ;Tao S., Dawson R.W.; Li P.G. and Cao J. (2001). Lake ecosystem health assessment: indicators and methods .Water Res.35(13):3157-67.

Yang, L.; Ma, K.M.; Guo, Q.H. and Zhao, J. Z. (2004).Impacts of the urbanization on waters non-point source pollution.Huan Jing Ke Xue.25(6):32-9.

Yatish, J. (2000). Studies on a polluted lentic water body of Jabalpur with special reference to its physico-chemical and biological parameters .J.Env Polln.7(2)83-87.

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